Hostaform®

Polyoxymethylene Copolymer (POM)

- easy to process
- high toughness (down to -40°C)
- high rigidity
- very high thermal and ageing resistance
- resistance to alkalis and hydrolysis

Hostaform® *Polyoxymethylene Copolymer (POM)*

Ticona

Contents

1. Introduction

Hostaform is the trade name for the European Ticona range of acetal copolymers. The base polymer has a linear structure and high crystallinity, which explain its good physical properties. Its chemical structure – molecular chains incorporating randomly distributed comonomer units – gives it high stability to thermal and oxidative degradation. The base polymer is characterized by:

– high toughness (down to −40 °C)
– high hardness
– high rigidity
– very good heat deflection resistance
– good electrical and dielectric properties
– good chemical resistance, eg to

- solvents
- fuels
- strong alkalis
- zinc (galvanized steel sheet)

– no environmental stress cracking
– high resilience
– good slip properties
– high dimensional stability
– straightforward processability.

The spectrum of properties exhibited by the base polymer can be modified in many different ways with suitable additives. Mainly the Hostaform product portfolio can be divided up into the following product groups:

– basic grades
– easyflowing basic grades
– extrusion grades
– glass fibre/glass sphere reinforced grades
– grades with improved slip properties
– high impact grades
– grades with improved media resistance
– electrically conductive grades
– emission optimized grades
– grades for medical technology
– UV stabilized grades.

The product portfolio is supplemented by a broad colour range and special colours for laser marking. This brochure aims to provide detailed information on the Hostaform range, the physical and chemical properties of the different grades, processing methods and the diverse applications of this engineering polymer.

2. Grades, supply form, colour range, quality assurance

Hostaform is produced in different grades with various degrees of polymerization. The individual grades differ from one another in their flow behaviour (melt mass-flow rate) and in the type and concentration of additives used. The Hostaform range can be divided into the following groups:

● Basic grades	These differ primarily in their melt flow rate and are geared to the requirements of different processing methods and conditions.
● Grades with improved slip properties	These are modified with special additives which improve slip properties and/or abrasion resistance.
● Reinforced grades	These contain glass fibres or glass spheres and differ from the basic grades – depending on the type of filler – in their higher ultimate tensile strength and/or higher rigidity.
● High-impact grades (Hostaform S)	These are blends with elastomers and have a higher impact strength than the basic grades.
● Special grades	This group includes all grades which cannot be assigned to one of the above groups.

A survey of the grades currently supplied is given by brief descriptions of the individual grades. For more detailed information on the properties of Hostaform, see attached leaflet.

The basic grades are designated by a letter (C or T) followed by four or five digits, of which the first two or three represent approximately ten times the level of the type-specific melt flow rate MFR 190/2.16 in g/10 min determined according to ISO 1133.

Hostaform S . . . is the designation for elastomer-modified, impact-resistant grades based on Hostaform C 9021 or C 27021. The last digit indicates in each case the level of increased toughness.

The letter suffixes used in the nomenclature of the other grades have the following meanings:

RM:	friction-reducing
M:	with molybdenum disulphide
K:	with special chalk
TF:	with PTFE
G:	with PE-UHMW (GUR®)
AW or SW:	with special additives
GV 1/XX:	based on Hostaform C 13021, with XX% (w/w) glass fibres; exception: GV 1/30, with 26 % glass fibres
GV 3/XX:	based on Hostaform C 13021, with XX% (w/w) glass spheres
EC:	with electrically conductive carbon black and elastomer
AST:	with antistatic finish
Oil Concentrate S:	masterbatch based on Hostaform C 9021, with silicone oil
Colour masterbatches:	based on blend ratio 1:25 or 2:25
LS or WS:	UV-stabilized Hostaform basic grades and high-impact grades
black 10/1570:	special formulation UV-stabilized with carbon black; owing to the carbon black content, melt flow rate and toughness may be slightly lower than the basic grades; not for all grades available .

Depending on the type and content of additive used, the modified grades differ from the Hostaform basic grades not only in terms of the physical properties but also in their resistance to environmental effects. This applies particularly to the Hostaform S grades because of their chemical structure (blends with elastomer components).

Easyflowing basic grades

C 52021
Extremely easyflowing injection moulding grade for complicated, thin-walled precision parts. Permits processing at reduced melt temperature and hence shorter cycle times compared with other grades.

C 27021
Very easyflowing injection moulding grade for long flow paths, complicated precision parts, thin-walled mouldings and multicavity molds.

C 13021
Easyflowing injection moulding grade for precision parts and thin-walled mouldings.

C 13031
As for C 13021 but with about 10% higher strength, rigidity and hardness over the entire permissible temperature range for Hostaform.

Basic grades

C 9021
Standard injection moulding grade.

C 2521
Stiff flowing. Injection moulding of thick-walled, void-free parts.

M15HP
Unreinforced injection moulding grade with improved impact and strength.

Extrusion grades

M30AE
Stiff-flowing, for extrusion of sheets, rods and hollow profiles.

M10AE
High melt strength, for extrusion of thick walled profiles and rods.

Glass-fiber/glass-sphere-reinforced grades

C 9021 GV 1/10
Injection moulding grade reinforced with 10% (w/w) glass fibers, for parts requiring increased rigidity and hardness.

C 9021 GV 1/20
Injection moulding grade reinforced with 20% (w/w) glass fibers, for parts requiring high rigidity and hardness.

C 9021 GV 1/30
Injection moulding grade reinforced with 26% (w/w) glass fibers, for parts requiring very high strength and rigidity and increased hardness. Reduced thermal expansion and shrinkage, slightly lower toughness (elongation).

C 9021 GV 1/40
Injection moulding grade reinforced with 40% (w/w) glass fibers, for parts requiring especially high rigidity. Elastic modulus approx. 40% higher than for C 9021 GV 1/30 but otherwise similar spectrum of properties.

C 9021 GV 3/10
Injection moulding grade reinforced with 10% glass spheres, for low-warpage parts requiring increased rigidity and hardness.

C 9021 GV 3/20
Injection moulding grade reinforced with 20% glass spheres, for low-warpage parts requiring higher rigidity and hardness.

C 9021 GV 3/30
Injection moulding grade reinforced with 30% glass spheres, for low-warpage, dimensionally stable parts requiring even higher rigidity and hardness.

C 27021 GV 3/30
Easyflowing injection moulding grade reinforced with 30% glass spheres. Low warpage.

Grades with improved slip properties

C 13021 RM
Easyflowing injection moulding grade similar to C 13021. Good low-friction properties in Hostaform/ Hostaform sliding combinations, e.g. for smooth running zip fasteners (zippers).

C 13031 K
Injection moulding grade similar to C 13031, modified with special chalk. Good wear properties, increased strength. For unlubricated or once-only lubricant sliding parts.

C 9021 M
Molybdenum disulphide-modified injection moulding grade similar to C 9021, for sliding combinations operating under high pressure loading at low sliding speed. Only slight tendency to stick-slip.

C 9021 K
Injection moulding grade similar to C 9021 but modified with special chalk. Good wear properties. For unlubricated or once-only-lubricated sliding parts.

C 9021 TF
Injection moulding grade based on C 9021, contains PTFE. For sliding combinations with very low coefficient of friction (maintenance-free bearings).

C 9021 G
Injection moulding grade with GUR® (PE-UHMW), for parts under abrasion stress.

C 9021 AW
Injection moulding grade similar to C 9021 but modified with special additives. Good wear properties and low coefficient of friction. This formulation can also be supplied with other basic grades.

C 9021 SW
Injection moulding grade similar to C 9021 but modified with noise-deadening and wear-protecting additives. Extra additives also reduce acoustic vibrations in the finished parts.

C 2521 G
Extrusion grade with GUR® (PE-UHMW), for semi-finished products, sliding and guide elements.

LW15EWX
Slip-modified grade for sliding combinations with PBT, PA, PC, PMMA and steel, with increased toughness/strength level.

LW90EWX
Slip-modified grade for sliding combinations with PBT, PA, PC, PMMA and steel, good weld line strength due to the special wax blend.

LW90BSX
Slip-modified grade for a wide range of tribological applications, including POM/POM pairings, contains silicone oil.

C 9021 GV 1/30 GT
Reinforced with 26% w/w glass fibers and slip-modified.

High-impact grades

S 27063
Easyflowing, elastomer-containing injection moulding grade based on C 27021, with higher impact strength and slightly lower hardness and rigidity than the basic grade. For thin-walled parts requiring high impact energy absorption.

S 27064
Easyflowing injection moulding grade similar to S 27063 but with higher toughness level.

S 27072 WS 10/1570 (black)
Easyflowing injection moulding grade similar to S 27063 but UV-stabilized for exterior applications.

S 9063
Elastomer-containing injection moulding grade based on C 9021, with higher impact strength and slightly lower hardness and rigidity than the basic grade. For parts requiring high impact energy absorption.

S 9064
Similar to S 9063 but with higher elastomer content and hence even higher toughness level.

S 9243
Injection moulding grade with good low-temperature impact strength. For parts requiring high impact energy absorption and excellent weld strength. Flow properties under injection moulding conditions similar to those of S 9063.

S 9244
Similar to S 9243 but even higher toughness level. Flow properties in injection moulding similar to those of S 9064.

Oil Concentrate S
Hostaform C 9021 with 20% (w/w) silicone oil for blending with other Hostaform grades. Improves low-friction and abrasion properties and ejection from the mold. The blend ratio depends on finished part requirements and should preferably be 1:10. At ratios > 2:10, processing problems may arise.

Grades with improved media resistance

C 13031 XF 50/5339
Yellow-colored grade specially formulated for applications involving contact with fuel, especially hot diesel.

C 13031 XF 10/9022
Black-colored, laser-weldable grade specially formulated for applications involving contact with fuel, especially hot diesel.

EC140XF
Conductive injection moulding grade with improved resistance to fuels, especially hot diesel.

MR 130ACS
Grade with improved resistance to aggressive media and chlorinated water.

Electrically conductive grades

C 9021 ELSX
Injection moulding grade with addition of conductive carbon black and elastomer. For parts requiring very low electrical resistance. Processing guidelines in section 3.3.

EC270TX
Similar to C 9021 ELSX but with higher toughness level.

C 27021 AST
Similar to C 27021 but antistatic-modified.

Hostaform® XAP®: Advanced Processing

Low-odor injection moulding grades that meet European automotive industry requirements for plastics used in vehicle interiors. In addition to the natural grades C 2521 XAP, C 9021 XAP, C 13021 XAP, C 13031 XAP, C 27021 XAP and C 52021 XAP, many standard and special grades based on C 9021 and C 27021 can be supplied. The colors in C 9021 XAP LS and C 27021 XAP LS are light-stabilized, while in C 9021 XAP AWLS, C 9021 XAP AW, C 9021 XAP TF and C 9021 XAP M, they also contain a special additive to reduce the coefficient of friction. All XAP grades undergo the VDA 275 test as an injection molded sheet and the results are documented in the acceptance test certificate.

Minimal odor values can only be achieved under optimized injection moulding conditions, especially low melt temperatures. More detailed information can be provided by our Technical Service team.

MT® grade range

For medical and pharmaceutical applications, please see section 4.8.2.

Supply form

Hostaform is supplied as opaque white, natural or coloured cylindrical granules or pellets with a particle size of approximately 3 mm (except for Oil Concentrate S). It is normally packed in 25 kg containers (plastic-film bags or multiwall paper bags) but by prior agreement may also be supplied in 500 and 1000 kg containers (especially the basic grades).

Color range

For the Hostaform basic grades, Ticona offers a standard range of 10 colors, which correspond to the RAL colors listed in Table 1. Most of these colors have approval for applications in, for example, the food and drinking water sector (see table 1). These standard colors are supplied as mass-colored pellets or color masterbatches.

Color masterbatches are supplied in two variants and are used to color natural Hostaform grades during processing into mouldings. For this purpose, depending on the particular masterbatch, 25 parts natural pellets to 1 or 2 parts color masterbatch are added. In general, the same colors are obtained as when using mass-colored pellets but no guarantee can be given as to the completely exact shade, since this depends on processing conditions (sufficient plasticization and homogenization) and the correct mix ratio.

Table 1: Standard colors and approvals (+ compliant, x non-compliant)

RAL Code	Color	FDA	BgVV	KTW
RAL 1003	Signal yellow	+	+	+
RAL 2010	Signal orange	+	+	+
RAL 3001	Signal red	+	+	+
RAL 4008	Signal violet	+	+	+
RAL 5005	Signal blue	+	X	X
RAL 6032	Signal green	+	+	+
RAL 7004	Signal grey	+	X	X
RAL 8002	Signal brown	+	+	+
RAL 9003	Signal white	+	+	+
RAL 9004	Signal black	X	X	X

The nomenclature consists of the Hostaform grade or color masterbatch and the RAL color code, e.g.:

– Hostaform C 9021 RAL 3001 is Hostaform C 9021 in Signal red
– Hostaform C 27021 RAL 6032 is Hostaform C 27021 in Signal green
– Hostaform FK 1:25 RAL 4008 is Masterbatch 1:25 in Signal violet

In addition to these standard colors, a large range of special colors is supplied for different industry sectors such as the automotive industry and industrial engineering. Color formulations tailored to customer specifications can also be provided. In this area, Ticona can draw on long-standing experience over many years. Special colors can also be supplied in UV-stabilized or weathering-resistant formulations. In addition, special colors have been developed that are particularly suitable for laser marking. These colors are listed in table 3, page 68. All colors are cadmium-free.

Where colored moulding materials are to be prepared by the processor from natural Hostaform granules, the pigments employed should be only those which withstand Hostaform processing temperatures without decomposition or color change, and which do not impair the thermal stability of Hostaform. Only by careful selection of colorants is it possible to ensure that the physical properties of Hostaform are not affected to an unacceptable degree. Optimum molded-part properties can only be achieved with original color masterbatches based on Hostaform.

Quality management

Meeting the quality requirements of our customers is a critical activity for Ticona. We constantly pursue and update the certifications needed for this purpose. Our quality management system has been certified to ISO 9000 standards since the early 1990s. In 2003, we built on this foundation by imple-menting the Global Ticona Integrated Management System (TIMS) for quality, environmental and risk management.

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Important certifications include the following standards:

- ISO 9001
- ISO 14001
- ISO/TS 16949
- ISO/IEC 17025

Quality Management System Certifications under ISO 9001:2000 and ISO/TS 16949:2002 have now been achieved for all production sites and supporting remote locations of Ticona worldwide. The ISO/TS 16949:2002 standard combines the automotive regulations in Europe of VDA 6.1, EAQF and AVSQ with the requirements of QS-9000 in North America and supersedes all of these. Ticona received the certification for this standard in 2003.

The Ticona Oberhausen site in Germany gained registration under ISO 14001, the Environmental Management System Standard, in 1999. All Ticona facilities in the Americas achieved certifi cation under ISO 14001 in 2002. At Kelsterbach, Germany, registration has been completed 2005.

The appropriate Ticona laboratories are accredited to meet general requirements according to ISO/IEC 17025:2000 for testing and calibration laboratories.

Our www.ticona.com website provides further information under “Company” > “Quality and Certifications”. This information includes the details of business lines and facilities covered and PDF files of all certificates of registration.

3. Physical properties

This section discusses the important characteristic properties of Hostaform and their dependence on temperature and time. These properties were determined largely by standard test methods.

The physical property values of Hostaform are given in a fold-out leaflet, B 264 FB E.

Descriptions of the Hostaform grades and their prop-erties are available on the Ticona homepage www.ticona.com.

The Hostaform basic grades cover a melt volume flow rate range from 0.9 to 39 $cm^3/10$ min and have a density of 1.41 g/cm^3. The addition of glass or elastomer lowers the melt flow rate; density is increased in the first case and reduced in the second. Hostaform has low water absorption.

3.1 Mechanical properties

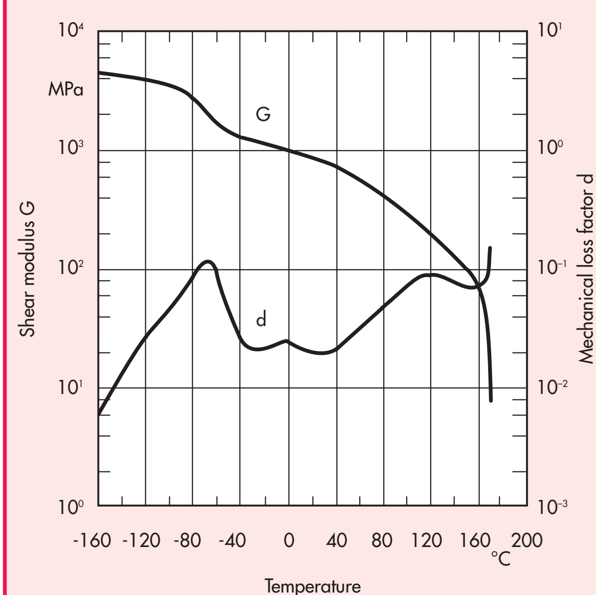
Determination of the properties of plastics by standard test methods yields valuable information for purposes of production control and facilitates preliminary selection of materials by the designer. However, the results of short-time tests are seldom a suitable basis for the dimensioning of structural elements.

Thermoplastics are viscoelastic materials. They exhibit the property known as creep, ie they tend to undergo deformation with time, depending on temperature and stress. After stress removal, depending on the level and duration of stress, a moulded part returns partially or completely to its original shape. The reversible deformation corresponds to the elastic portion and the permanent deformation to the plastic portion. This viscoelastic behavior must be borne in mind when designing moulded parts.

From the above, it follows that the mechanical properties of a plastic are primarily dependent on three important basic parameters: time, temperature and stress. Further important influences are: design, conditions of manufacture and environmental conditions. One important factor which characterizes a plastic is the dependence of shear modulus G on temperature.

The temperature dependency of the shear modulus G and the mechanical loss factor d are shown in fig. 1 for Hostaform C 9021 and in fig. 2 for Hostaform S 9064 and Hostaform S 9244 (see also section 3.2 "Thermal properties").

Fig. 1 · Shear modulus G and mechanical loss factor d of Hostaform C 9021 as a function of temperature; torsional oscillation test DIN 53 445



The property values determined on test specimens by standard methods are guide values and can be used as a basis for comparing different materials. However they have only limited applicability to finished parts. The strength of a component depends to a great extent on design and hence design strength is the criterion used to assess loadbearing capacity [14, 15].

Other properties measured under short-term stress are the tensile modulus and flexural modulus, both determined according to ISO 527 and ISO 178. These values provide an indication of rigidity and are used not only to characterize plastics but also for strength calculation and the design of moulded parts.

Fig. 2 · Shear modulus G and mechanical loss factor d of Hostaform S 9064 and S 9244 as a function of temperature; torsional oscillation test DIN 53 445

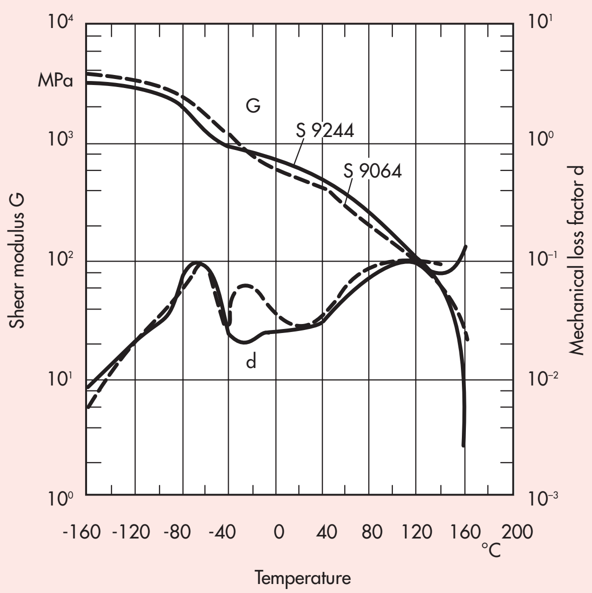
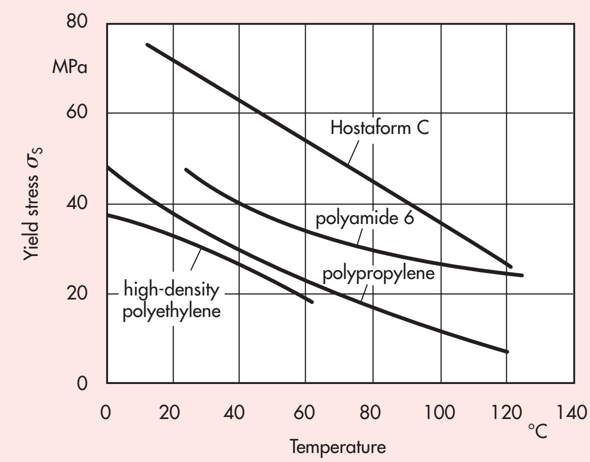


Fig. 3 · Yield stress of various thermoplastics as a function of temperature (deformation rate 12.5 mm/min, test specimen 3 with dimensions in the ratio 1:4, prepared from compression moulded sheet)



Hostaform C has higher rigidity values than the standard polymers and because of its particular spectrum of properties is classed as an engineering plastic.

3.1.1 Properties under short-term stress

The behaviour of materials under steady, short-term stress can be examined in the tensile test according to ISO 527. This test enables the yield stress, elongation at yield, ultimate tensile strength and elongation at break.

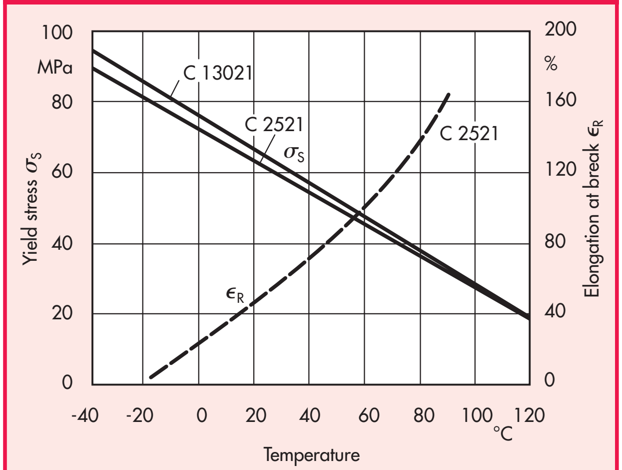
Fig. 3 shows the yield stress of various thermoplastics as a function of temperature. It can be seen that Hostaform C has considerably higher strength than the standard plastics.

3.1.1.1 Hostaform basic grades

These have yield stresses of between about 60 and 70 MPa and elongation at break values of between about 15 and 35%. These values are plotted against temperature in fig. 4 for grades C 13021 and C 2521.

The moduli of the Hostaform basic grades are between 2400 and 3100 MPa.

Fig. 4 · Yield stress σ_S of Hostaform C 2521 and C 13021 and elongation at break ϵ_R of Hostaform C 2521 as a function of temperature (deformation rate 50 mm/min, test specimen 3)



3.1.1.2 Reinforced grades

The glass-fibre-reinforced grades have no yield stress values but only ultimate tensile strength values and corresponding elongation at break values. The ultimate tensile strength values of the glass-fibre-reinforced grades, although varying according to glass fibre content, are significantly higher than those of the basic grades and attain 135 MPa; the elongation at break values on the other hand are lower. Reinforcement with glass fibres also brings a considerable increase in rigidity; moduli of up to 13 000 MPa can be achieved.

Glass spheres used as reinforcing materials increase only the moduli (to 3100 – 3700 MPa). Unlike in reinforcement with glass fibre, ultimate tensile strength values decrease somewhat with increasing glass sphere content. Elongation at break values are also reduced.

3.1.1.3 Hostaform/elastomer blends

With increasing elastomer content, the elongation at break of Hostaform increases considerably. Yield stress and modulus decrease.

3.1.2 Properties under long-term stress

The results of long-term tests carried out under various conditions provide the design engineer with a basis for calculation when designing components subjected to prolonged stress.

The properties of plastics under long-term tensile stress are tested by two basic methods:

- creep rupture test according to ISO 899 (deformation increase in specimen held under constant stress)
- stress relaxation test according to DIN 53 441 (stress decay in specimen held under constant strain).

The first test gives the creep strength, ie the time to rupture of a test bar loaded with a specified stress under defined environmental conditions. These tests are carried out on tensile test bars (uniaxial stress condition) or on pipes (multiaxial stress condition) in air or another medium.

The strain values and creep moduli determined in the creep rupture test under tensile stress also serve as a good approximation for the values to be expected under flexural and compressive stress. To provide a certain safety margin against failure, a strain of 0.5 to 1% is usually allowed for in design calculations.

The deformation of a plastic component is not only time- and temperature-dependent but is also a function of the type of stress. Strictly speaking, separate characteristic values should be determined for each type of stress. However, for deformation ≦ 2%, the variation between the characteristic values is negligible so that, for example, the time-dependent compression of a component under compressive stress may be calculated with sufficient accuracy using the flexural creep modulus (determined under flexural stress).

The results of creep tests under uniaxial stress have only limited applicability to the multiaxial stress state.

Fig. 5 shows the creep strength of pipes made from Hostaform C 2521 under internal pressure.

Fig. 5 · Creep strength of pipes made from Hostaform C 2521 (test temperature 20 to 60°C, water inside and outside)

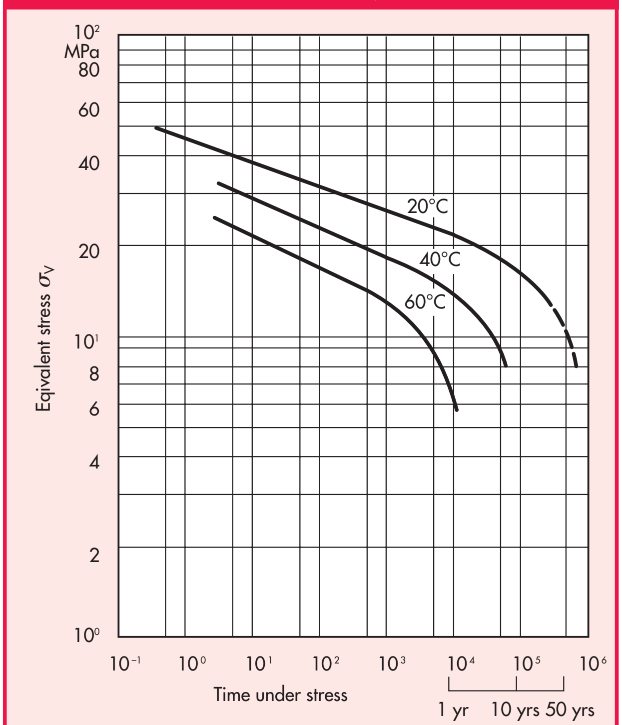


Fig. 6 shows the creep curves (time-strain curves) determined with tensile test bars made from Hostaform C 9021 for various stresses at a test temperature of 23 °C in air. By joining the end points of these lines, the failure curve is obtained; this represents the creep strength. For a stress of 10 MPa, for example, and a time under stress of 10 years, a strain of 1.1% is obtained.

Fig. 6 · Time-strain curves (creep curves) for Hostaform C 9021, measured at 23°C (also a good approximation for the other unmodified Hostaform grades)

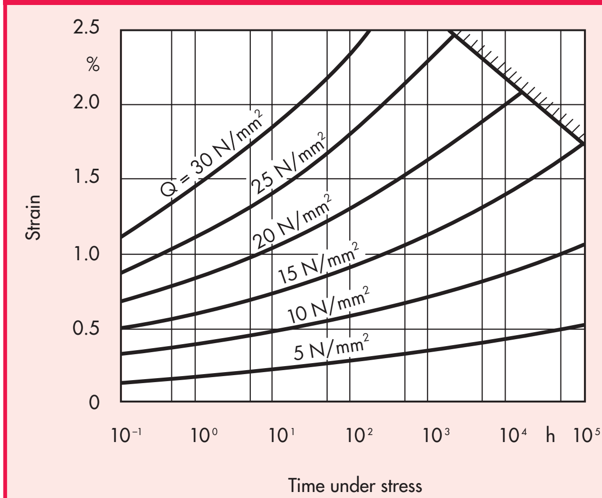
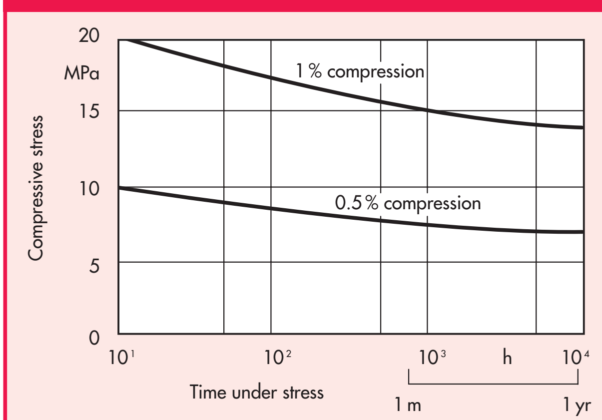
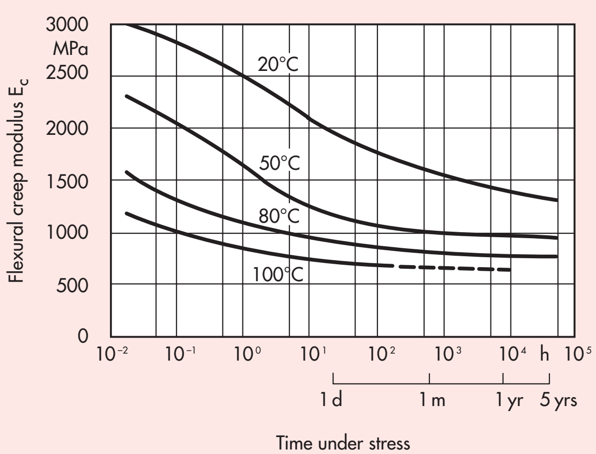


Fig. 7 · Time-compressive stress curve for Hostaform C 9021 at 20°C



The time-compressive stress curves for Hostaform C 9021 are similar to those for time-tensile stress. By analogy with the time-strain limits, it is possible in this case to speak of time-compression limits. From fig. 7, the permissible compressive stress for a given time under stress and percentage compression may be deduced. For a period under stress of one year and a permissible compression of 0.5%, the continuous compressive stress may amount to 7.5 MPa. With a permissible compression of 1%, 14 MPa would be possible.

Fig. 8 · Flexural creep modulus of Hostaform C 9021 at various temperatures (measured with an outer-fibre stress σ_b = 10 MPa)



In addition to the information provided by creep tests under tensile stress or internal pressure as described above, knowledge of behaviour under flexural stress is important in designing many structural components. Fig. 8 shows the flexural creep modulus of Hostaform C 9021 as a function of time and temperature.

Fig. 9 shows that the flexural creep modulus of Hostaform C 13031 is about 10% higher than that of Hostaform C 13021 throughout the test period.

The addition of glass fibres substantially reduces creep, even in the case of rigid thermoplastics. Fig. 10 compares the flexural creep modulus of unreinforced and glass-fibre-reinforced Hostaform.

It can be seen that the flexural creep modulus of glass-fibre-reinforced Hostaform after one year's loading at 80 °C is still higher than the initial flexural creep modulus of unreinforced material at 20 °C.

Fig. 9 · Flexural creep modulus of Hostaform C 13031 (a) and Hostaform C 13021 (b) (test specimen injection moulded, outer-fibre stress σ_b = 10 MPa, test temperature 23°C)

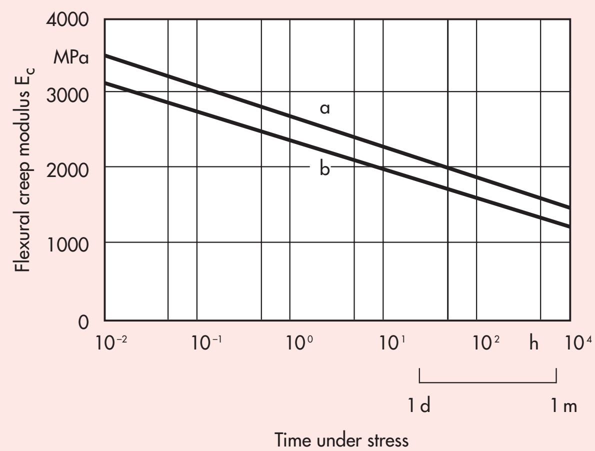
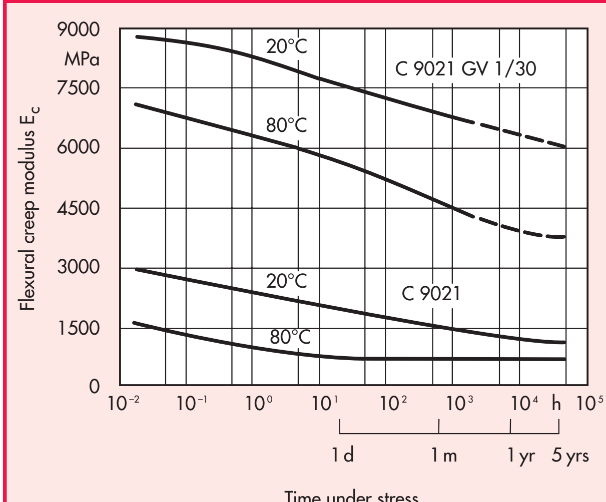
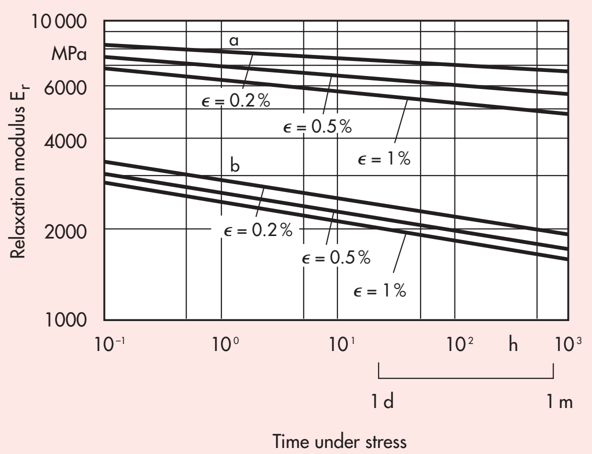


Fig. 10 · Flexural creep modulus of Hostaform C 9021 GV 1/30 and Hostaform C 9021 (outer-fibre stress σ_b = 10 MPa, test temperatures 20 and 80°C)



The results of stress relaxation tests in accordance with DIN 53 441 are shown in fig. 11. It can be seen that the relaxation moduli of glass-fibre-reinforced Hostaform C 9021 GV 1/30 are markedly higher than those of the unreinforced Hostaform C 9021; moreover, they have a considerably flatter curve. This means that the glass-fibre-reinforced product not only has less tendency to creep than the unreinforced material (as confirmed by the flexural creep test) but also relaxes more slowly.

Fig. 11 · Relaxation modulus E_r of Hostaform C 9021 GV 1/30 (a) and Hostaform C 9021 (b) as a function of time under stress at room temperature



An indication of the creep behaviour of the high-impact Hostaform grades is given in figs. 12 a to 12 d. These show the time-strain curves for Hostaform S 9063, S 9064, S 9243 and S 9244 determined in the creep rupture test under tensile stress (ISO 899) at 23 °C for several stresses.

3.1.3 Properties under impact stress

The toughness of moulded articles made from visco-elastic materials is very much a function of deformation rate as well as being influenced by factors such as design, state of orientation, manufacturing conditions and the service environment, especially temperature. A material which exhibits relatively high extensibility at a low deformation rate, as for example in a conventional tensile test with deformation rates v_D = 0.1 to 10% per sec, may fail without elongation in a tensile impact test at deformation rates v_D of, for example, 10 000% per sec and thus appear to be a brittle material.

Like high deformation rates, low temperatures also cause a decrease in toughness.

Notches have the same effect. They create a stress concentration point at the root of the notch (which may be expressed by the notch shape factor α_K [14]). This leads to a reduction in strength, particularly at high deformation rate. Notches should therefore be avoided if at all possible in the design of plastic parts.

Information on the behaviour of plastics at high deformation rates is provided by flexural impact, drop and penetration tests.

3.1.3.1 Hostaform basic grades

The glass transition temperature of the Hostaform base polymer (– 60 to – 65 °C) is low compared to that of other plastics. This explains its remarkably high-impact strength even at low temperature.
The impact strength of the Hostaform basic grades decreases slightly with increasing melt mass-flow-rate (= decreasing molecular weight). This relationship between molecular weight and resistance to impact stress can be discerned in all the test methods used. The easyflowing grades C 9021, C 2521 and T 1020 are therefore suitable for the production of impact-resistant mouldings, provided these have medium to large wall thickness.

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Fig. 12 a · Time-strain curves (creep curves) for Hostaform S 9063 natural (test temperature 23°C, measured in air, determined according to ISO 899)

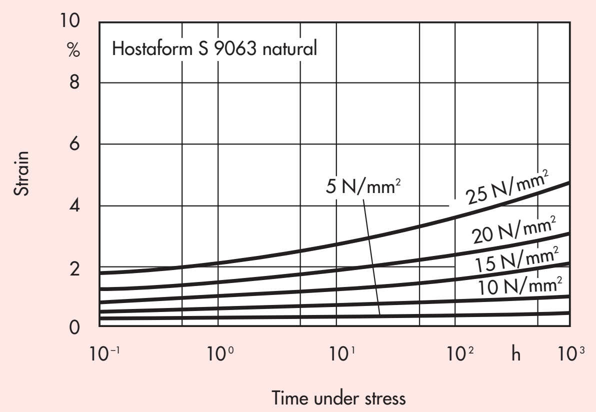


Fig. 12 c · Time-strain curves (creep curves) for Hostaform S 9243 natural (test temperature 23°C, measured in air, determined according to ISO 899)

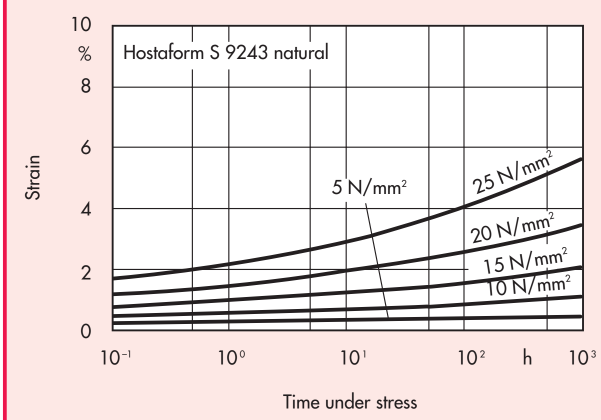


Fig. 12 b · Time-strain curves (creep curves) for Hostaform S 9064 black 10/1570 (test temperature 23°C, measured in air, determined according to ISO 899)

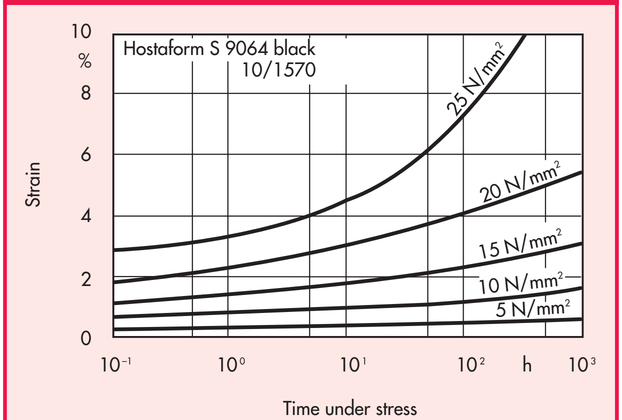
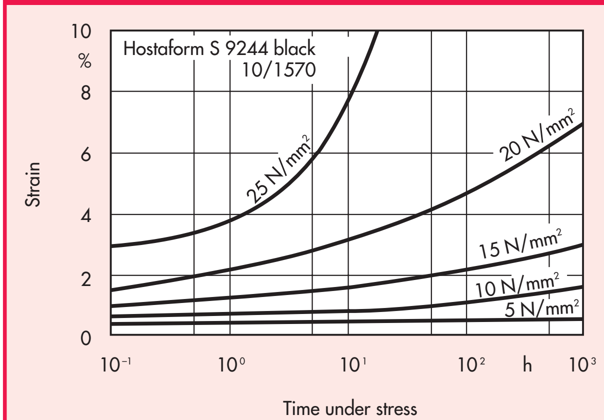


Fig. 12 d · Time-strain curves (creep curves) for Hostaform S 9244 black 10/1570 (test temperature 23°C, measured in air, determined according to ISO 899)



The use of high-molecular-weight grades such as C 2521 for thin-walled parts can lead to orientation of the molecular chains in the flow direction, resulting in mouldings with high internal stresses and anisotropy of mechanical properties. Easier-flowing grades give rise to less oriented, stress-free mouldings with considerably higher toughness than mouldings made from high-molecular-weight grades.

3.1.3.2 Reinforced and filled grades

Incompatible additives have the effect of reducing toughness. This can be attributed to the micronotches introduced into the polymer matrix. As table 1 shows, this applies particularly to the reinforced Hostaform grades but also to C 9021 TF, C 9021 G and C 2521 G; with these grades, there is a marked reduction in impact strength but notched impact strength is also lower. This tendency is also discernible with C 9021 K.

For the same reason, Hostaform formulated with black 10/1570 also has slightly lower toughness than the corresponding natural grades.

In the case of C 9021 ELSX, EC 270 TX, the loss of toughness associated with the electrically conductive carbon black content is partially offset by incorporating an elastomer component.

In drop tests, the decline in toughness of the reinforced and filled grades as compared with unreinforced grades is less pronounced than in the impact and notched impact strength tests. This is the reason why mouldings produced from these grades have adequate design strength, even under impact stress.

3.1.3.3 Hostaform/elastomer blends

The good toughness of the basic grades can be raised to an even higher level by the addition of suitable elastomers. These grades are therefore blends and are given the name Hostaform S. Their toughness depends on the type and content of elastomer. The last digit of the code designation indicates the level of toughness, ie the higher the last digit, the higher the toughness while at the same time strength, hardness and rigidity decrease. The following figs. provide information on the nature of the improved toughness and the level of increase. In figs. 13 and 15, the S grades are compared with Hostaform C 9021 on the basis of results from penetration tests with electronic data recording. Figs. 13 and 14 show the work to damage, figs. 15 and 16 the deformation, in each case as a function of temperature. The high impact energy absorption capacity and deformability of S 27076 and increased impact strength of S 9244, particularly at low temperature, can be clearly seen.

Fig. 13 · Work to damage of Hostaform S and Hostaform C as a function of temperature (penetration test with electronic data recording as specified in ISO 6603-2)

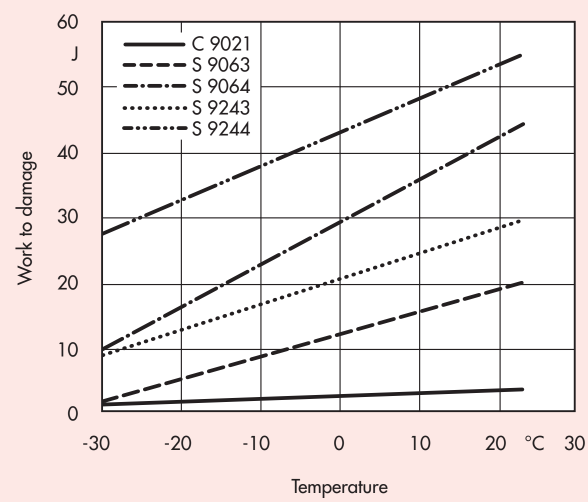


Fig. 14 · Work to damage of Hostaform S as a function of temperature (penetration test with electronic data recording as specified in ISO 6603-2)

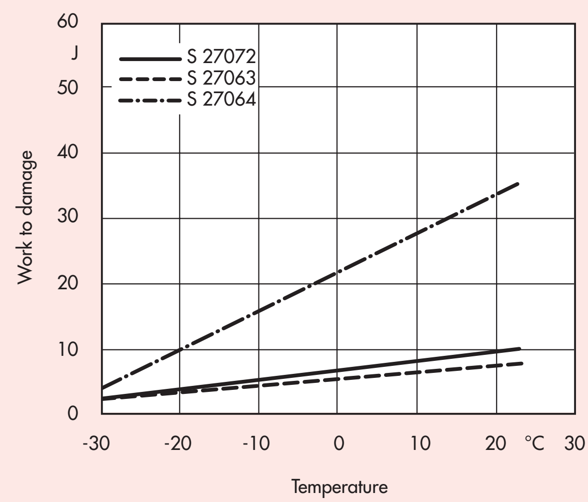


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Fig. 15 · Deformation of Hostaform S and Hostaform C as a function of temperature (penetration test with electronic data recording as specified in ISO 6603-2)

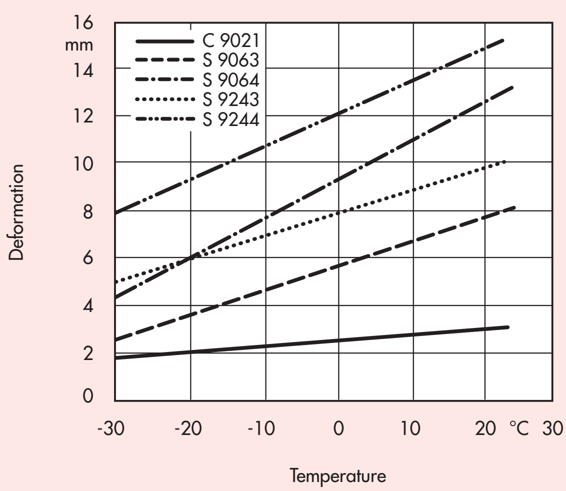
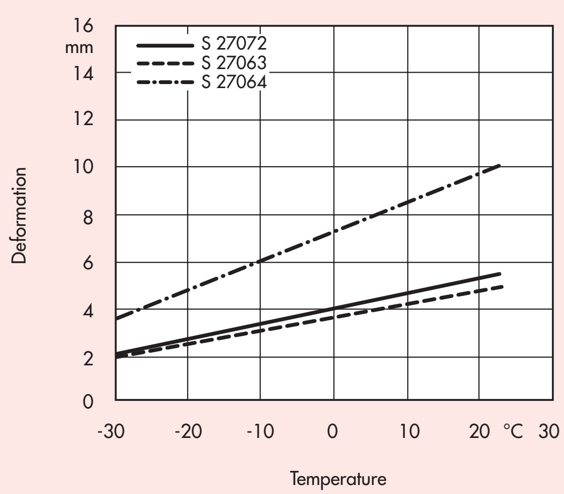


Fig. 16 · Deformation of Hostaform S as a function of temperature (penetration test with electronic data recording as specified in ISO 6603-2)



Figs. 17 and 18 show the effect of temperature on the notched impact strength of the S grades; fig. 17 makes a comparison with Hostaform C 9021.

Fig. 17 · Notched impact strength (Charpy) according to ISO 179/1 e A of Hostaform S compared with Hostaform C as a function of temperature

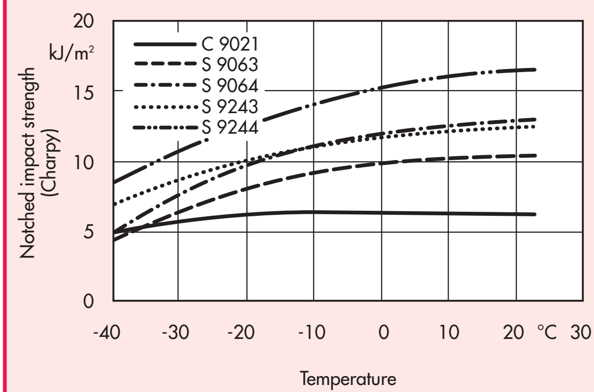
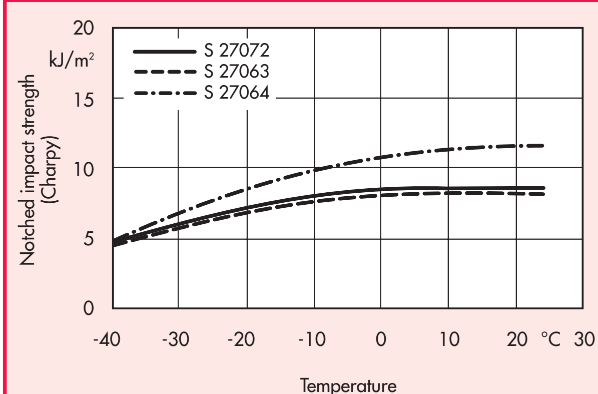


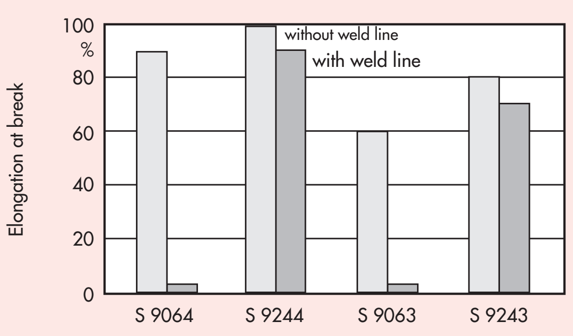
Fig. 18 · Notched impact strength (Charpy) according to ISO 179/1 e A of Hostaform S as a function of temperature



At room temperature, the differentiation evident in table 1 can be seen; at –40 °C, most grades are at the same level while grades S 9243 and S 9244 show significantly better toughness.

Grades S 9243 and S 9244 have flow properties comparable with those of S 9063 and S 9064 but can be processed without macroscopic phase separation (delamination). In addition they have high weld strength. As can be seen from fig. 19, the elongation at break values of test specimens gated on one and both sides are practically the same.

Fig. 19 · Elongation at break of some Hostaform S grades, determined on test specimens (no. 3, ISO 527) gated on one and both sides

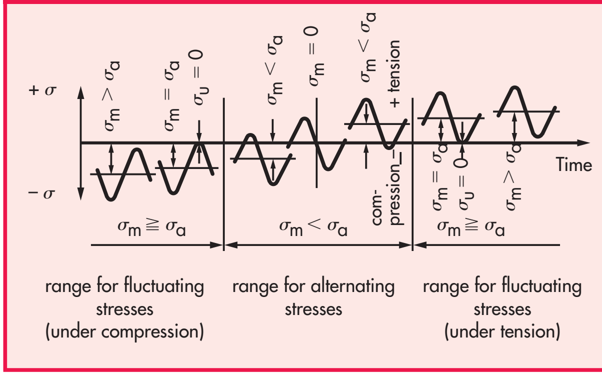


3.1.4 Properties under cyclic stress

Structural components subject to periodic stress must be designed on the basis of fatigue strength, ie the cyclic stress amplitude σ_a obtained in the fatigue test – at a given mean stress σ_m – which a test specimen withstands without failure over a given number of stress cycles, eg 10^7, ("Wöhler curve"). The various stress ranges in which tests of this nature are conducted are shown in fig. 20.

For most plastics, the fatigue strength after 10^7 stress cycles is 20 to 30% of the ultimate tensile strength determined in a tensile test. It decreases with increasing temperature and stress cycle frequency, and with the presence of stress concentration peaks in notched components.

Fig. 20 · Stress ranges in fatigue tests



In the following figs., Wöhler curves are shown for Hostaform C 9021 (applicable with good approximation to the other basic grades as well) and also for Hostaform C 9021 GV 1/30 (determined in the alternating and fluctuating flexural stress ranges).

The Wöhler curve for tensile/compressive alternating stress is reproduced in fig. 21. According to the diagram, the fatigue strength under tensile/compressive alternating stress for 10^7 stress cycles amounts to $\sigma_w = \pm 20$ MPa.

Fig. 22 shows the behaviour of Hostaform in the fluctuating tensile stress range.

Fig. 21 · Wöhler curve for Hostaform C 9021, determined in the tensile/compressive alternating stress range (test specimen 3 from tensile test ISO 3167; also a good approximation for the other unmodified Hostaform grades)

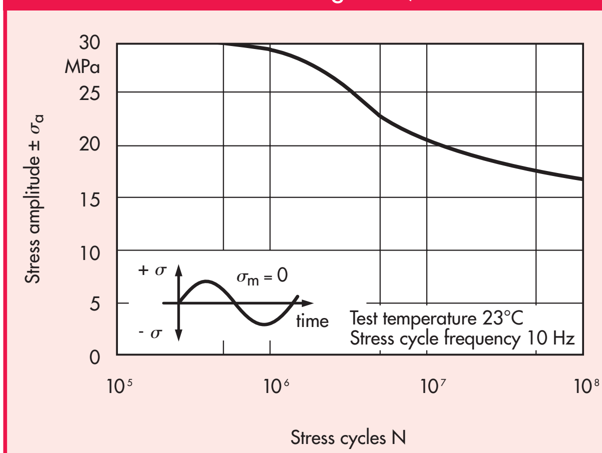


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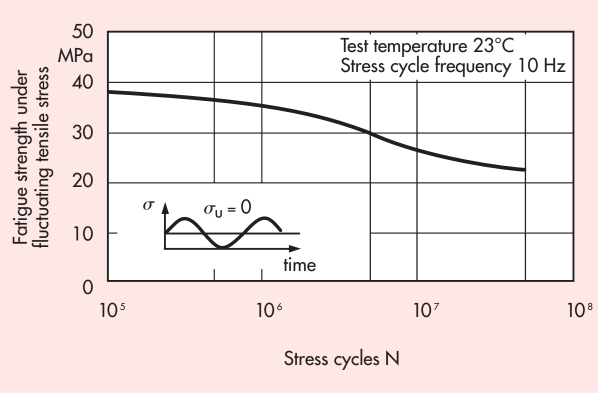
Fig. 22 · Wöhler curve for Hostaform C 9021, determined in the fluctuating tensile stress range (test specimen 3 from tensile test ISO 3167; also a good approximation for the other unmodified Hostaform grades)



The Wöhler curves for alternating flexural stress obtained with test specimen 1 (6 mm thick) are shown in fig. 23 and those for fluctuating flexural stress in fig. 24.

Fig. 23 · Wöhler curves for Hostaform C 9021 GV 1/30 (a), C 9021 (b), S 9244 (c) and S 9064 (d) determined alternating flexural stress range (curve b is also a good approximation for the other unmodified Hostaform grades)

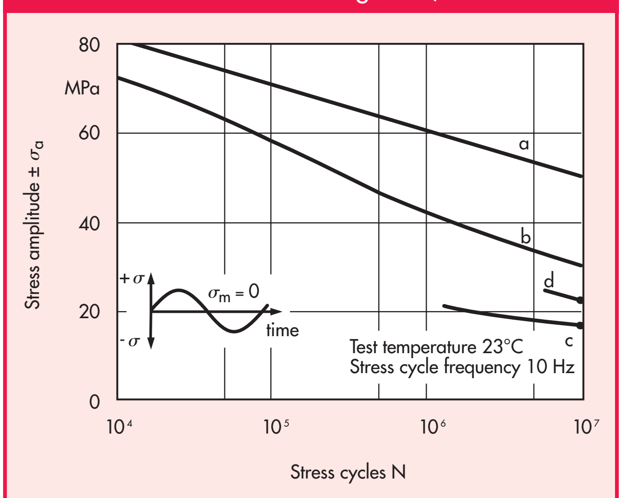
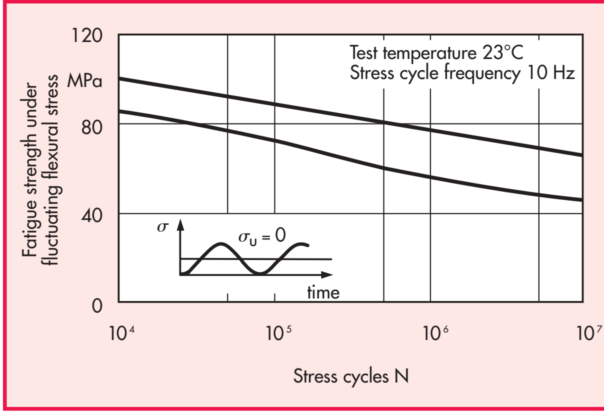


Fig. 24 · Wöhler curves for Hostaform C 9021 (b), and Hostaform C 9021 GV 1/30 (a), determined in the fluctuating flexural stress range (curve b is also a good approximation for the other unmodified Hostaform grades)



Similarly in fatigue strength tests under torsional stress, values under fluctuating and alternating torsional stress conditions are determined. The Wöhler curves obtained on test specimens with a circular cross section (diameter in the measuring zone 8 mm) at room temperature and a test frequency of 10 Hz are shown in figs. 25 and 26.

Fig. 25 · Wöhler curve for Hostaform C 9021, determined in the fluctuating torsional stress range (also a good approximation for the other unmodified Hostaform grades)

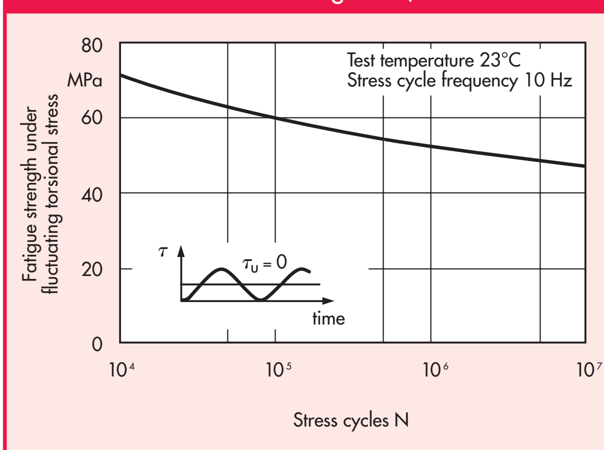


Fig. 26 · Wöhler curve for Hostaform C 9021, determined in the alternating torsional stress range (also a good approximation for the other unmodified Hostaform grades)

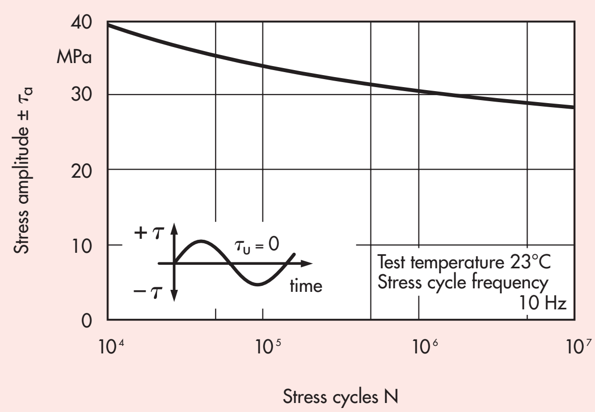
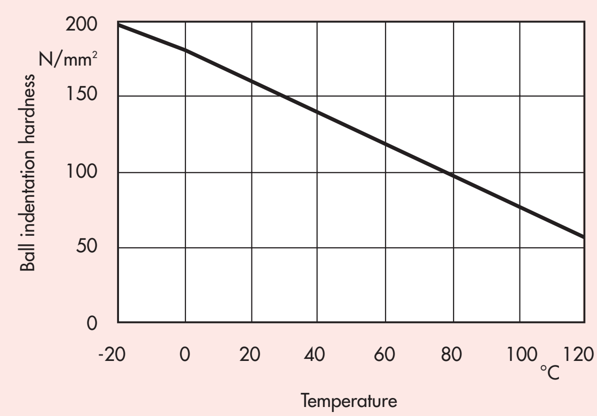


Fig. 27 · Ball indentation hardness of Hostaform C 9021 as a function of temperature (according to ISO 2039 part 1, 30-sec values)



3.1.5 Surface properties

Hostaform has outstandingly good surface properties, such as hardness, abrasion resistance and low-friction behaviour, which are important in many technical applications.

Hardness

For thermoplastics, it is customary to determine ball indentation hardness in accordance with ISO 2039 part 1. The effect of temperature on the ball indentation hardness of Hostaform C 9021 is shown in fig. 27.

The other basic grades have comparable hardness, except the grades C 2521 and M30AE based on the low molecular weight POM.

The reinforced grades have a higher ball indentation hardness than Hostaform C 9021 while the high-impact grades possess lower hardness. In each case, the type and quantity of reinforcing material or additive makes a difference to the actual hardness value.

Slip properties

Mouldings made from Hostaform have good slip properties, which accounts for the successful use of this material for gearwheels, bearings and sliding and control elements.

It should be remembered that slip properties are always characteristic of a particular system. In other words, coefficients of friction are not material constants but depend on the sliding partner, surface pressure loading, sliding speed and measuring equipment used, ie they are a function of the whole system.

Tests carried out at 20 to 90 °C to determine the friction coefficient of Hostaform against itself (both materials unmodified) showed mean values of 0.35 for the static and 0.25 for the dynamic friction coefficient. Fig. 28 compares the friction coefficients of unmodified Hostaform, Hostaform C 9021 K and C 9021 M (region b), C 9021 TF (region c) and C 9021 GV 1/30 (region a) in sliding contact with hardened and polished steel with a roughness height of 2.5 μm as a function of the pressure loading p at a constant sliding speed of v = 10 m/min. The measurements were carried out under simulated bearing conditions using a system of steel shaft and plastic bearing.

Fig. 28 · Dynamic friction coefficient μ of various Hostaform grades as a function of loading pressure in sliding contact with steel with a roughness height of 2.5 μm at a sliding speed of v = 10 m /min

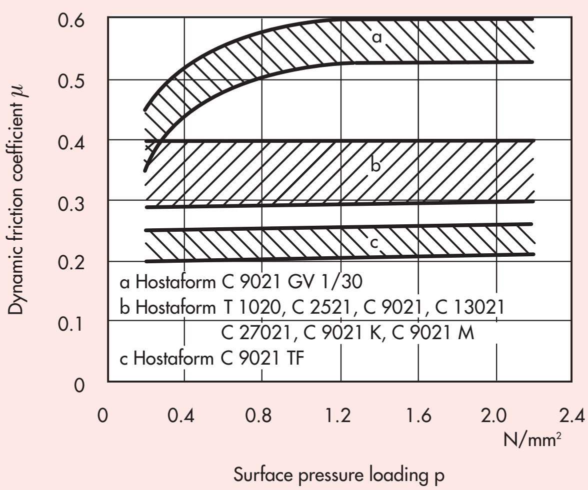


Fig. 30 · Dynamic friction coefficient μ of various Hostaform grades as a function of surface pressure loading p in sliding contact with steel with a roughness height of 2 μm at a sliding speed of v = 5 mm /min

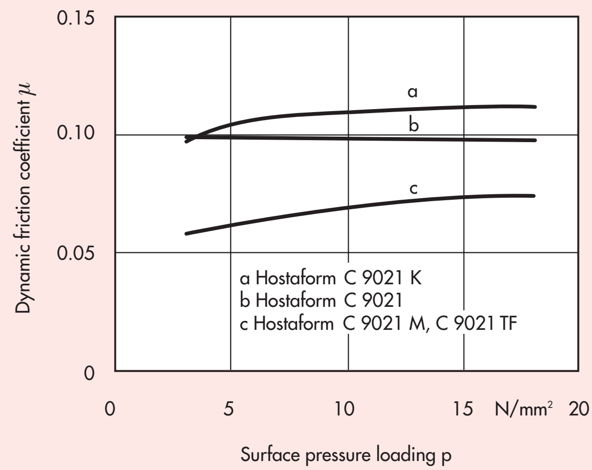
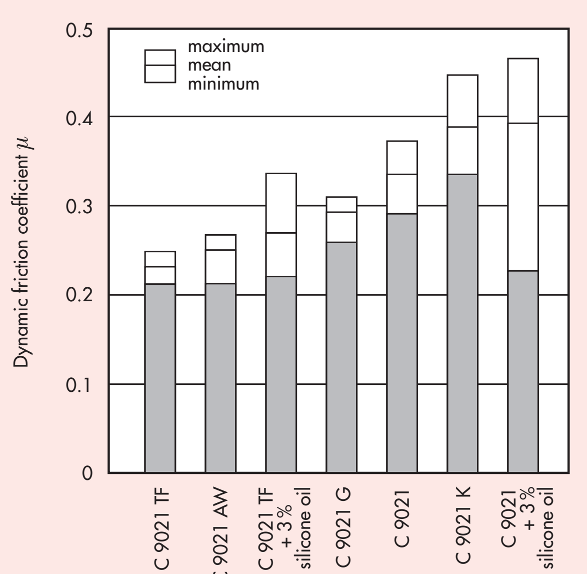


Fig. 29 · Dynamic friction coefficient μ of various Hostaform grades, determined under simulated bearing conditions in sliding contact with steel (sliding speed v = 20 m/min, mean pressure loading p = 1.25 N/mm², test duration ≈ 30 min)



With the same test arrangement but at a sliding speed of 20 m/min and a constant pressure loading of 1.25 N/mm², the dynamic friction coefficients shown in fig. 29 were determined. From this comparison, it can be seen that grade C 9021 G comes between C 9021 and C 9021 TF.

The slip behaviour of various Hostaform grades against steel with a roughness height $R_t \approx 2$ μm at a low constant sliding speed of 5 mm/min and comparatively high pressure loadings is shown in fig. 30.

Apart from the inherently low level of friction coefficient for all Hostaform grades, the beneficial effect of MoS_2 and PTFE (curve c) under the test conditions is clearly seen.

Hostaform C 9021 M can therefore be used where low sliding speeds, high pressure loadings and short slide paths occur, as is frequently the case in pendulum bearings, guides and similar applications.

Under the above conditions, the PTFE-modified grade Hostaform C 9021 TF is equally effective. This grade performs better than C 9021 M at higher sliding speeds, as the following comparison shows:

dynamic friction coefficient μ at sliding speed and pressure loading	v = 230 mm/min p = 6 N/mm²
Hostaform C 9021 M	μ = 0.12
Hostaform C 9021 TF	μ = 0.09

For sliding parts operating under normal conditions, it is best to use unmodified Hostaform or Hostaform C 9021 K which, with its more advantageous wear properties, is particularly suitable for unlubricated sliding elements.

The load-carrying capacity of slide bearings is expressed by the p · v values, which are the product of the specific bearing load p (N/mm²) and the peripheral speed of the shaft journal v (m/min).

The peripheral speed v is calculated from equation (1):

$$v = \frac{\pi \cdot d_W \cdot n}{1000} \quad [\text{m/min}] \qquad (1)$$

d_W shaft diameter [mm]
n shaft speed [1/mm]

Using fig. 31, this calculation is simplified to:

$$v = f \cdot n \quad [\text{m/min}] \qquad (2)$$

The specific bearing load p is calculated from equation (3) by dividing the bearing load F by the projected bearing surface:

$$p = \frac{F}{d_L \cdot l} \quad [\text{N/mm}^2] \qquad (3)$$

where F bearing load [N]
d_L inside diameter of bearing [mm]
l length of bearing [mm]

For peripheral speeds up to about 30 m/min, on the basis of previous test results we may, according to fig. 32 for unlubricated bearings, assume the value:

$$p \cdot v = 8 \, \frac{N}{mm^2} \cdot \frac{m}{min}$$

Fig. 31 · Factor f for calculating the peripheral speed v according to equation (2)

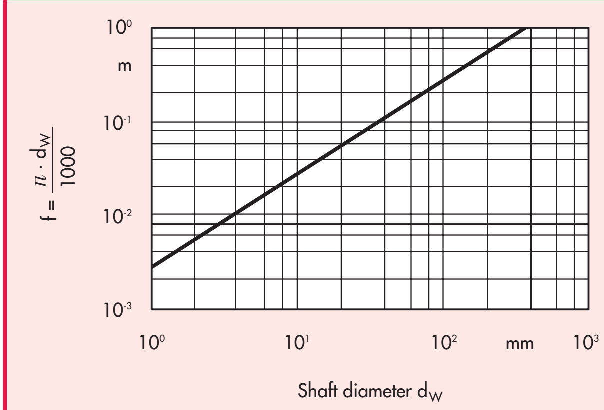
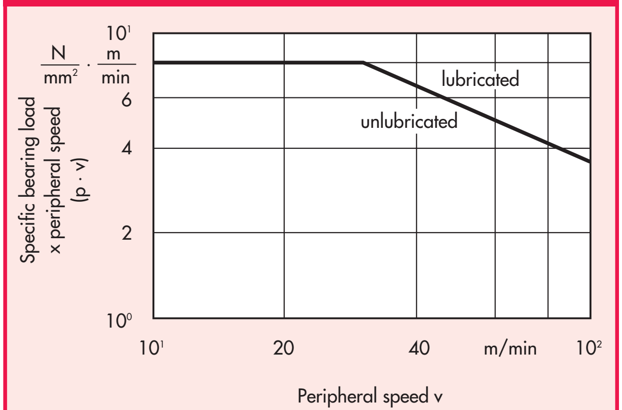


Fig. 32 · Recommended load limits for unlubricated bearings made from Hostaform



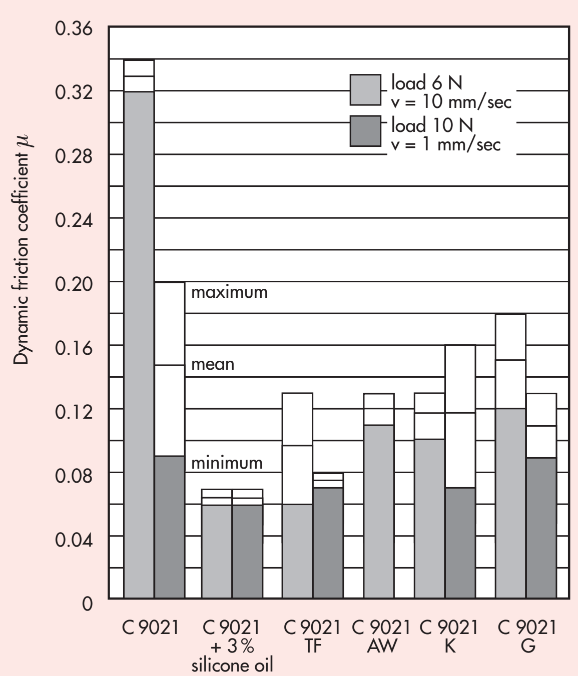
For higher p · v values, bearings must normally be lubricated. Rise in bearing temperature is usually unpredictable, so that each bearing should be tested under service conditions.

Reliable long-term operation was achieved, for example, with a lubricated bearing having an inside diameter of 25 mm at a peripheral speed of 60 m/min and a p · v value of 30 N/mm² · m/min.

It should be borne in mind that the curve in fig. 32 does not represent a universally valid characteristic function; the p · v values shown should be regarded as guide values. The values obtainable in individual cases are dependent on numerous design and operational factors and may therefore be below, but possibly also above, the stated values. Where service temperatures exceed 20 °C, safety factors should be applied to the stated p · v values. Where temperatures in the sliding zone of the bearing exceed 80 to 100 °C, a marked increase in wear must be expected. For this reason, the ambient temperature should not exceed 50 to 60 °C.

With reciprocating motion between Hostaform and steel, loads of 6 and 10 N and speeds of 10 and 1 mm/sec, the dynamic friction coefficients shown in fig. 33 are obtained.

Fig. 33 · Dynamic friction coefficient μ, measured with reciprocating motion between Hostaform and steel



The slip behaviour of Hostaform S is shown in fig. 34 (under simulated bearing conditions) and fig. 35 (reciprocating motion). While in the first case the S grades have slightly higher friction coefficients than Hostaform C 9021, in the second they are practically the same.

Fig. 34 · Dynamic friction coefficient μ of Hostaform S and Hostaform C, determined under simulated bearing conditions (sliding speed v = 20 m/min, pressure loading p = 1.25 N/mm², roughness height of steel = 2.5 μm)

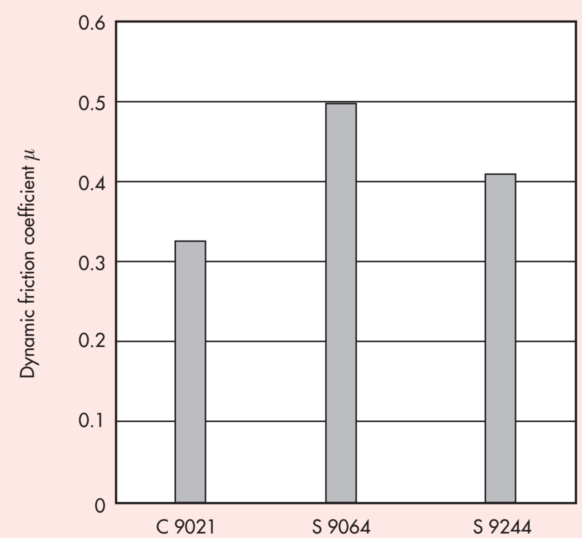
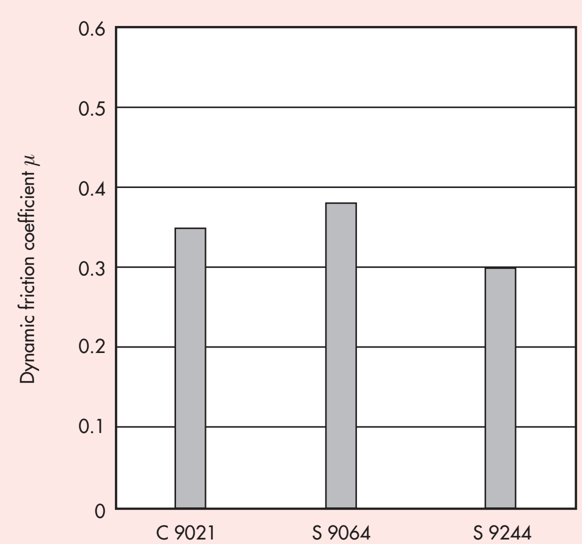


Fig. 35 · Dynamic friction coefficient μ of Hostaform S and Hostaform C, determined with reciprocating motion (steel ball on Hostaform sheet, sliding speed v = 600 mm/min, F = 6 N, test duration 480 min)



Wear

Like slip behaviour, wear is not a material constant but a system characteristic which severely limits the general applicability of test results.

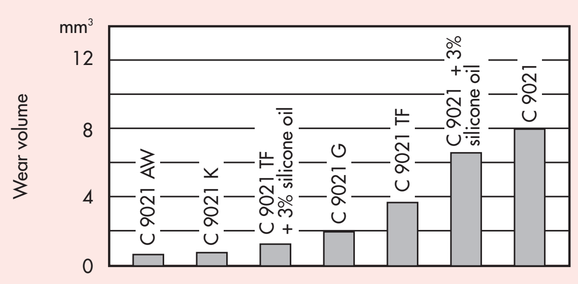
High hardness and a low friction coefficient are contributory factors in the better wear resistance which components made from Hostaform often exhibit as compared with parts manufactured from other plastics or from metals. In abrasion tests conducted with the aid of the Taber CS 17 abrader wheel used in the USA (10 N load, 23 °C, 50% relative humidity), there was very low weight loss.

Similar good results were obtained in wet abrasion tests with grinding media in ball mills.

Comparative trials conducted with both cylindrical sliding elements and bearing bushes have shown that in wear tests against steel the abrasion properties of Hostaform may be described as very good compared with other plastics, when the surface roughness of the opposing steel R_t is $\leqq 2\ \mu m$.

The test results shown in fig. 36 a relate to trials in which cylindrical specimens of plastic were pressed under slight load against a rotating steel shaft.

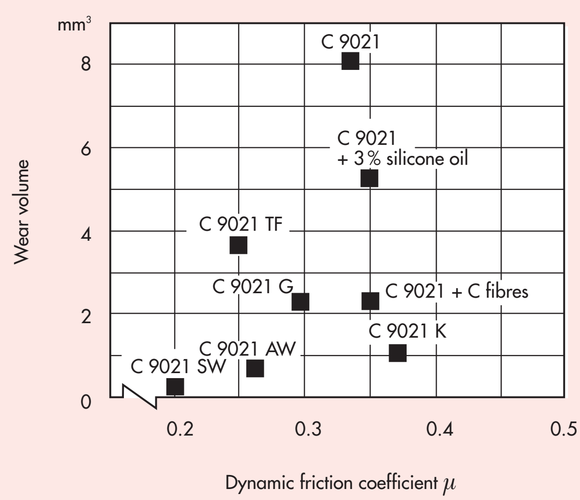
Fig. 36 a · Wear of various Hostaform grades in dry sliding contact with a rotating polished steel shaft (roughness height 0.8 μm, peripheral speed of the shaft v = 136 m/min, load F_N = 3.1 N)



The criterion for comparison is the volume of the groove worn into the specimen after a given time. The much lower wear susceptibility of the Hostaform grades C 9021 AW, C 9021 K, C 9021 G and C 9021 TF as compared with unmodified Hostaform C 9021 can be clearly seen, although the latter grade may still be classed as low-wear compared with other materials. To reduce wear, therefore, the grades with improved slip properties should be used. Another possibility is to add silicone oil, which can improve both slip properties and abrasion resistance. Since this improvement depends not only on the opposing material but also on the silicone oil content of the formulation, practical trials to determine the optimum blend ratio are recommended. Further options include once-only lubrication or pairing of different materials, eg Hostaform C 9021/C 9021 K or Hostaform/Celanex® [20].

Low friction coefficient combined with low wear are also provided by grades Hostaform C 9021 AW and C 9021 SW. The wear slip properties are summarized in fig. 36 b.

Fig. 36 b · Dynamic friction coefficient μ and wear volume of some Hostaform grades (opposing ma-terial: steel; wear volume determined with wear shaft – pin/roll – for 60 h; dyn. friction coefficient determined with friction balance 0.5 h, p = 1.25 N/mm², v = 10 m/min)



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The pigmentation of Hostaform can influence its wear properties. Preliminary tests are therefore recommended whenever coloured material is to be used.

As fig. 37 shows, the elastomer-modified Hostaform S grades have similar good sliding and wear properties to the corresponding unmodified Hostaform C grades. In addition, the S grades, because of their elastomer content, have better damping properties than the C grades and are therefore ideal for the production of quietly operating sliding parts, eg for drive pinions.

Further information on the sliding behavior of Hostaform is given in the brochure "Plain bearings made from engineering thermoplastics" (order no. B.2.3), the product information brochure "Products for tribological applications" (IT BR 1007D) and the Hostaform Tribology Navigator (TS-DS 1008), which helps you preselect a grade for a specific application from the range of Hostaform tribology specialties.

3.2 Thermal properties

The most important thermal properties of a plastic include:

- melting point, transition temperatures or phase change regions, specific heat, enthalpy, thermal conductivity, coefficient of expansion
- thermal stability (stability of the melt at processing temperature).

Specific heat

Fig. 38 shows the specific heat of Hostaform C 9021 as a function of temperature. The increase in enthalpy, calculated from the specific heat and based on an enthalpy value of zero at 20 °C, is shown in fig. 39.

It is essential in designing processing machines and in design calculations for moulded parts to know how much heat must be supplied or removed in processing Hostaform. In determining the approximate amount of heat to be removed, for example, in cooling the Hostaform melt from 220 °C to 90 °C, the following procedure is adopted (see fig. 39):

	enthalpy at 220 °C	586 kJ/kg
–	enthalpy at 90 °C	105 kJ/kg
=	heat to be removed	481 kJ/kg

Fig. 37 · Wear of Hostaform S and Hostaform C in dry sliding contact with a rotating polished steel shaft (roughness height 0.8 μm, peripheral speed of the shaft v = 136 m/min, load F_N = 3.1 N)

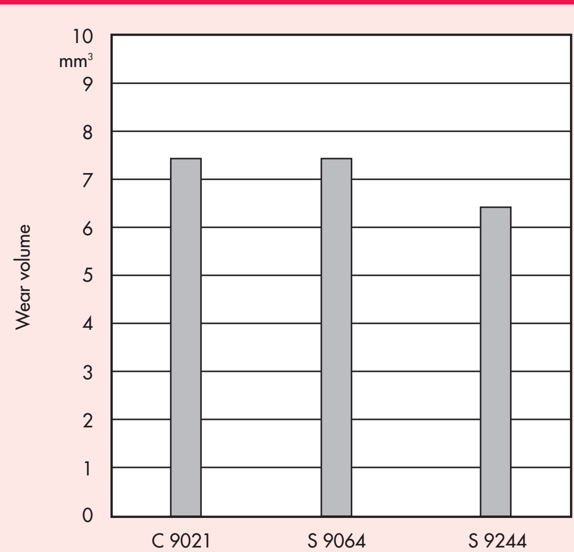


Fig. 38 · Specific heat of Hostaform C 9021 as a function of temperature

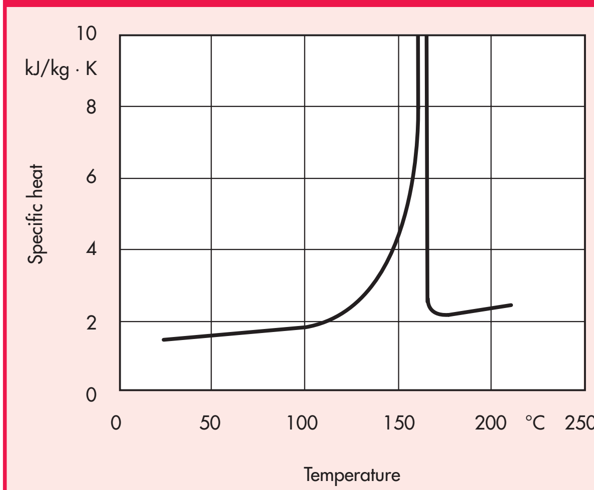


Fig. 39 · Enthalpy curve for Hostaform C 9021 (based on 20°C)

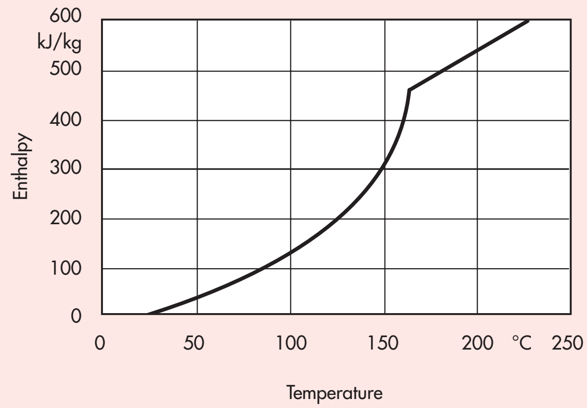
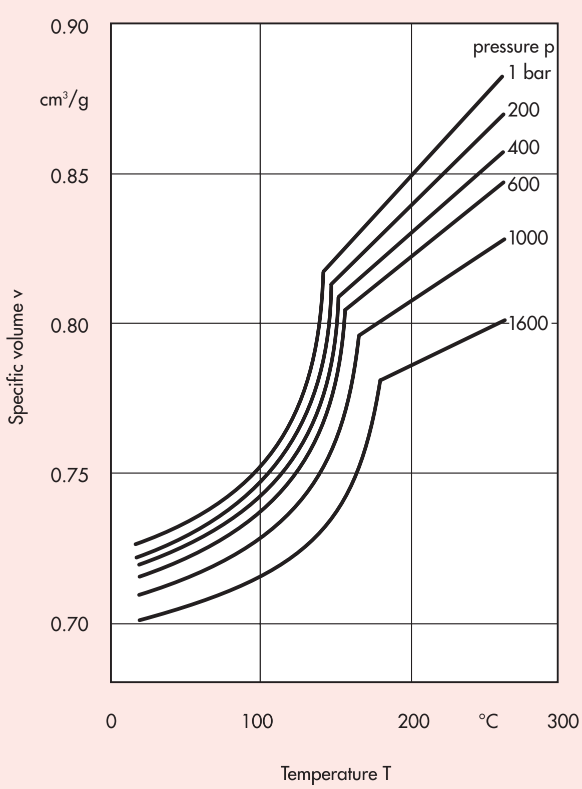


Fig. 40 · Specific volume v of unreinforced Hostaform C as a function of temperature T and pressure p (p-v-T-graph), measured at a cooling rate of 12 K/s



Specific volume

The specific volume (= reciprocal of density) of the Hostaform basic grades can be read off the p-v-T (pressure-specific volume-temperature) graph for the temperature range 20 – 250 °C (fig. 40).

Thermal conductivity

The thermal conductivity of the Hostaform basic grades at 20 °C is λ = 0.31 W/m · K; for Hostaform C 9021 GV 1/30, the conductivity value is 0.41 W/m · K and for the high-impact grades ranges between 0.27 and 0.34 W/m · K.

3

Coefficient of linear expansion

The linear expansion coefficient α of the Hostaform basic and reinforced grades is shown in fig. 41 as a function of temperature. As with most materials, it increases with rising temperature. As can also be seen from fig. 41, the glass-fibre-reinforcement reduces both the value and rate of increase of α. Furthermore, with Hostaform C 9021 GV 1/30, α is dependent on flow direction owing to orientation of the glass fibres during processing.

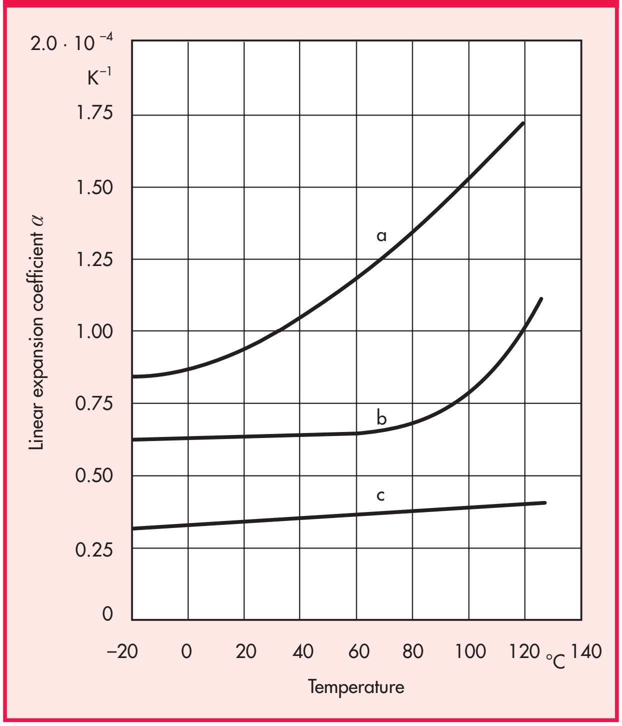
The Hostaform S grades have about a 20 to 30% higher expansion coefficient than the basic grades.

Using the mean value for the coefficient of linear expansion α_m, the length l of a moulding at temperature ϑ may be calculated according to the equation:

$$l_\vartheta = l_0 [1 + \alpha_m (\vartheta - \vartheta_0)] \quad (4)$$

where l_0 is the length of the moulded article at the reference temperature ϑ_0. The mean value α_m at various temperatures can be read off fig. 41.

Fig. 41 · Linear expansion coefficient α of unreinforced Hostaform C and Hostaform C 9021 GV 1/30
a Hostaform C, unreinforced
b Hostaform C 9021 GV 1/30 perpendicular to flow direction
c Hostaform C 9021 GV 1/30 parallel to flow direction

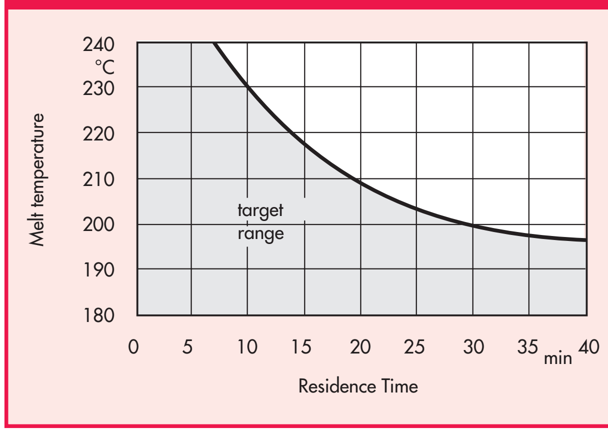


Thermal stability

Thermal stability is meant here in its narrow sense, ie the thermal stability of the melt at processing temperature. The thermal stability of Hostaform derives from comonomer units with stable C-C bonds, which are statistically distributed in the molecular chains of the base polymer. When the polymer is subject to thermooxidative attack, chain scission does indeed start to occur accompanied by formation of low-molecular-weight polymers and thermally unstable end groups. However, degradation can proceed only as far as the next comonomer unit, is therefore minimal and the remaining fragments are thermally stable. The rate of thermooxidative attack increases with rise in temperature while the extent of attack is time-dependent.

For this reason, it is advisable to remain within the target processing range shown in fig. 42, ie the maximum melt-temperature-related residence time of the Hostaform basic grades in the plasticizing cylinder of a processing machine should not be exceeded; the specified range should also be observed when processing the high-impact and glass-sphere-reinforced grades.

Fig. 42 · Recommended maximum residence time of Hostaform basic grades in the plasticizing cylinder of a processing machine



Thermal degradation during processing, eg injection moulding, which might impair moulded-part properties can be readily determined by measuring the melt mass-flow rates MFR 190/2.16 and MFR 190/15 and then dividing MFR 190/15 by MFR 190/2.16.

If this value, determined on specimens taken from the moulded part, has significantly increased over the value of the starting material, then the moulding material has been thermally degraded during processing and correction of processing conditions, eg melt temperature and/or residence time t_V in the plasticizing cylinder, is required. The following applies:

$$t_V = \frac{\text{weight of melt in the cylinder x cycle time}}{\text{weight per shot including sprue}}$$

3.3 Electrical properties

Hostaform has good electrical insulating and dielectric properties, except for the electrically, conductive grades. These in combination with its good mechanical properties have made Hostaform a valued material for numerous applications in the electrical sector.

Volume resistivity

The volume resistivity of Hostaform is $\rho_D = 10^{12}\ \Omega \cdot m$ for all grades, except for the high-impact and electrically conductive materials; it is therefore largely unaffected by the presence of additives.

Hostaform C 9021 ELSX and EC270TX have a considerably lower volume resistivity. This is due to the formation of a current bridge by the electrically conductive carbon black. Destruction of the carbon black morphology and/or strong orientation of the carbon black particles can impair the current bridge and allow volume resistivity to increase. Selection of adequate wall thickness will counteract this; in addition, low injection rates and high mould wall temperatures should be preferred in processing Hostaform C 9021 ELSX and EC270TX.

Surface resistivity

Surface resistivity gives an indication of the insulation resistance across the surface of a material. The dependence of this value on humidity and surface contamination must be taken into account. In the case of Hostaform, it is appreciably lower than that exhibited by hydrophilic polymers such as certain polyamides. The surface resistivity of most Hostaform grades is in excess of $10^{14}\ \Omega$. Antistatic modification reduces this to $10^{13}\ \Omega$, while in the case of C 9021 ELSX and EC270TX the value is lowered even further to $10^{3}\ \Omega$. The surface resistivity of C 9021 ELSX and EC270TX – and also its volume resistivity – can be influenced by processing parameters and moulded-part design. Therefore the electrical properties have to be controlled at the moulded part.

Relative permittivity, dissipation factor

The relative permittivity ε_r of the unreinforced Hostaform grades is around 4, that of the reinforced grades between around 4 and 5 and that of the high-impact grades between around 3.6 and 5.

The effect of temperature on relative permittivity is shown in fig. 43 and the effect of frequency in fig. 44.

Fig. 43 · Effect of temperature on the relative permittivity of various plastics (measured at 10^5 Hz)

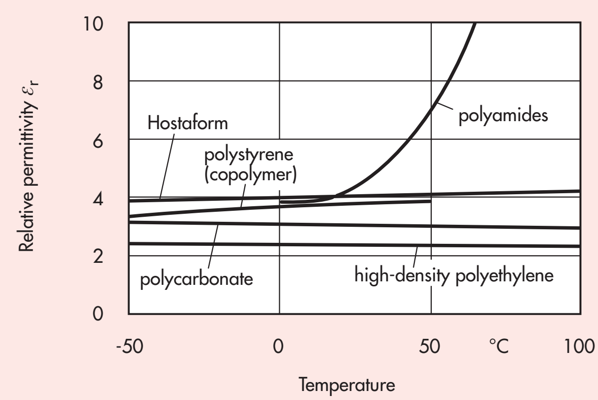
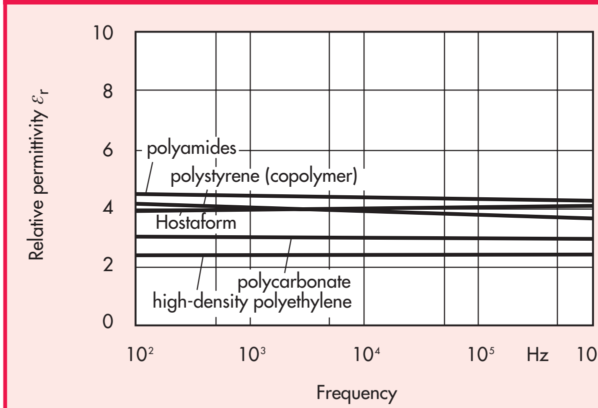


Fig. 44 · Effect of frequency on the relative permittivity of various plastics (measured at 25°C)



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The dissipation factor tan δ is a measure of the energy loss in the dielectric by conversion into heat.

Hostaform has a low dissipation factor. Depending on the grade, it is 10^{-3} to 10^{-2} in the frequency range 100 Hz to 1 MHz.

The effect of temperature on the dissipation factor tan δ is shown in fig. 45 for a frequency of 10^5 Hz.

Fig. 46 shows the effect of frequency on the dissipation factor tan δ at 25 °C.

The excellent dielectric properties of Hostaform preclude the use of high-frequency heating and welding for this material.

Fig. 45 · Effect of temperature on the dissipation factor tan δ of various thermoplastics (measured at 10^5 Hz)

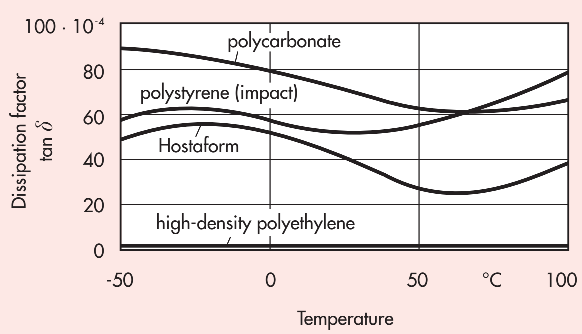
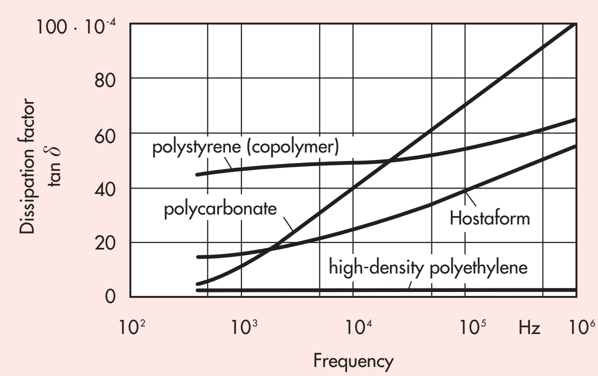


Fig. 46 · Effect of frequency on the dissipation factor tan δ of various thermoplastics (measured at 25°C)



Dielectric strength

Dielectric strength describes behaviour under short-term, high-voltage stress. It is not a measure of permissible continuous stress. In dielectric strength tests, the voltage (f = 50 Hz) is steadily increased at a rate of 1 kV/s until insulation breakdown occurs.

In tests according to IEC 60 243 part 1, the Hostaform basic grades showed dielectric strength values of 28 to 35 kV/mm.

Static charge accumulation

Hostaform in general does not tend to accumulate static charge. For applications in which dust attraction must be absolutely avoided, however, the use of the antistatic-modified grade Hostaform C 27021 AST has proved successful.

The antistatic modification reduces surface resistivity and at the same time considerably increases the discharge rate, as the following table shows:

Property	Unit	Test method	Hostaform C 27021	Hostaform C 27021 AST
Surface resistivity	Ω	IEC 60 093	10^{14}	10^{13}
Discharge rate* (half-value time)	S	–	about 60	10 to 25

* Decline in the field strength of a capacitor with the test specimen as a dielectric to 50% of its initial value after charging with 1000 volts.

The antistatic modification has little or no effect on all other properties of Hostaform.

3.4 Optical properties

Hostaform mouldings range from more or less translucent to opaque-white, depending on wall thickness. When a parallel beam of light falls vertically on a compression moulded sheet with parallel faces, the proportion of diffuse light transmission is as follows:

thickness 1 mm: about 60%
2 mm: about 45%
4 mm: about 35%

The refractive index n for light in the visible wavelength range is 1.48.

Gloss is dependent mainly on the surface quality of the mould.

3

4. Effect of the service environment on the properties of Hostaform

In this section, the properties of Hostaform in the presence of certain media and their dependence in some cases on temperature and time of exposure are described. Particular consideration is given to:

- air at elevated temperature
- water
- motor fuels
- chemicals
- weathering
- high-energy radiation
- flammability.

Finally, the status of Hostaform under food legislation comes into this context.

4.1 Properties in air at elevated temperatures

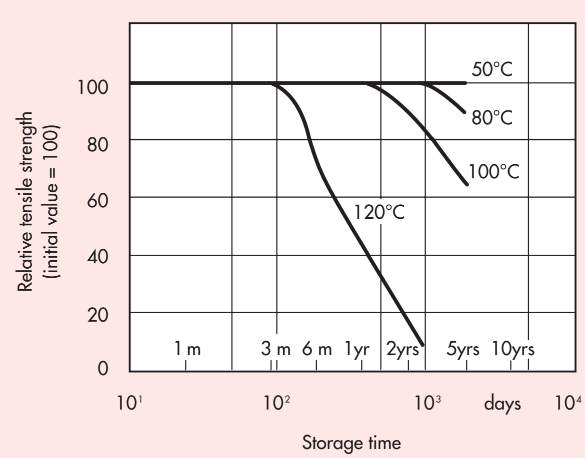
All Hostaform grades are stabilized against thermo-oxidative degradation so that they can be safely processed if the recommendations for the individual grades in section 5 are followed. In addition, finished parts made from Hostaform are able to withstand heat stresses in service, although the level of heat resistance will depend slightly on the particular grade. The progressive deterioration in properties through heat ageing is influenced by a large number of service environment factors in various ways. Terms such as "heat resistance", "continuous service temperature", etc. do not therefore describe material constants but should be regarded only in the context of particular application requirements. Experience has shown that short-term temperature stresses of 140 °C (several hours) and continuous stresses of up to 100 °C (months to years) are permissible [4]; grades S 9243 and S 9244 have 20 – 30 °C lower maximum service temperatures, depending on the nature of the stress.

Most Hostaform grades are approved by Underwriters Laboratories (USA) up to temperatures of 50 to 105°C, depending on stress (category QMFZ 2, file no. E 42 337, master batches are listed under category QMQS2, file no. E 93384).

Figs. 47 to 50 show the change in some physical properties of Hostaform C 9021 when stored in hot air as a function of time and temperature. The properties chosen were tensile strength and elongation at break. The test specimens (acc. to ISO 3167) were not under mechanical stress during the storage period.

The changes in properties are represented in two ways. Fig. 47 shows the relative tensile strength as a function of storage time at 50, 80, 100 and 120 °C.

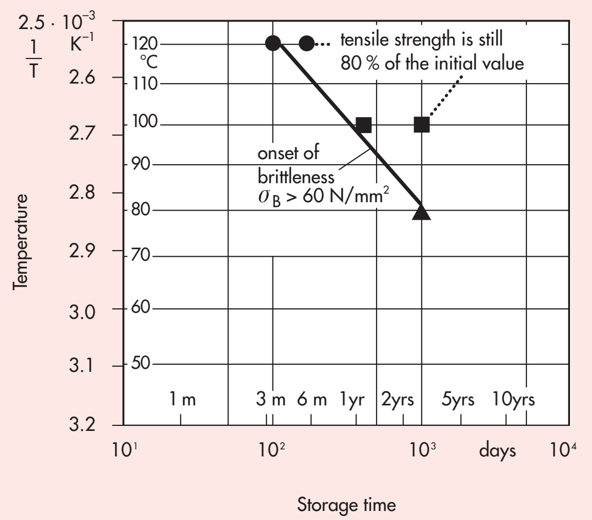
Fig. 47 · Relative tensile strength of Hostaform C 9021 as a function of storage time in air at elevated temperature



From this the very good ageing resistance of Hostaform C 9021 up to temperatures of 100 °C can be seen. At 120 °C, the polymer starts to become brittle after about three months and subsequently the strength falls away relatively quickly.

In fig. 48, the results from fig. 47 are reproduced in an Arrhenius diagram. The x-axis represents time on a logarithmic scale and the y-axis shows the reciprocal value of absolute temperature on a linear scale and the corresponding temperature scale in °C.

Fig. 48 · Change in the tensile strength of Hostaform C 9021 as a function of storage time and temperature represented on an Arrhenius diagram



From this diagram, it is possible to determine the temperature which a plastic can withstand for a certain period of time without a specified property value dropping below a certain limit value. The bold line in fig. 48 gives the time/temperature combinations at which tensile strength starts to decline but is still > 60 N/mm²; this value was selected because it may be regarded as defining the start of embrittlement. At the points marked above the bold line on the 100 °C and 120 °C horizontals, tensile strength is still 80% of the initial value.

In the case of Hostaform, as with other thermoplastics, elongation at break is the property most influenced by temperature. From a comparison of figs. 49 with 47 and 50 with 48, it can be seen that elongation falls away more rapidly than strength.

Fig. 49 · Relative elongation at break of Hostaform C 9021 as a function of storage time in air at elevated temperature

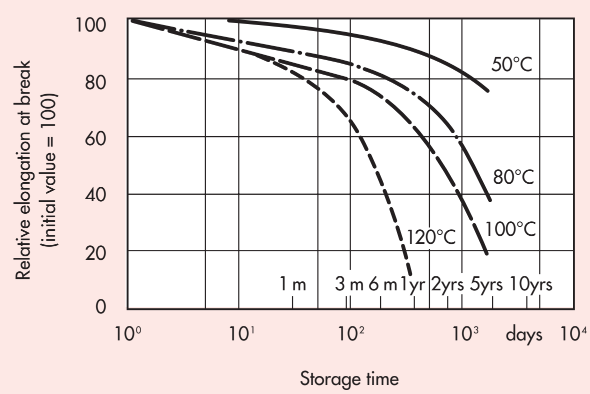
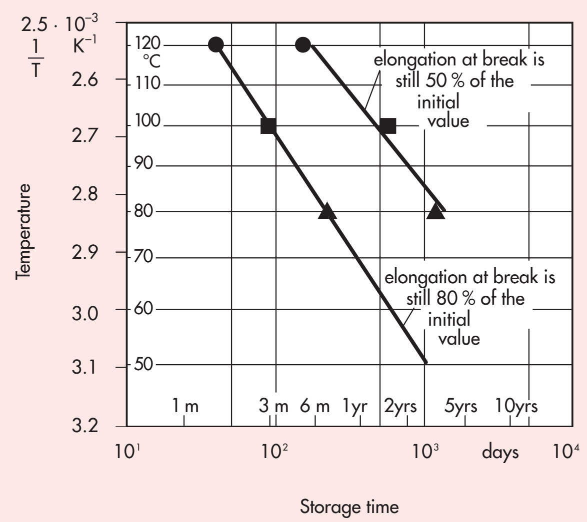


Fig. 50 · Change in the elongation at break of Hostaform C 9021 as a function of storage time and temperature (in air) represented on an Arrhenius diagram



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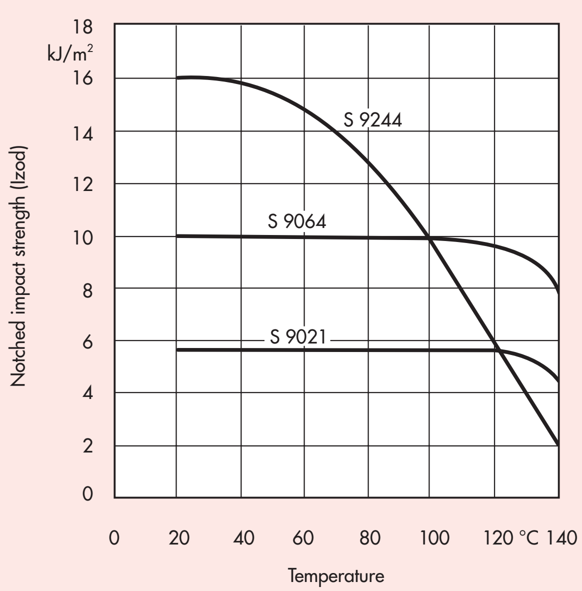
The aforementioned data on Hostaform C 9021 are generally applicable to the other basic grades, the high-impact grades, except for S 9243/S 9244, and glass-fibre-reinforced Hostaform, except for the elongation at break results. The low-friction and special grades are of course not primarily intended for applications at elevated temperature.

The notched impact strength of Hostaform S 9064 and S 9244 after 1000 hours' storage at various temperatures is shown in fig. 51 in comparison with Hostaform C 9021.

Fig. 51 · Notched impact strength (Izod) of Hostaform C 9021, S 9064 and S 9244 after 1000 hours' storage in air as a function of temperature

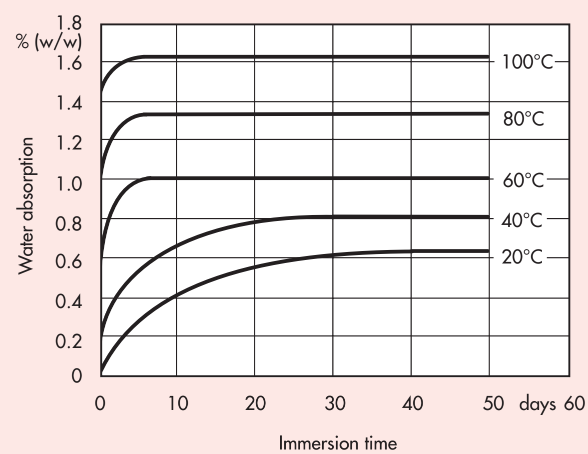


4.2 Properties in water

4.2.1 Water absorption

Hostaform has very low water absorption. The basic grades and most low-friction grades have values of appr. 0.1% after 24 hours and appr. 0.2% after 96 hours when tested at 20 °C. The other grades have slightly higher values. The saturation value according to ISO 62 is between 0.12 and 0.25% at 23 °C and 50% relative humidity. Fig. 52 shows the water absorption of Hostaform C 9021 as a function of time over the temperature range 20 to 100 °C. Even at a temperature of 100 °C, water absorption does not exceed about 1.6%.

Fig. 52 · Water absorption of Hostaform C 9021 as a function of immersion time at various temperatures (ISO 62)



The change in length of Hostaform C 9021 due to saturation with water at various temperatures is shown in fig. 53 (measured at room temperature).

Water absorption by Hostaform is a reversible process, ie on subsequent storage in air the absorbed water is given up again until equilibrium is reached.

Fig. 53 · Change in length of Hostaform C 9021 as a function of water absorption

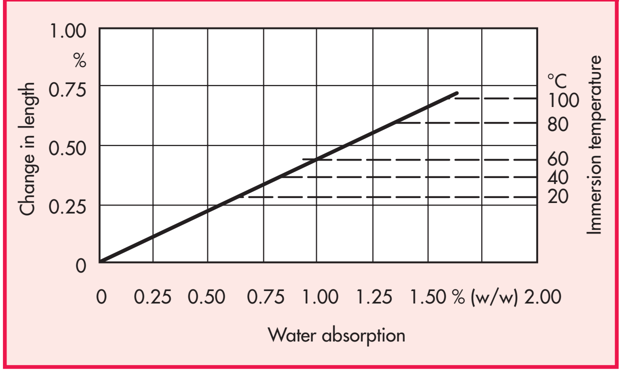
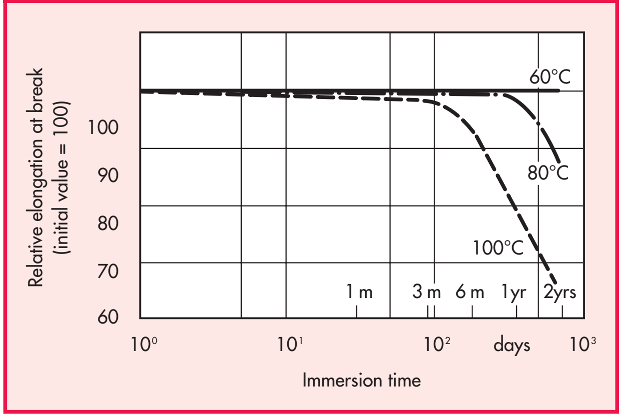


Fig. 55 · Relative elongation break of Hostaform C 9021 as a function of immersion time in hot water

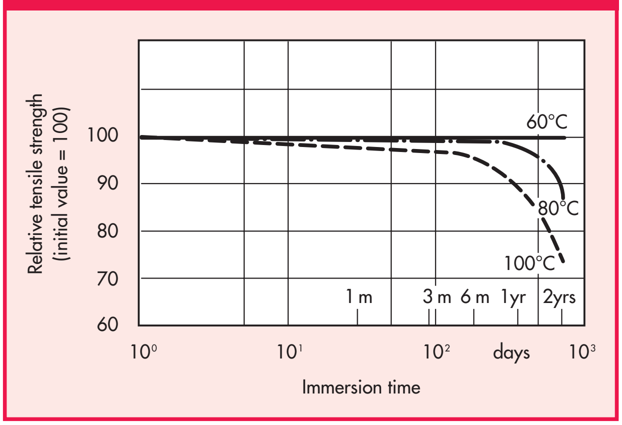


4.2.2 Service temperature in hot water

4.2.2.1 Hostaform basic grades

The high thermal stability which Hostaform mouldings exhibit in air is again evident in hot water immersion tests. Figs. 54 and 55 show the changes with time in the tensile strength and elongation at break of Hostaform C 9021 on immersion in hot water at temperatures of 60, 80 and 100 °C.

Fig. 54 · Relative tensile strength of Hostaform C 9021 as a function of immersion time in hot water



The minimal decline in these values shows clearly the resistance to hydrolysis achieved through the special chemical structure of Hostaform C. When Hostaform C is heated at the boil in a 1% detergent solution, the resultant change in properties is about the same as after boiling in water. The high ageing resistance in hot water, low water absorption and good resistance to detergent solutions of Hostaform C make it a particularly suitable material for washing-machine and dish-washer components and for kettles. The test specimens which provided the data for figs. 54 and 55 were not mechanically stressed during heat ageing. For this reason, it is not possible to deduce from the results the potential suitability of a particular Hostaform grade for applications involving mechanical stress, eg internally stressed components for sanitary engineering. The criterion for making such an assessment is creep strength as described in section 3.1.2. In addition, the disinfectants used in drinking water (chlorine, ozone) must be taken into account, since they have an adverse effect on creep strength, depending on their concentration.

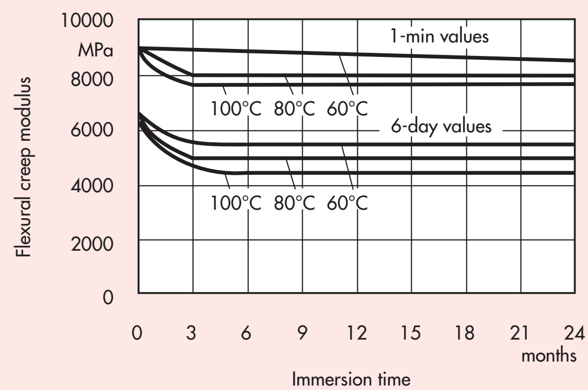
4.2.2.2 Reinforced grades

Glass-fibre-reinforced Hostaform exhibits a relatively rapid loss in tensile strength on contact with hot water and drops back to about the same level of strength as the basic grade (fig. 56). During the further course of heat ageing, glass-fibre-reinforced Hostaform behaves like the unreinforced material, ie the initial decline in tensile strength is not attributable to degradation of the Hostaform matrix; the thermal stability of the reinforced material is practically the same as that of the basic grade. The reason for the initial decline in tensile strength is rather that water attacks the glass fibre/Hostaform interface.

In contrast to tensile strength, the flexural creep modulus of glass-fibre-reinforced Hostaform shows only a slight initial decline on immersion in hot water and then remains at the same level; the extent of the decline is temperature-dependent (fig. 57).

Glass-sphere-filled Hostaform has only limited suitability for use in hot water but can be specially modified for this purpose; our Hostaform Research and Development Department will be pleased to give more detailed information on this.

Fig. 57 · Properties of Hostaform C 9021 GV 1/30 in contact with water; flexural creep modulus as a function of immersion time and temperature



4.2.2.3 Hostaform/elastomer blends

The high-impact Hostaform grades have somewhat lower resistance to hot water than the basic grades. Fig. 58 shows this using the example of the change in tensile strength with time of Hostaform S 9064 and C 9021 on immersion in water at 60, 80 and 100 °C.

Fig. 56 · Properties of Hostaform C 9021 GV 1/30 in contact with water; relative tensile strength as a function of immersion time and temperature

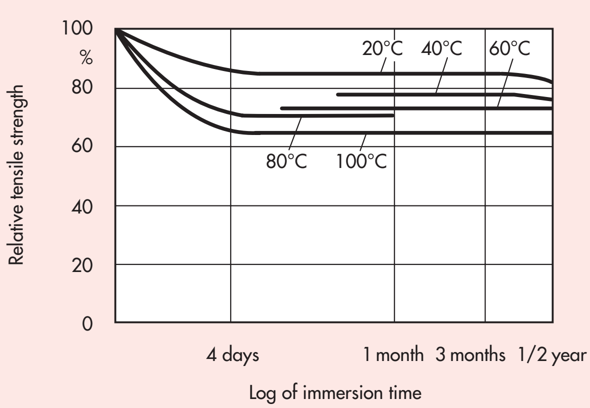
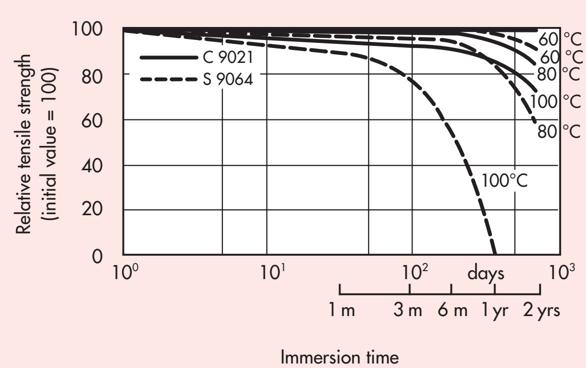


Fig. 58 · Relative tensile strength of Hostaform C 9021 and S 9064 as a function of immersion time in hot water



4.2.3 Resistance to chlorinated drinking water

Hostaform is already used for fluid handling in many drinking water applications. Hostaform MR130ACS is supplied as a special grade with better resistance to chlorinated drinking water than the standard Hostaform grade C 9021. This is shown by the results of the tests described below.

Hostaform MR 130ACS and Hostaform C 9021 were immersed stress-free in chlorinated water using the following test parameters:

– Medium: Chlorine solution with 10 mg/l free chlorine (chlorine bleaching solution)
– Temperature: 60°C – controlled
– pH-Value: 6.5 – controlled
– Test duration: 2000 h

The chlorine concentration was held constant throughout the immersion period by adding chlorine.

This complies with a regular drinking water supply in real applications.

The results are shown in Figures 59a (tensile stress at break) and 59b (elongation at break). The tests confirm the better resistance of Hostaform MR130ACS to chlorinated water as compared with Hostaform C 9021. This is even more pronounced at low wall thickness.

Fig. 59a · Relative change in the tensile stress at break of Hostaform C 9021and MR130ACS after immersion in chlorinated water (60 °C/10 mg/l chlorine concentration); ISO 527 A and 1/4 test bars (4 mm/1 mm wall thickness)

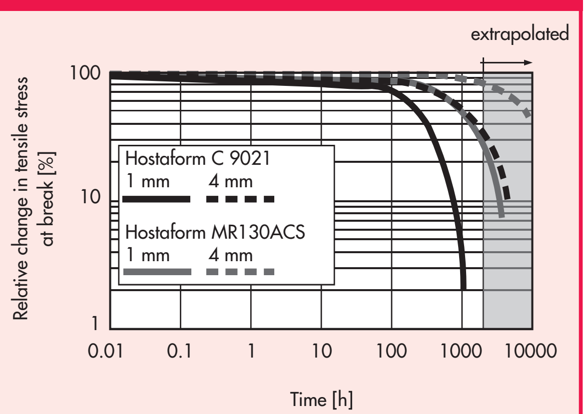
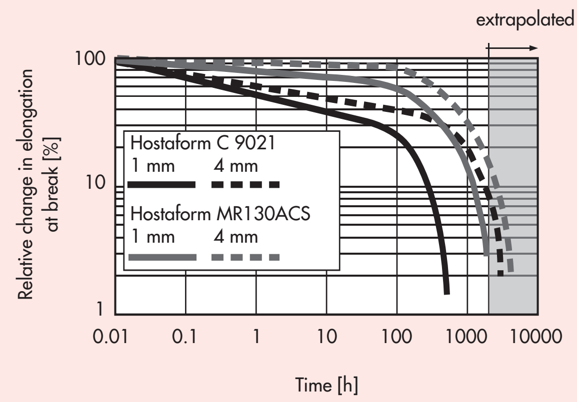
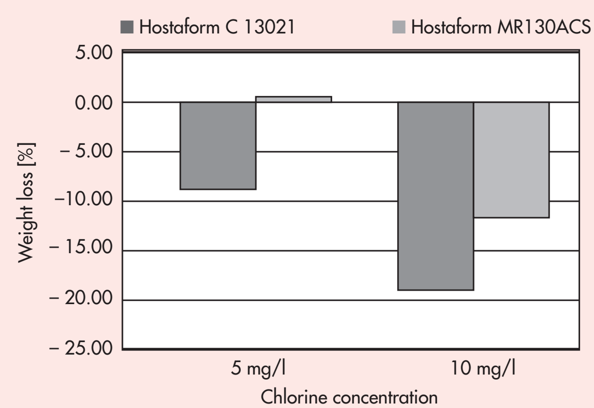


Fig. 59b · Relative change in the elongation at break of Hostaform C 9021and MR130ACS after immersion in chlorinated water (60 °C/10 mg/l chlorine concentration); ISO 527 A and 1/4 test bars (4 mm/1 mm wall thickness)



Orienting tests with a chlorine solution with 5 mg/l free chlorine (according to the WHO recommendations, fig. 60) confirmed the test results.

Fig. 60 · Weight loss of Hostaform C 9021 compared to MR130ACS at 5 mg/l and 10 mg/l chlorine concentration after 2000 h immersion at 60 °C



Compared to standard POM Hostaform MR130ACS demonstrates also a better resistance to highly active acidic cleaning agents. Further information you find in the Product Info “Hostaform® MR130ACS in contact with highly active acidic cleaning agents and chlorinated drinking water”, ordering no. TI-BR1014E.

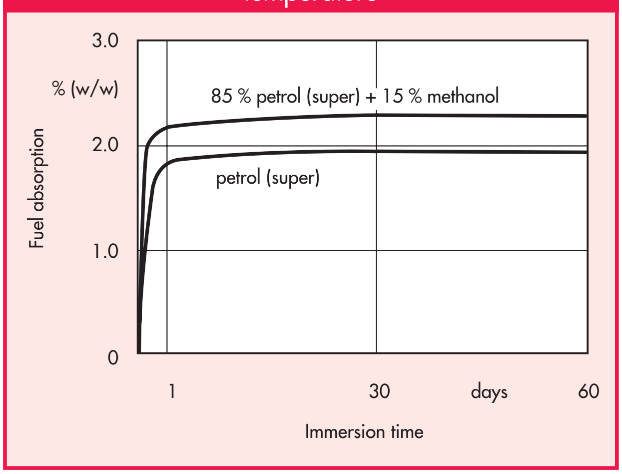
4.3 Fuel resistance

4.3.1 Hostaform basic grades

The Hostaform basic grades are resistant to petrol (including fuels containing 15 to 20% methanol) and to diesel. They are not chemically attacked according to the definition in table 2.

In addition to chemical resistance, the degree of swelling is an important factor in assessing the suitability of Hostaform for use in contact with fuels. Fig. 61 shows the fuel absorption of the Hostaform basic grades in contact with super-grade petrol and a super-grade/methanol mixture (85/15) as a function of immersion time at room temperature. Saturation was reached at an absorption level of about 2% and was only slightly increased by the presence of methanol. The absorption process – as in the case of water – is reversible.

Fig. 61 · Fuel absorption of the Hostaform basic grades as a function of immersion time at room temperature



4.3.2 Reinforced grades

For the Hostaform matrix of the glass-fibre-reinforced grades, the same applies as for the basic grades, ie it is not chemically attacked by fuels and the only effect is slight swelling. However, contact with fuels – as with water – brings an initial decline in tensile strength due to attack on the glass fibre/Hostaform interface. The rate of this decline is temperature- and time-dependent. When this initial phase of decline is complete, the fuel causes no further loss in tensile strength.

4.3.3 Hostaform/elastomer blends

The change in weight of the high-impact grades Hostaform S 9064 and S 9244 after 120 days' immersion at 40 °C in a test fuel (DIN 51 604 A), methanol and diesel is compared with that of Hostaform C 9021 in fig. 62. In contact with diesel, both S grades behave in essentially the same way as C 9021; the slightly higher weight increase in contact with the test fuel (DIN 51 604 A) needs to be taken into account in component design. S 9064 is not resistant to methanol.

Fig. 62 · Fuel absorption of Hostaform C and S (immersion temperature 40°C, immersion time 120 days)

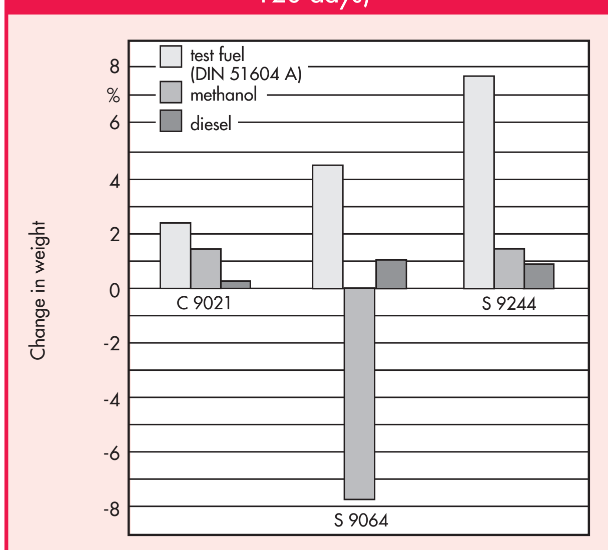
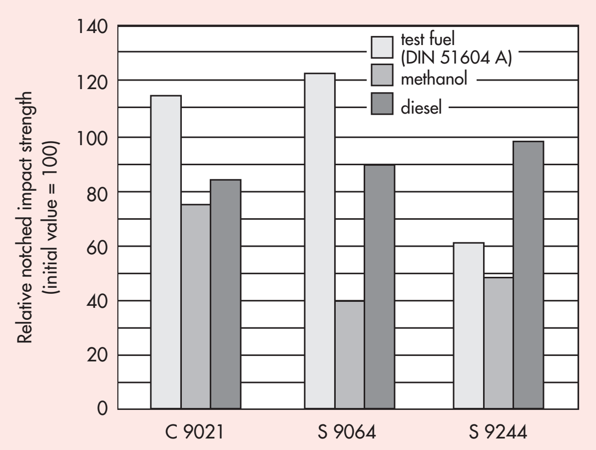


Fig. 63 shows the notched impact strength of the above grades after 120 days' immersion at 40 °C in the same media. It can be seen that, except in methanol, the heat ageing of Hostaform S 9064 corresponds to that of C 9021 while S 9244 has slightly lower fuel resistance, except in diesel.

Fig. 63 · Ageing of Hostaform C and S after immersion in different fuels (40°C, 120 days)

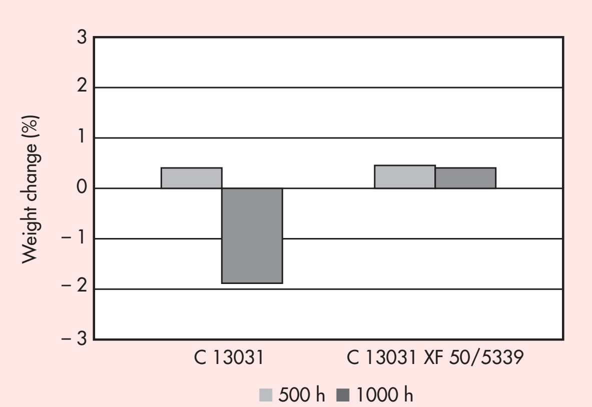


4.3.4 Grades with increased hot diesel resistance

The introduction of diesel direct injection systems has led to a significant rise in fuel system temperature. As a result, the diesel is aged by the high temperatures of over 100°C and produces aggressive decomposition products. To meet these demanding requirements, Ticona has developed Hostaform grades that are more resistant to hot diesel: Hostaform C 13031 XF 50/5339 and the electrically conductive grade Hostaform EC140XF.

Fig. 64 shows the weight change in Hostaform C 13031 XF 50/5339 as compared with Hostaform C 13031 after immersion* in Haltermann test diesel at 100°C.

Fig. 64 · Weight change in Hostaform C 13031 and Hostaform C 13031 XF 50/5339 after immersion in Haltermann test diesel at 100 °C for 500 and 1000 hours



Before these grades are used, it is essential to conduct practical trials because the aging behavior of diesel fuel in a running engine is not defined.

* Test conditions:
Fuel: Haltermann test diesel RF-73-A-93, test system with defined air contact, weekly fuel change, immersion temperature 100°C, standard tensile test bar as per ISO 3167.

4

4.4 Chemical properties

4.4.1 Chemical resistance

4.4.1.1 Hostaform basic grades

The Hostaform basic grades have high resistance to many organic and inorganic chemicals. Very few solvents are known which can dissolve the material below its crystalline melting point. One of these is hexafluoroacetone sesquihydrate. Hostaform withstands strong alkalis (for example 50% NaOH), even at high temperatures but is attacked by oxidizing agents and strong acids (pH < 4). A survey is given in table 2.

Generally speaking, Hostaform is not prone to environmental stress cracking.

Table 2: Chemical resistance of the Hostaform basic grades

The results were determined after a test period of 60 days on 1 mm-thick test specimens injection moulded from Hostaform C 9021. During the tests, the specimens were not under external stress.

The quoted ratings apply to all Hostaform basic grades. The reinforced and S grades may deviate from these in individual cases.

+ resistant	weight increase < 3% or weight loss < 0.5% and/or decrease in tensile strength < 15%
/ limited resistance	weight increase 3 to 8% or weight loss 0.5 to 3% and/or decrease in tensile strength 15 to 30%
– not resistant	weight increase > 8% or weight loss > 3% and/or decrease in tensile strength > 30%

Substance	20 °C	60 °C
acetic acid (10%)*	+	+
acetic acid (80%)	/	–
acetone	+	/
acetylene tetrabromide	/	–
ammonia (10%)	+	+
ammonia, conc.	+	+
ammonium sulphate (10%) (pH 5.8)	+	–
benzene	/	/
benzene with 15 to 20% methanol	+	+
butanol	+	+
butyl acetate	+	/
butyraldehyde	/	/
butyric acid (1%)*	+	+
butyric acid (98%)	/	/
calcium ammonium nitrate	+	+
calcium chloride (10%)	+	+
calcium nitrate (10%) (pH 6.4)	+	+
cananga oil	+	+
carbon disulphide	+	+
carbon tetrachloride	+	/
chlorobenzene	/	/
chloroform	–	–
chromic acid (3%)	/	/
citric acid (10%)*	+	–
Clophen® A 60 (Bayer)	+	+
coffee (Nescafé®)	+	+
Complesal® Typ Blau 12 + 12 + 17 + 2 (10%, pH 5.8)	+	+
Complesal® Typ Gelb 15 + 15 + 15 (10%, pH 5.8)	+	+
Complesal® Typ NP 20 + 20 + 0 (10%, pH 5.7)	+	+
Complesal® Typ Rot 13 + 13 + 21 (10%, pH 5.4)	+	+
copper sulphate (10%)	+	+
developer solution 1:100 (pH 10.4) (Rodinal® Agfa)	+	+
developer solution 1:50 (pH 10.9) (Rodinal® Agfa)	+	+
dibutyl phthalate	+	+
diesel oil	+	+
dimethyl phthalate	+	/
dioctyl sebacate	+	+
dioxane	/	/
engine oil BP HP 20	+	+
engine oil SAE 40 (Caltex)	+	+
ethanol (96%)	+	+

Substance	20 °C	60 °C
ether (DAB 6)	+	+
ethyl acetate	/	/
ethyl chloride (DAB 6)	+	/
ethyl glycol	+	/
ferric chloride (10%)	/	–
fixing bath solution (pH 5.4)	+	/
fluorocarbons (partially halogenated)	–	–
fluorocarbons (perhalogenated)	+	+
formaldehyde (40%)	+	+
formic acid (10%)*	+	–
fuel oil EL	+	+
galbanum resin	+	–
Genantin®/tap water 1:1 (+ 1% Donax® C, Shell)	+	
glacial acetic acid	/	–
glycerol	+	+
glycol	+	+
glycol/distilled water 48:52	+	+
Grisiron® GBF 1 (5 g to 100 g H_2O)	+	+
hydrochloric acid (10%)	–	–
hydrogen peroxide (30%)*	+	–
hydroxycitronellal	+	+
ink (Pelikan® ink, blue-black)	+	–
isopropyl alcohol	+	+
jet fuel JP 1 (Shell)	+	+
jet fuel JP 4 (Shell)	+	+
lactic acid (10%)*	+	/
lactic acid (90%)*	+	–
lavender oil, highest-quality	+	+
lemongrass oil	+	+
lime, chlorinated (approx. 10%)	–	–
methanol	+	+
methyl acetate	/	/
methyl bromide	–	–
methyl ethyl ketone	/	/
methyl glycol	/	/
methyl glycol acetate	/	–
methyl isobutyl ketone	+	+
methyl isopropyl ketone	+	+
methylene bromide	–	–
methylene chloride, technical	–	–
mineral oil	+	+
Mobil® oil SAE 20	+	+
Mobil oil HD SAE 20 after 3000 km	+	+
n-hexane	+	+
natural gas	+	+
nickel sulphate (10%)	+	+
nitric acid (10%)	–	–

Substance	20 °C	60 °C
nitrogen phosphate (10%) (pH 5.1)	+	+
nitrous gases	–	–
oil of cloves	+	
olive oil	+	–
ozone	–	–
peat water (pH 3.7)	+	+
perchloroethylene	+	–
Persil® 59 (5%) (Henkel)	+	+
petrol, standard-grade	+	+
petrol/benzene mixture (super-grade petrol)	+	+
petroleum	+	+
petroleum fraction (boiling point 100 – 140 °C)	+	+
phenol	–	–
phosphoric acid (25%)*	+	–
potassium hydroxide (caustic potash solution)	+	+
potassium permanganate (10%)*	+	+
rape oil nethyl ester	+	+
refrigerant R 134 a (System Reclin)	+	+
sea water (North Sea)	+	+
sodium bicarbonate (10%)	+	+
sodium bisulphite liquor (pH 4.5)	–	–
sodium carbonate (10%)	+	+
sodium chloride	+	+
sodium hydroxide (caustic soda solution)	+	+
sodium hypochlorite (bleaching solution, about 12.5% active chlorine)	/	–
sodium nitrate Hoechst® (10%) (pH 8.8)	+	+
sodium orthophosphate, monobasic (10%)	+	+
sodium orthophosphate, dibasic (10%)	+	+
sodium orthophosphate, tribasic (10%)	+	+
soya bean oil	+	+
sulphur dioxide gas	–	–
sulphuric acid (10%)*	+	–
sulphuric acid (50%)	–	–
tetrahydrofuran	/	/
Tetralin® (Henkel)	+	/
thiophene	/	/
toluene	+	+
transformer oil (Univolt® 36, Esso)	+	+
trichloroethylene	/	/
urine	+	+
water, distilled	+	+
xylene	+	+

4.4.1.2 Reinforced grades

The resistance ratings shown in table 2 apply to the polymer matrix. Since glass itself may be regarded as having adequate inertness to the chemicals listed there, the ratings given in the table may be deemed to apply to the reinforced grades as well. As already mentioned, however, the tensile strength of glass-fibre-reinforced Hostaform declines in contact with water or fuels; in fact this loss is apparent not only with the two media mentioned but with liquid media in general. Change in tensile strength is one of the rating criteria. If these criteria were to be strictly applied, glass-fibre-reinforced Hostaform would have different ratings. However, this only needs to be taken into account in applications where full retention of tensile strength is an essential requirement.

4.4.1.3 Hostaform/elastomer blends

Both components of Hostaform S, ie the matrix and the elastomer, contribute proportionally to its chemical resistance, which is why only generalizations are possible.

Hostaform S 9063, S 9064, S 27063 and S 27064 are resistant to fuels, ie non-polar hydrocarbons, but have only limited or no resistance to methanol, ie polar solvents; in addition to alcohols, this group includes ketones and esters. The behaviour of the above grades in water is described in section 4.2.2.

Hostaform S 9243 and S 9244 are swollen by fuels and their toughness declines somewhat with immersion time; they are however resistant to diesel. In contact with methanol, swelling is slight but again a decline in toughness occurs.

Our Hostaform Research and Development Department will be pleased to give further information.

* Because of the acid or oxidizing nature of these chemicals, trials are recommended before prolonged contact with Hostaform.

4.4.2 Gas and vapour permeability

The permeability of containers made from the Hostaform basic grades to air and other gases is very low compared with values for other thermoplastics. These grades also have very low permeability to aliphatic and halogenated hydrocarbons.

The following permeability values were measured on 0.08 mm-thick film with a density of 1.405 g/cm³ at 23 °C:

oxygen	49 cm³ (0 °C, 1 bar) m² · d · bar
carbon dioxide	1110 cm³ (0 °C, 1 bar) m² · d · bar
water vapour	32 g/m² · d (with a moisture gradient of 85%),

on 3-mm thick sheets at 23 °C:

helium	7.0 cm³/m² · d · bar

An internal test conducted by Ticona to determine permeability to petrol (fig. 65a) showed very low values for Hostaform C compared with those for PA 6 and PE-HD. The tests were carried out on 1-mm thick sheets at 40 °C. The dependence of petrol vapour permeability (super, unleaded) on temperature is shown in fig. 65b.

According to tests carried out by the Institut für Gastechnik, Feuerungstechnik und Wasserchemie (Institute for Gas and Fuel Engineering and Water Chemistry) at the University of Karlsruhe, Hostaform C is resistant to fuel gases and therefore suitable for use in the manufacture of gas fittings. As numerous storage tests have shown, Hostaform C is also very suitable for the production of aerosol containers requiring high mechanical strength, chemical resistance and aromaseal properties. In selecting products to fill these containers, the relatively high water vapour permeability of Hostaform should be taken into account.

Fig. 65a · Permeability to petrol of Hostaform C and other thermoplastics as a function of exposure time (test fuel M 15, test temperature 40°C)

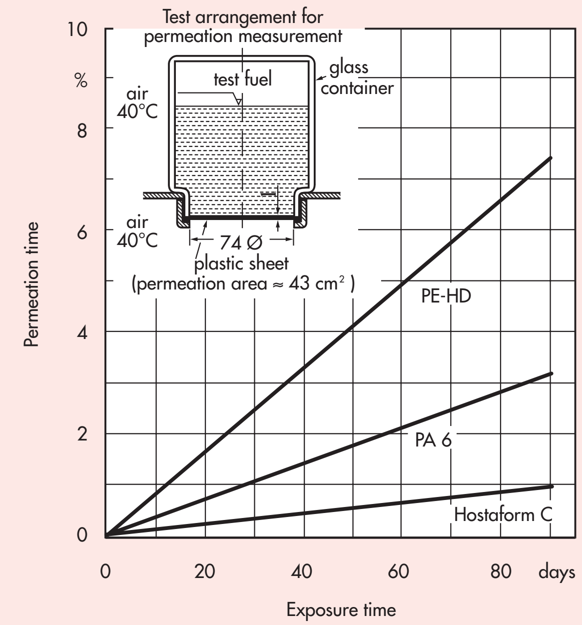
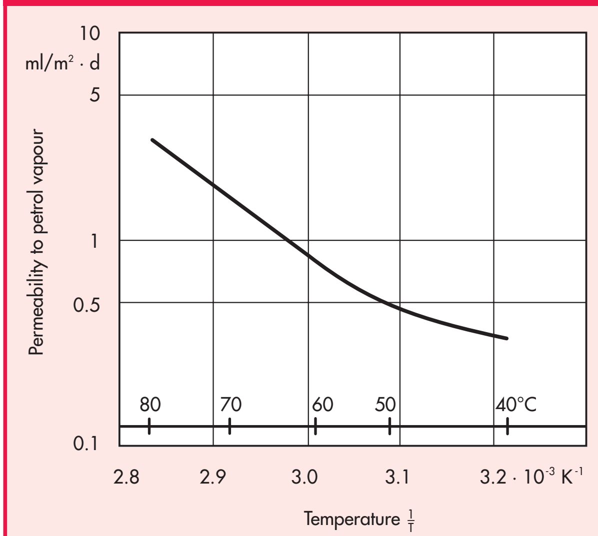


Fig. 65b · Permeability of Hostaform C 27021 to petrol vapour as a function of temperature (test fuel: super, unleaded, wall thickness 1.22 mm)



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4.5 Resistance to light and weathering

4.5.1 General

Polyacetals – like other plastics – are damaged over a period of time by exposure to weathering. The primary agent is UV radiation. This causes a white deposit of degraded material to form on the surface (“chalking”) with consequent loss of gloss and change in colour as well as a deterioration in mechanical properties. The smaller the wall thickness, the more rapidly these effects occur. The behaviour of the unstabilized Hostaform C grades on exposure to natural and accelerated weathering is described in [5].

Effective light stabilizer systems have long been available for Hostaform and are continually being further developed and optimized.

4.5.2 Light-stabilized grades

The addition of light stabilizers helps to delay degradation. Effective stabilization is provided by certain pigments, polymer-soluble light stabilizer systems and combinations of these. The effectiveness of light stabilizers is tested both by natural weathering and accelerated weathering with suitable lamps. Outdoor weathering tests can be carried out in a central European climate but southern Europe or California is preferred to reduce the testing time. The results obtained at different sites naturally differ and are not “interconvertible”.

Accelerated weathering equipment differs in the type of UV radiation source used (carbon arc or xenon lamp), radiation intensity and mode of operation (choice of filter, temperature, light/dark cycle, dry/wet). It is obvious then that there is no reliable correlation between results obtained from accelerated weathering – which differ in themselves anyway – and those from outdoor weathering.

Both weathering and light resistance can be tracked and evaluated by measuring mechanical properties and/or characterizing specimen surfaces as a function of exposure time. The large number of test parameters makes evaluation and particularly presentation of test results difficult.

Fig. 66 · Relative tensile strength of unstabilized and UV-stabilized Hostaform C as a function of weathering time

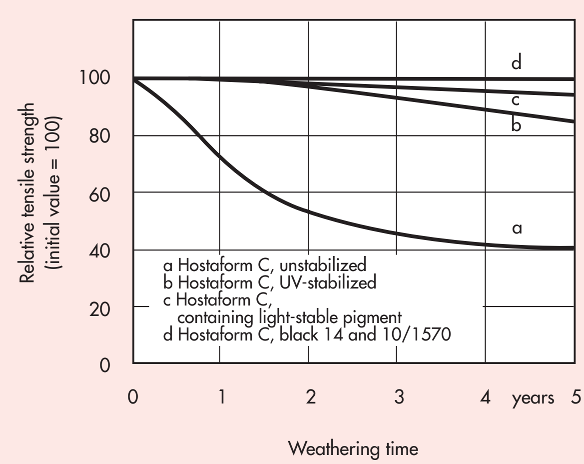
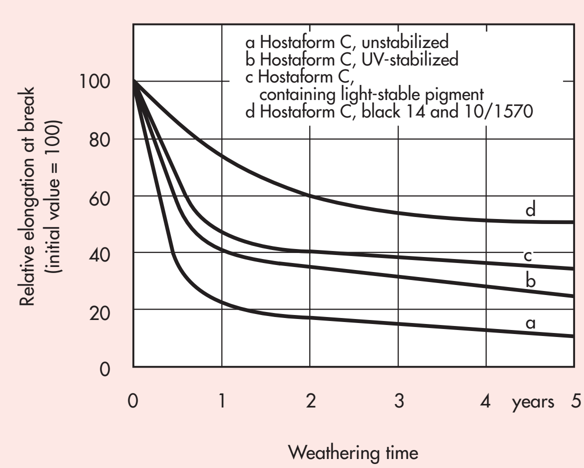


Fig. 67 · Relative elongation at break of unstabilized and UV-stabilized Hostaform C as a function of weathering time



4.5.2.1 Light stabilization with pigments

UV-radiation-absorbing pigments delay the light-induced degradation of polyacetals and thus have a stabilizing effect. Particular mention should be made of active carbon black and titanium dioxide. The most effective light stabilization is provided by the special formulation black 10/1570, followed by the colour formulations black 14, white 22 and grey 33. Service or special shades with sufficient content of carbon black and/or TiO_2 are also included among the light-stabilizing, pigmented formulations; information on these can be obtained from our Hostaform Research and Development Department. The behaviour under natural weathering conditions and artificial light of Hostaform C formulations stabilized in various ways is described in [6].

Figs. 66 and 67 show the mechanical properties of the Hostaform basic grades in various formulations as a function of weathering time in a central European climate. The beneficial effect of suitable pigments and carbon black on the retention of tensile strength (curves c and d as compared with a in fig. 66) can be seen. With all grades, elongation at break exhibits a greater change (fig. 67) but follows the same general curve as tensile strength.

In terms of mechanical property retention, the black formulations 10/1570 and 14 perform equally well; however, the special formulation black 10/1570 significantly reduces chalking as compared with black 14. This is not apparent from the graphs selected for presentation here.

Figs. 68 and 69 show the mechanical property curves for Hostaform S 9064, S 9244 and C 9021 in the black 10/1570 formulation after exposure to accelerated weathering in the Xenotest 1200. While the tensile strength of all grades is unchanged after 4000 hours' exposure, the elongation at break of the S grades has declined more than that of C 9021. Hence when it comes to toughness (strain), the S grades – even in the black 10/1570 formulation – are less UV-stable than the Hostaform basic grades.

Fig. 68 · Tensile strength (ISO 1/4 tensile test bar) of Hostaform C 9021, S 9064 and S 9244 in the black 10/1570 formulation as a function of exposure time in the Xenotest 1200

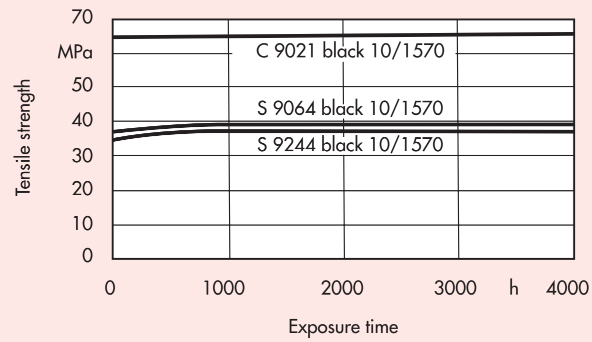
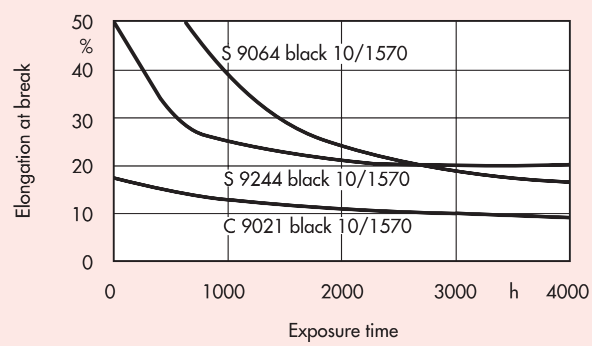


Fig. 69 · Elongation at break (ISO 1/4 tensile test bar) of Hostaform C 9021, S 9064 and S 9244 in the black 10/1570 formulation as a function of exposure time in the Xenotest 1200



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4.5.2.2 Grades with soluble light-stabilizer systems

Unlike the pigments mentioned above, the substances generally known as light or UV stabilizers are soluble in polyacetals; they may therefore be used for natural or pigmented grades and are without exception combinations of UV absorbers and radical scavengers. Hostaform can be supplied with one of these light-stabilizer systems; this modification is indicated in the product designation with the suffix letters "LS", eg C 9021 LS, and has proved successful in many applications. The weathering behaviour of UV-stabilized Hostaform is shown in figs. 66 and 67, curves b; the improvement over unstabilized Hostaform, curves a, can be seen, particularly in relation to tensile strength retention, but it is also apparent that the UV-stabilizer system does not quite match the effectiveness of titanium dioxide or even carbon black. As already mentioned, these curves apply to mechanical properties but give no information on possible surface changes. In this aspect, too, the "LS" formulation, e.g. Hostaform C 9021 LS, offers improved performance. The first occurrence of microcracks in the surface is deferred without loss of natural colour until relatively long exposure times have elapsed.

4.5.2.3 Pigmented grades with soluble light-stabilizer systems

The weathering stability (always a relative term) of pigmented Hostaform grades containing UV-stabilizer systems depends on the effectiveness of the light stabilizers added and in some cases on the stabilizing effect of the pigments used. The basis for evaluating the behaviour of polyacetals in outdoor or accelerated weathering tests has recently shifted away from determination of mechanical property retention to assessment of surface changes arising as a result of exposure to light (colour retention, occurrence of microcracks). In addition, test conditions have become more rigorous and black-pigmented mouldings have been rejected in favour of colour-pigmented, UV-stabilized materials. Pigmented Hostaform basic grades in "LS" formulation (= light-stabilized) meet requirements for applications in automotive interiors. This applies not only to dark, opaque shades but also to white and bright red for instance.

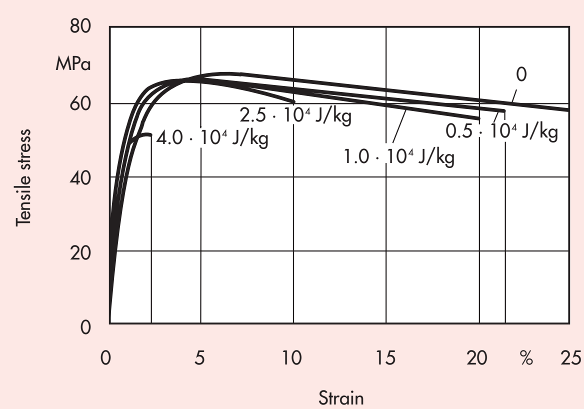
For impact-resistant components exposed to weathering, Hostaform S 27072 WS black 10/1570 is recommended (WS = weathering-stabilized); this grade meets requirements for exterior car body parts.

4.6 Resistance to high-energy radiation

Mouldings made from polyacetals should not be used where the total radiation dose exceeds about $3 \cdot 10^4$ J/kg. At higher exposure levels, mouldings become discoloured and brittle.

Fig. 70 shows stress-strain curves for Hostaform C at various dosage levels. It can be seen that tensile stress at yield remains practically constant up to a dose of $2.5 \cdot 10^4$ J/kg, whereas the increasing brittleness of the test specimens is particularly evident in the decline in elongation.

Fig. 70 · Stress-strain curves for Hostaform C as a function of radiation dose



When sterilizing plastic vessels and containers with ionizing radiation, a dose of $2.5 \cdot 10^4$ J/kg is used. This dose alters the strength of Hostaform C only minimally but through degradation reactions it leads to an appreciable decrease in elongation at break (see fig. 67) and hence also toughness. For this reason, and to avoid the risk of uncontrolled exposure to higher doses, superheated steam or ethylene oxide should be used in preference to gamma radiation for the sterilization of Hostaform.

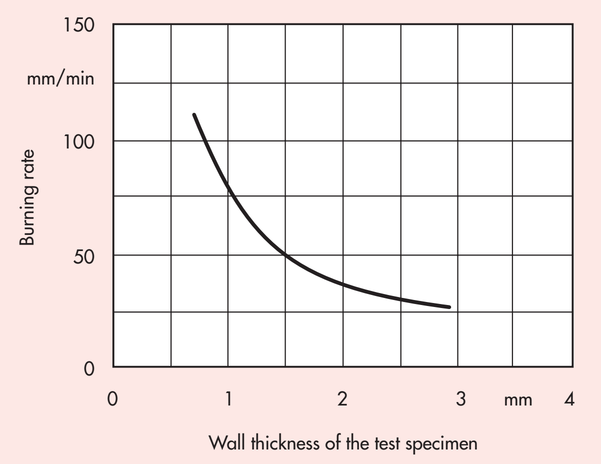
4.7 Flammability

Polyacetals ignite on exposure to flame, continue to burn with a pale blue flame when the ignition source is removed and drip as they burn. When extinguished or if they continue to smoulder, they give off acrid-smelling formaldehyde.

According to the UL 94 flammability test, Hostaform is classified as “HB”. It is not possible to produce a formulation with the classification “V-O”.

The burning rate determined on Hostaform sheet > 1 mm thick is below the maximum allowed by FMVSS 302 (fig. 70a).

Fig. 70a • Burning rate of Hostaform C according to FMVSS 302, as a function of specimen wall thickness



4.8 Toxicological assessments

4.8.1 Assessment concerning food contact legislation

National regulations of EU member states governing the use of plastics in contact with food are at present being harmonized by the European Union.

The framework regulation 2004/1935/EC (replacing: EU-Directive 89/109/EC) is the basis for food contact regulation in the EU, with polymers being regulated by Directive 2002/72/EC (replacing: 90/128/EC) and its amendments: 2004/1/EC, 2004/19/EC und 2005/79/EC which are implemented into German food contact law through the German Bedarfsgegenstände-Verordnung (BGVO = consumer goods ordinance).

According to these regulations, polymers can be used for food contact applications as defined in the revised version of the German Food and Consumer Articles (food contact) Law (Lebensmittel- und Bedarfsgegenständegesetz or LMBG), provided that:

- the monomers / starting materials used are listed in the german food contact regulation (Bedarfsgegenstände-Verordnung = BGVO)
- migration of substances from the article into the food do not exceed the limits specified in the BGVO
- the articles are suitable for their intended use and
- the finished products do not impart odour or taste to food.

Additives which are not yet regulated by EU-law will continue to be covered by national law until they will be inserted into suitable EU Regulation. In Germany, those additives are regulated by the Recommendations of BfR (Bundesinstitut für Risikobewertung = Federal Insitute for Risk Assessment), e.g. concerning Hostaform: Recommendation XXXIII “Acetal resins”, where applicabe, Recommendation IX “Colorants for the coloration of plastics and other polymers for consumer articles” and LII “Fillers . . .”.

In the EU assessment of the health of polymers under food legislation varies from one country to another until full harmonization is achieved.

We will be pleased to answer specific inquiries to the best of our knowledge.

4

4.8.2 Pharmaceutical/medical applications

In order to meet the particularly high standards for materials used in medical engineering, and to be able to comply with legal requirements varying from one country to another, Ticona has specially tailored a number of engineering polymers for healthcare applications.

Hostaform MT grades are equipped with special characteristics to meet the specific requirements of medical applications. The existing benefits of polyacetal, such as high toughness, hardness and stiffness, excellent friction and wear properties, low water absorption, are supplemented by distinguishing features regarding material quality, conformance, and availability. Extensive testing of each individual lot demonstrates material purity and property consistency. At the same time a new standard of quality assurance is established.

The following grades are available:

Grade	Description
MT 2U01	unreinforced stiff flowing grade
MT 8U01	unreinforced standard grade
MT 12U01	unreinforced standard grade, medium flowability
MT 12U03	unreinforced, improved strength
MT 24U01	unreinforced, best flow properties
MT 8R02	modified friction properties, low noise
MT 12R01	modified friction properties
MT 8F01	PTFE modified
MT 24F01	PTFE modified, improved flowability
MT 8F02	highly PTFE modified for low speed sliding
MT 24F02	highly PTFE modified, improved flowability

For approvals in the US, the above mentioned product grades are listed in Drug Master File No. 11559.

Hostaform MT8U01 and MT 24U01 were tested according to United States Pharmacopoeia (USP) XXIII and meets the following test requirements:

- USP Biological Class VI
  (extraction temperature 70 °C, for 24 h)
- USP Physico-Chemical
  (extraction temperature 70 °C, for 24 h)
- Cytotoxicity
  (extraction temperature 37 °C, for 24 h).

Ticona does not support the use of its plastics for implant applications. Irrespective of the position as regards responsibility, Hostaform should not be used for permanent implants because of the risks involved.

For further information please ask for our brochure "New Polymer Grades for Medical and Laboratory Engineering" (B 281 E) or contact us directly.

5. Processing

Hostaform may be run on all standard processing machinery for thermoplastics, such as injection moulding machines, extruders, injection and extrusion blow moulding machines and compression moulding machines. Pretreatment is not generally necessary but where through poor storage arrangements the product has been exposed to a damp atmosphere or has been in contact with water, it has to be dried at 100 to 120 °C in a circulating air oven for about 3 – 6 hours, depending on layer depth (which should not exceed 40 mm).

5.1 Safety recommendations

General safety precautions during processing

In processing Hostaform, extraction hoods should be installed immediately above the machinery. The melt temperature should not exceed 240 °C, depending on the permissible residence time in the cylinder (fig. 42) (recommended processing temperatures given in section 5.2.2). When subjected to excessive thermal stress or residence time in the cylinder, Hostaform is decomposed with liberation of formaldehyde. This gas has a pungent odour and irritates the mucous membranes.

In addition, the pressure of the gaseous decomposition products if the nozzle is obstructed or frozen may be so great that relief through the feed opening of the machine is sought. Should this not be possible, there is a risk that the rising pressure could cause damage to the machine and injury to operators. It is therefore important to ensure that injection nozzles or extruder orifices are never, for example, blocked by plugs of frozen material.

Should thermal degradation in the cylinder be suspected or determined, the material should be run out with the heating switched off. It is advisable to immerse severely degraded material in water to prevent unnecessary odour nuisance.

Hostaform is immiscible with most other thermoplastics; if these should contaminate the material they will lead, even in small quantities, to inhomogeneous mouldings. Special care should be taken with thermoplastics which have a decomposing effect, particularly PVC; since this polymer can induce a severe decomposition reaction, even in low concentrations, PVC-contaminated Hostaform should on no account be processed.

Hostaform, like many other organic materials, is combustible. It is in the interests of the manufacturer when storing, processing or fabricating plastics to take the necessary fire precautions. Special fire prevention requirements may apply to certain end products and fields of application.

Statutory safety regulations vary from one country to another and local national requirements should always be met. It is the responsibility of the raw material processor to ascertain and observe these requirements. Important notes are contained in the safety data sheets, which we will be pleased to supply on request.

In Germany at the present time, a maximum permissible formaldehyde concentration at the workplace (MAK value) of 0.5 ppm is stipulated.

The MAK value is the average of a number of measurements spread over a working day or a shift. These can be carried out with a Dräger gas detector*) and the appropriate “Formaldehyde 0.2/a” measuring tube. The samples should be taken close to the operator at head height. More details are given in the MAK value lists, which are revised every year and can be obtained for example from the German employers’ liability insurance associations (Berufsgenossenschaften).

Starting up empty machines

The cylinder temperatures are set to about 200 °C. After the plasticizing cylinder has been filled, a few shots are ejected into the open. Particular attention must be paid to nozzle temperature. If this is too low, the melt will freeze and block the nozzle.

Short- and long-term interruption of moulding cycles

When the cycle is only briefly interrupted, cylinder temperatures should be reduced slightly but the nozzle temperature may be maintained.

*) Drägerwerk AG, D -24116 Lübeck, Germany

When the moulding cycle is interrupted for longer periods, the procedure to be adopted is as follows:

– stop granule feed
– switch off cylinder and nozzle heating
– disconnect cylinder from mould
– eject melt fully from cylinder.

Restarting the machine with Hostaform

Heat up the machine and set the cylinder temperature to 150–160 °C. Increase the nozzle temperature to 200 °C and the cylinder temperature by stages to 190 °C. It is important to ensure that the nozzle is not blocked by a plug of frozen material.

As soon as the correct temperature has been reached and the moulding material uniformly heated, a few shots are ejected into the open at low screw advance rate.

When the material is flowing freely, it may be injected into the mould as soon as the final processing temperature has been set.

Changing from another thermoplastic to Hostaform

Thermoplastics requiring higher processing temperatures, such as polyamide or polycarbonate, must be completely removed from the machine by purging with a polyolefin before the machine can be charged with Hostaform. In the same way, plastics unstable at Hostaform processing temperatures and particularly those whose decomposition products promote degradation of Hostaform (for example polyvinyl chloride) must also be completely removed by a polyolefin purge. The detailed procedure to be adopted is as follows:

– the cylinder heaters are set at the processing temperature for the thermoplastic

– after it has been thoroughly heated the melt is ejected into the open

– an easyflowing polyolefin is forced through in rapid shot sequence until the previous thermoplastic has been completely removed

– the cylinder and nozzle temperatures are set to 200 °C. With the mould disconnected, residual polyolefin in the cylinder is purged with the aid of Hostaform. Once the Hostaform melt is free of all polyolefin, injection moulding may be commenced.

In cases of doubt, the preferred method is to remove the screw and carry out mechanical cleaning.

Changing from Hostaform to another thermoplastic

At a melt temperature of about 200 °C, Hostaform is purged from the cylinder into the open with the aid of an easyflowing polyethylene.

The cylinder temperatures are then set to the appropriate level for processing the required thermoplastic and the operation is continued in the usual way. The directions set out above apply, mutatis mutandis, to extrusion processing.

5.2 Injection moulding

5.2.1 Machine requirements

Hostaform may be processed on all standard injection moulding machines in current use, except for vented machines.

Special screws have not generally proved necessary, ie it is sufficient to fit the machine with standard screws in accordance with the manufacturer’s recommendations. For processing glass-fibre-reinforced Hostaform, it is advisable to use a wear-resistant version of the injection moulding unit such as most machinery manufacturers supply these days as a normal option in their range.

Processing Hostaform on hot-runner moulds is state-of-the-art technology. It should be noted, however, that not all systems on the market are equally suitable.

5.2.2 Processing conditions

Hostaform is no problem to process. Machine settings for the production of optimum moulded parts – including precision injection mouldings – are discussed in the following sections. The settings are detailed in fig. 71. Guidance on start-up, shutdown and changeover of material is given in section 5.1.

Further information you will find in the booklet "Processing Guide Hostaform", TI-BR 1022 DE.

Cylinder temperatures/melt temperature

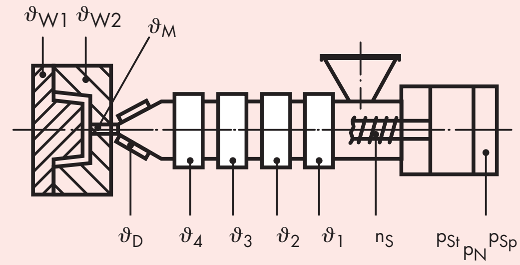
The melt temperature range is between 190 and 230 °C. Optimum processing temperatures are between 190 and 210 °C. With the impact-modified grades, an effective melt temperature of 210 °C should not be exceeded.

These temperatures can be measured manually in the space in front of the screw tip by inserting a probe. Deviations from the setpoint value should normally be corrected by adjusting the cylinder and nozzle heating. Melt temperature should always be monitored in this way because the melt temperature sensors in the injection moulding machine do not usually show the actual temperature of the melt.

The required melt temperature is achieved through cylinder heating (external heat supply) and friction (heat generated by internal and external friction resulting from rotation of the screw and back pressure).

The proportion of shear and frictional heat in the total heat supply should be kept as low as possible with Hostaform and hence careful control of screw speed and temperatures is essential (see below). Fig. 72 shows the peripheral screw speed as a function of screw for various screw diameters. With standard screws, peripheral speeds of 0.1 to 0.3 (0.5) m/s should not be exceeded. Suggested temperature settings are given in fig. 71.

Fig. 71 · Typical injection moulding conditions for Hostaform



ϑ_1 = 170°C to 180°C
ϑ_2 = 180°C to 190°C
ϑ_3 = 190°C to 200°C
ϑ_4 = 190°C to 210°C
ϑ_D = 190°C to 210°C
ϑ_M = 190°C to 210°C (max. 230°C)*

maximum residence time in the cylinder
20 min at ϑ_M = 210°C

p_{Sp} = 60 to 120 MPa (typical range: 80 to 100 MPa)

p_N: 60 to 120 MPa (typical range: 80 to 100 MPa)

p_{St}: 0 to 40 bar (typical range: 1 to 2 MPa)

screw speed $n_S = v_s/d \cdot \pi$

v_s (peripheral velocity of screw) = 0.1 to 0.3 m/s

injection time [s] ≈ 0.5 to 1 · wall thickness [mm]

holding pressure time [s] ≈ 2 to 3 · (wall thickness)² [mm]

residual cooling time [s] ≈ 2 to 3 · (wall thickness)² [mm]

ϑ_{W1}, ϑ_{W2} = 80 to 120°C

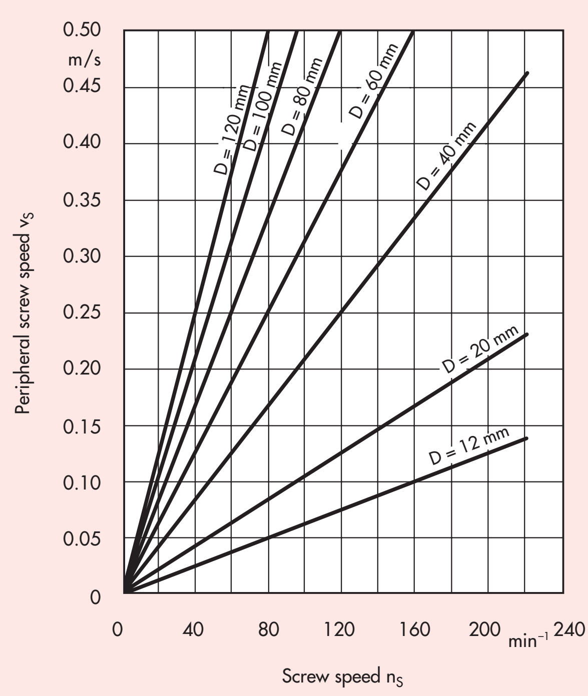
nozzle design: open or shut off nozzle, preferably open

Notes:
* Measure ϑ_M on material ejected into the open.
The lower melt temperature should be targeted for the S grades (do not exceed 210°C) and should if possible also be used for the easyflowing grades (potential reduction in cycle time).
Vented machines are not recommended.

Mould wall temperatures

The mould wall temperature can be chosen within the 80 to 120 °C range. For engineering components, the optimum mould wall temperature is about 90 °C and for precision components 120 °C. For processing the impact-modified grades, a mould wall temperature of $\vartheta_w \leqq 80$ °C is recommended.

Fig. 72 · Peripheral screw speed v_S as a function of screw speed n_S and screw diameter D



Injection pressure/holding pressure

Injection and holding pressures are necessary to force the melt into the mould cavity and to compensate at least partially for the volume contraction which takes place when the melt freezes. The required injection pressure is dependent on melt viscosity, the flow path/wall thickness ratio and the type of gate. It is normally 60 to 120 MPa.

For the manufacture of precision mouldings, it has generally proved an advantage for the injection pressure and holding pressure to be equal. This results in minimum variation in the dimensions and weights of the mouldings. A melt cushion is required to compensate for volume contraction and maintain the pressure in the mould. The melt cushion amounts to about 1/10 of the shot volume.

Just as important as the injection and holding pressure to be used is the time during which the pressure is effective. The holding-pressure time must be such that while the material in the gate cross-section remains plastic, sufficient melt can be forced into the mould cavity to compensate for volume contracting during cooling.

The required holding-pressure time is determined by increasing the time while maintaining a constant overall cycle time. The weights of the moulding in each shot sequence are determined. If the weight remains constant despite longer holding-pressure time, the correct holding-pressure time in this case has been achieved, provided the gate cross-section is adequately dimensioned. In most cases, holding-pressure time amounts to more than 40% of total cycle time.

The screw advance rate (injection rate) should be set only high enough for the mould cavity to be filled completely so that no sink marks occur. For thin-walled mouldings, rapid injection gives the best results whereas with increasing wall thickness slower rates are preferred. With increasing screw advance time (slower injection rate), there is a noticeable increase in the toughness of the moulded article. Perfect filling must however be ensured.

5.2.3 Flow properties and flow path length

To characterize the flow behaviour of Hostaform, use is made of the melt mass-flow rate MVR 190/2.16 in accordance with ISO 1133 and the length of a spiral injection moulded under defined conditions. The Hostaform range at present covers an MFR spread of 1 to 40 cm^3/10 min and hence meets the requirements of all current production processes. Since choice of the most suitable Hostaform grade depends on the processing method and, in the case of injection moulding,
also on the design of the moulded part and mould (wall thickness, flow path length), the melt mass-flow rate is an important product characteristic and so forms the basis for grade nomenclature and organization of the product range.

Fig. 73 · Flow path length l (spiral flow test) of most Hostaform grades, spiral section thickness 3 mm, injection pressure 100 MPa, melt temperature 205°C, mould wall temperature 80°C

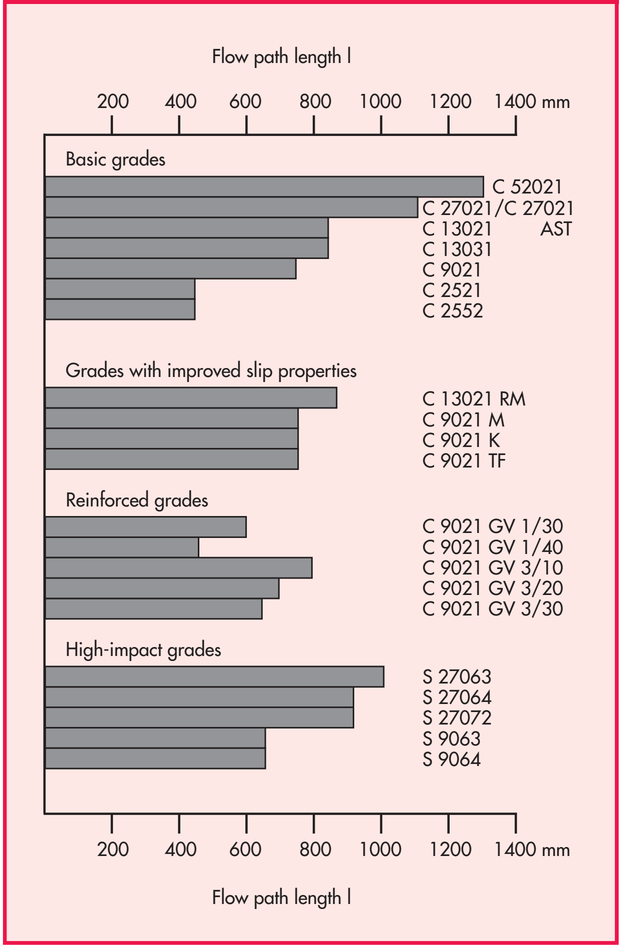


Fig. 73 shows the flow path length of most Hostaform grades with a section thickness of s = 3 mm under the same processing conditions.

Fig. 74 plots spiral flow length (at a melt temperature of 205 °C, a mould temperature of 80 °C and an average injection pressure of 100 MPa) against the melt different spiral section thickness.

Fig. 75 shows viscosity η as a function of shear rate $\dot{\gamma}$ at different melt temperatures for the easyflowing grade Hostaform C 27021 and the extrusion grade Hostaform C 2521. The range indicated approximately covers the conditions prevailing in extrusion and injection moulding.

Fig. 74 · Flowability of the Hostaform C basic grades at various test spiral section thicknesses

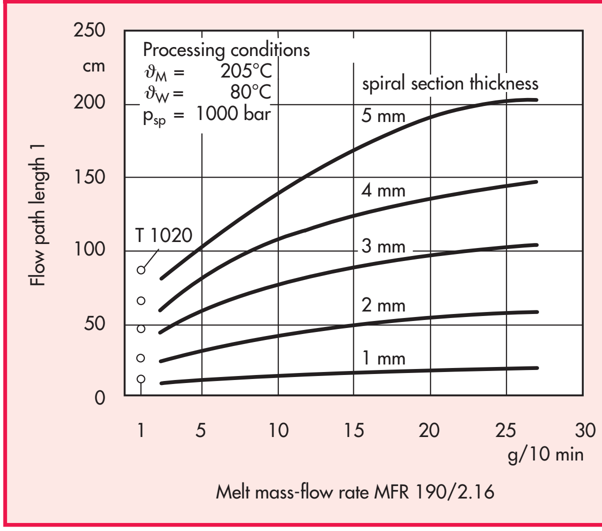
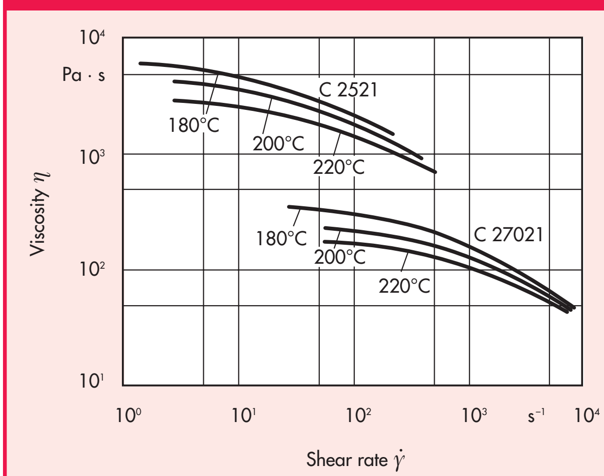


Fig. 75 · Viscosity η as a function of shear rate $\dot{\gamma}$ for Hostaform C 27021 and C 2521



5.2.4 Shrinkage

In defining shrinkage, a distinction is made between mould shrinkage MS and after-shrinkage AS. The sum of mould shrinkage MS and after-shrinkage AS is described as total shrinkage TS, figs. 76 to 78.

Note: Shrinkage is measured on test plaques (60 mm x 60 mm x wall thickness) in the flow and transverse directions. The shrinkage result obtained might thus be termed “flat-area” shrinkage. In the case of relatively thick-walled mouldings, higher values must be assumed!

Fig. 76 · Total shrinkage TS of Hostaform as a function of wall thickness s (ϑ_W = 90°C, $p_{Sp} = p_N$ = 1000 bar, ϑ_M = 205°C)

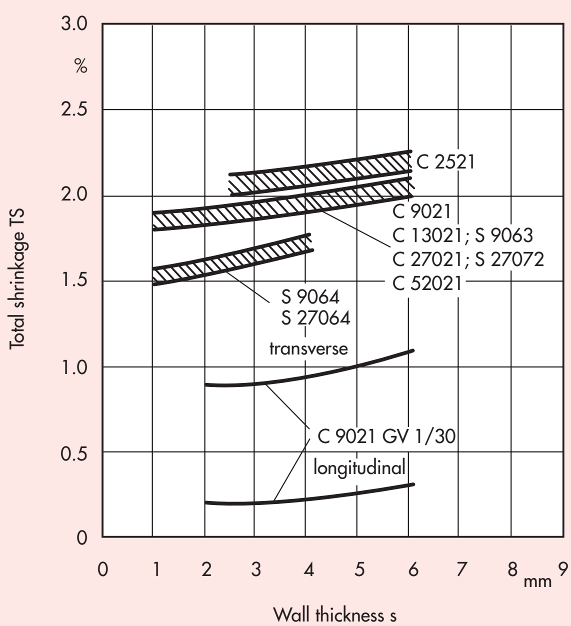


Fig. 77 · Total shrinkage TS of Hostaform C 9021 G (modified with PE-UHMW), S 9243 and S 9244 as a function of wall thickness s (ϑ_W = 90°C, $p_{Sp} = p_N$ = 1000 bar, ϑ_M = 205°C)

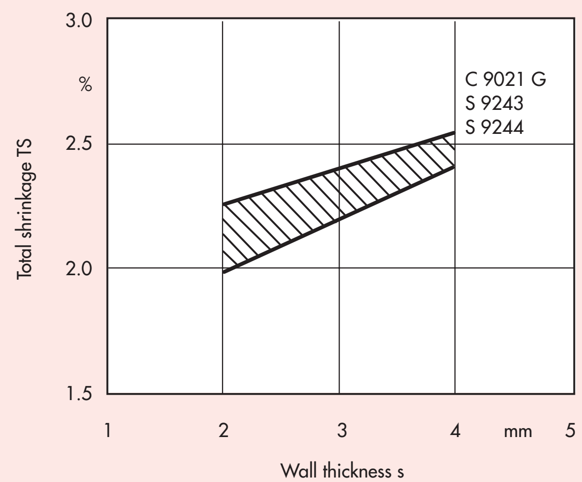
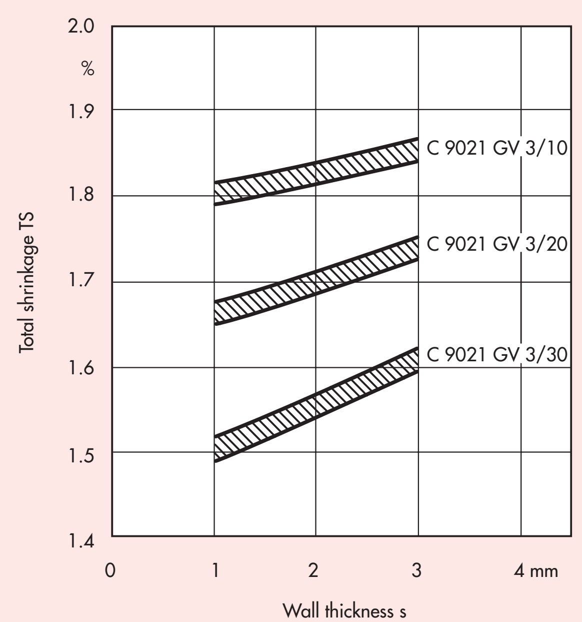


Fig. 78 · Total shrinkage TS of glass-sphere reinforced Hostaform grades as a function of wall thickness s (ϑ_W = 90°C, $p_{Sp} = p_N$ = 1000 bar, ϑ_M = 205°C)

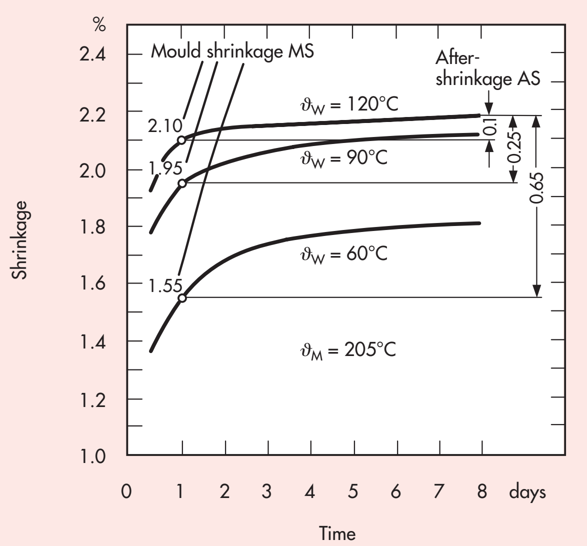


Shrinkage is a key factor in the dimensional accuracy of a moulding and – particularly when there is differential shrinkage in a moulded part – can lead to warpage. It can also have an effect on the nature and level of internal stresses and on the design strength of a moulding, especially if shrinkage is restricted.

All shrinkage phenomena are dependent not only on the plastic itself but on a variety of factors related to processing, application and design. Hence in a brochure describing material properties, it is only possible to quote guide values. The most important variables which influence shrinkage properties are:

Mould wall temperature: with increasing mould wall temperature ϑ_W, mould shrinkage MS increases but after-shrinkage AS decreases (fig. 79). This fact, which is of great importance for precision injection moulding, means that mould wall temperature must be as high as possible to ensure dimensionally stable mouldings (low after-shrinkage). In consequence, greater mould shrinkage has to be accepted.

Fig. 79 · Moulds shrinkage MS and after-shrinkage AS of Hostaform C 9021 as a function of time and mould wall temperature



Pressure: during injection moulding the moulding material is exposed to different pressures such as injection pressure, holding pressure etc. Generally speaking, with increasing pressure, mould shrinkage and total shrinkage decrease (fig. 80). This means it is possible during processing to carry out small shrinkage (dimensional) adjustments by changing the injection/holding pressure which determines mould cavity pressure. But assuming optimum holding pressure, the mould cavity pressure has practically no effect on the amount of after-shrinkage to be expected.

Flow path length: with increasing flow path length, mould cavity pressure drops. Because of this pressure drop, mould shrinkage and total shrinkage in areas remote from the gate are generally greater than in the gate region. However, there is practically no change in after-shrinkage.

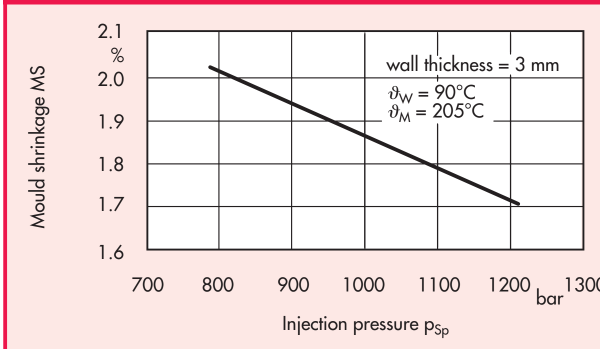
Thickness of the moulding: with increasing moulded part thickness, mould shrinkage also increases [14]. This higher mould shrinkage with greater wall thickness can lead to warpage if the moulded part exhibits significant wall thickness differences.

Filler orientation: while the Hostaform bacis grades exhibit only a negligibly small difference between longitudinal and transverse shrinkage, glass-fibre-reinforced Hostaform shrinks much less in the flow direction (because of glass-fibre orientation) than in the transverse direction, fig. 76.

To obtain warp-free mouldings, the aim should be to restrict differential shrinkage to a minimum.

Differential shrinkage is negligible in the case of grades with improved slip properties (eg Hostaform C 9021 K), the impact-modified grades (eg Hostaform S 9063) and the glass-sphere-reinforced grades (eg Hostaform C 27023 GV 3/30).

Fig. 80 · Mould shrinkage MS of Hostaform C 9021 as a function of injection pressure



The mould shrinkage MS of the grades with improved slip properties closely approximates to that of the basic grade Hostaform C 9021. Small differences can be offset by varying the injection/holding pressure.

The total shrinkage of the impact-modified grades is shown in figs. 76 and 77 and that of the glass-sphere-reinforced grades in fig. 78.

5

When planning a step-by-step programme of

- moulding design
- mould design
- mould construction
- mould proving,

allowance should always be made for changes such as modification to the mould, since shrinkage-induced dimensional or design deviations in a moulding are frequently inevitable. Attempts to use mathematical models to predict mould shrinkage as accurately as possible have so far proved unsuccessful. The same applies to predicting fibre orientation in reinforced thermoplastics. Practical experience with the actual part is thus the most valuable guide.

5.2.5 Gate and mould design

The quality of a plastics moulding in terms of its suitability for a particular application is basically determined by the following factors:

– properties of the moulding material
– processing of the moulding material
– design of the moulded part [15].

Only optimization of all three factors will ensure a high-quality moulding. This requires close cooperation between the material manufacturer, designer and end user.

Processing involves the machine, mould and temperature control units. For mechanical, thermal and rheological design of a mould, modern mathematical methods are used in critical cases to back up the practical experience which is so necessary. The same applies to the design of complicated mouldings.

It is often possible to predict whether a moulding will match up to requirements (which should be comprehensively known) with the aid of materials science but trials which simulate practical conditions as closely as possible should always be carried out to demonstrate serviceability. Component testing under practical (or simulated) conditions should be accorded the greater importance [14].

Hostaform can be processed without any problem on hot-runner moulds [16, 17]; it should be remembered, however, that not all systems are equally suitable. It is advisable to heed the experience of the system suppliers.

The type of gate and its location in the mould are determined by various factors such as

– wall thickness
– flow path
– flow direction
– weld lines
– sink marks.

The size of the gate depends on the wall thickness of the moulding. If the gate is too large, cooling time and hence cycle time may be unacceptably long.

An undersized gate may cut short the holding-pressure time through freezing effects or cause excessive shear heating of the melt.

As a rough guide, the gate diameter should be about 2/3 of maximum wall thickness. The gate should be located in the area of greatest wall thickness in the moulding.

With submarine and pinpoint gates, no finishing is required.

Sprue and diaphragm gates require finishing and generally leave a clearly visible mark on the moulding surface.

5.2.6 Precision injection moulding

Injection moulded components with very close dimensional tolerances such as those used in the watchmaking and office machinery industries or generally in the field of precision engineering are produced by what is known as the precision injection moulding method.

Optimization of machine settings

Machine settings for the injection moulding of precision components are optimized in accordance with the start-up procedure shown in fig. 82. An indispensable aid is a precision balance with an accuracy of 1/100 to 1/1000 g. Generally speaking, the cylinder temperatures and the nozzle temperature (ϑ_1, ϑ_2, … ϑ_D) are set on the temperature controllers to provide a steady rise in temperature from the feed zone to the nozzle. A typical temperature profile would be:

ϑ_1 = 170 °C
ϑ_2 = 180 °C
ϑ_3 = 190 °C
ϑ_4 = 200 °C
ϑ_D = 210 °C.

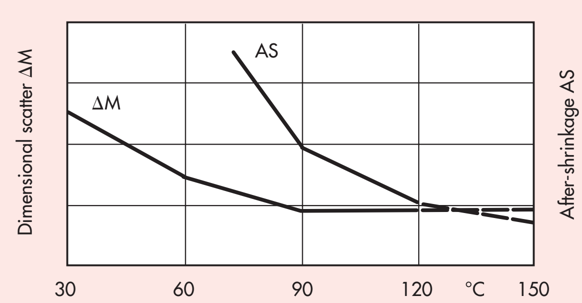
The screw speed (n_S) is set as shown in fig. 69 in accordance with screw diameter and peripheral screw speed v_S, which may be anything between 0.1 and 0.3 m/s. The specific back pressure (p_{St}) should be between 0 and 20 bar. This serves both to improve melt homogeneity during plasticization and to increase the internal supply of heat due to friction and shear effects. The injection pressure p_{Sp} should equal holding pressure p_N and be between 600 and 1200 bar, depending on the trial series. The injection time t_S is dependent among other things on the wall thickness of the moulding. For thin sections it is short and becomes longer as section thickness increases. Cooling time t_K and changeover time t_P are set according to empirical values. The mould clamping force F is dependent on injection pressure, the projected area of the moulding(s) and runner system and on the injection rate. It should be sufficient to prevent the mould from being forced open (formation of flash). ϑ_{T1} and ϑ_{T2} are the temperatures on the temperature control unit. They should be set so that the mould wall temperature ϑ_W is 120 °C. The metering stroke s_D and melt cushion s_p are determined by the size of the moulding.

When all the settings have been made, the machine is started up and after about 30 cycles each moulding is weighed. If the weight remains constant within the permitted scatter range for 10 cycles then it can be assumed that thermal equilibrium has been established in the machine and mould (fig. 83).

The machine cycle is interrupted and the volume of material for one shot is discharged onto a heat-insulating surface. The temperature of the melt is measured with a needle pyrometer and compared with the specified melt temperature for Hostaform (205 ± 5°C). If the temperatures are not in agreement, the settings for the cylinder and nozzle heating are adjusted and the procedure for melt temperature measurement repeated. When the actual and specified temperatures agree, the machine is run until weight constancy of the mouldings is obtained once more.

The machine cycle is interrupted again to measure the mould temperature. The specified value for both mould wall temperatures (ϑ_{W1}, ϑ_{W2}) is 120 °C because this is the temperature at which dimensional scatter and after-shrinkage are least, fig. 81. When the specified and actual values agree, the first trial series at a minimum of three different pressure setting levels is commenced. For each pressure setting level, 50-100 trial mouldings are produced. These are then evaluated.

Fig. 81 · Dimensional scatter ΔM and after-shrinkage AS of Hostaform as a function of mould wall temperature



Using statistical methods, the mean value $\overline{X}$ and the 3 x standard deviation (± 3 s), ie 6 s, for the relevant dimensions (eg dimension A and dimension B, fig. 84) are determined at each injection pressure setting [8].

Fig. 82 · Machine settings for injection moulding

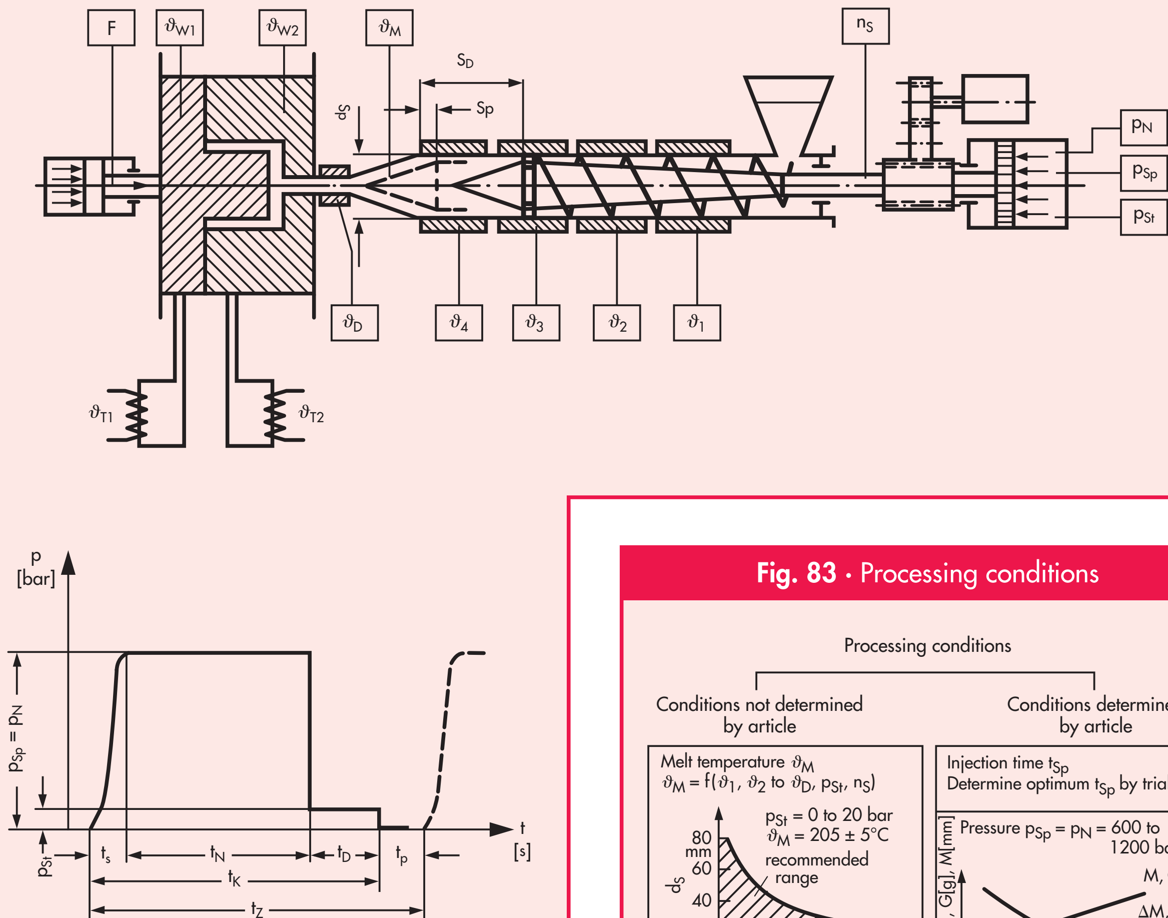
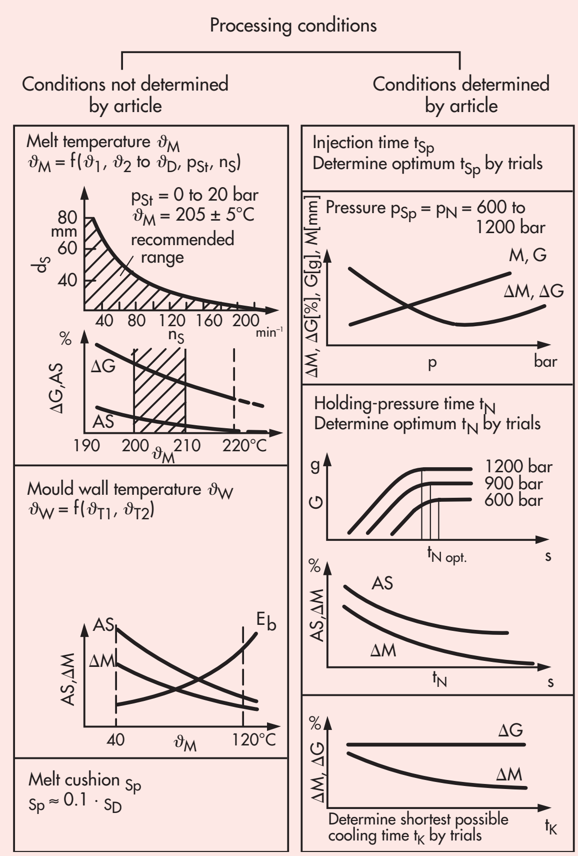


Fig. 83 · Processing conditions



ϑ_1, ϑ_2 to ϑ_D	°C	cylinder temperatures, nozzle temperature
ϑ_M	°C	melt temperature
ϑ_{W1}, ϑ_{W2}	°C	mould wall temperatures
ϑ_{T1}, ϑ_{T2}	°C	set value on the temperature control units
n_S	min^{-1}	screw speed
p_{St}	bar	back pressure
p_{Sp}	bar	injection pressure
p_N	bar	holding pressure
F	N	clamping force
s_D	mm	metering stroke
s_p	mm	melt cushion
d_S	mm	screw diameter
t_S	s	injection time
t_N	s	holding-pressure time
t_K	s	cooling time
t_D	s	mould filling time
t_p	s	changeover time
t_Z	s	cycle time
E_b	J	fracture energy
AS	%	after-shrinkage
ΔM	%	dimensional variation
ΔG	%	weight variation

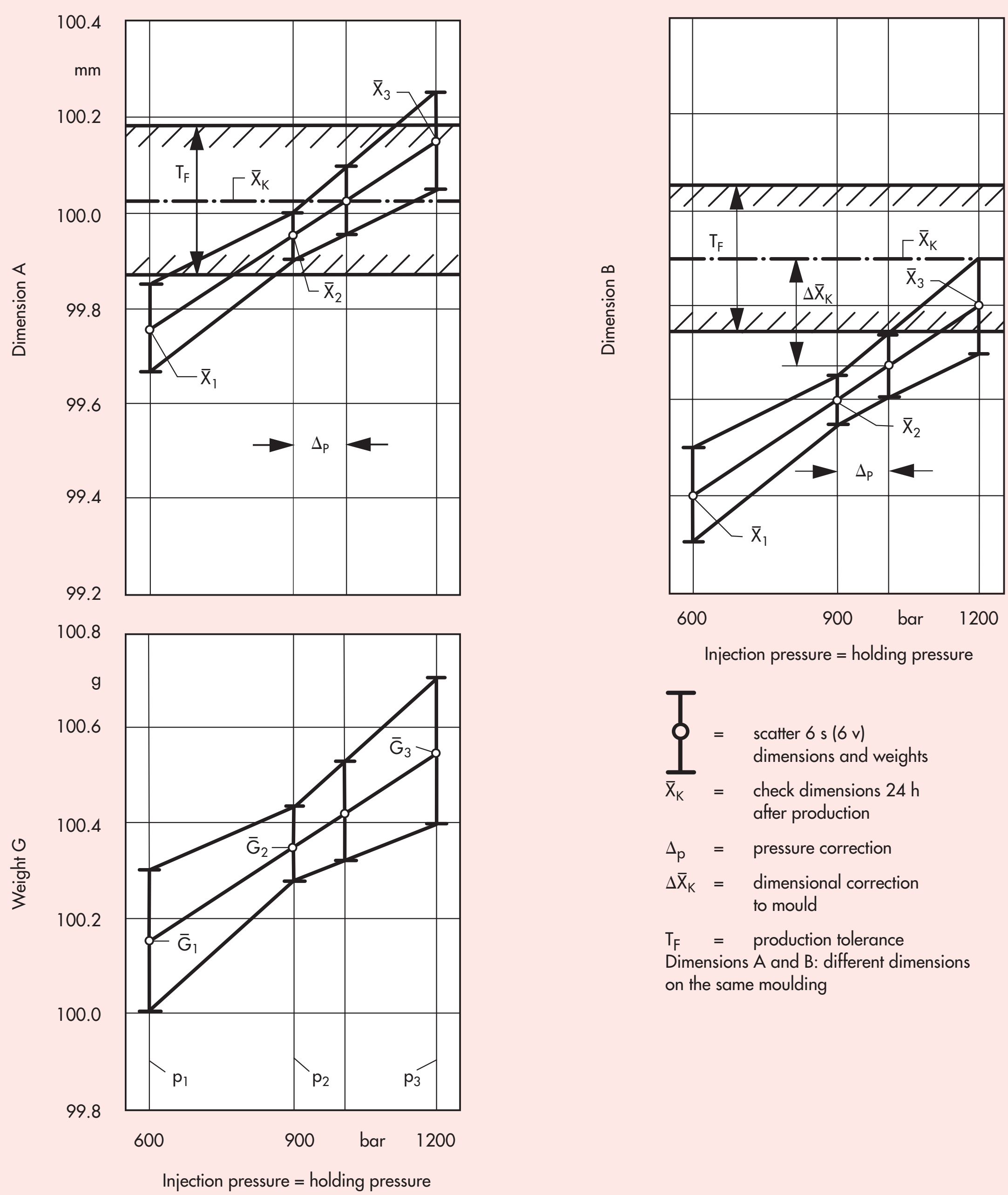


Fig. 84 · Evaluation of trial mouldings

The target range of tolerance (production tolerance T_F and check dimension $\overline{X}_K$) is entered on the diagram and the achieved dimensions and their scatter are compared with the tolerance range and with the position of the pressure optimum. The following procedure is then adopted:

1. Carry out pressure correction Δp to bring as many dimensions as possible within the tolerance range. In so doing, it is important to ensure that the pressure is not adjusted too far from the optimum pressure range as otherwise dimensional scatter will be increased.

2. For those dimensions still outside the tolerance range after pressure adjustment, it is necessary to correct the dimensions ($\overline{X}_K$) of the mould itself (see dimension B in fig. 84).

3. When the modification to the mould is complete, injection moulding is resumed at the corrected pressure. The dimensions of the mouldings obtained are checked and average weight determined.

From the optimization process, all required processing conditions are known. The correct injection pressure (= holding pressure) is ascertained by evaluating the dimensions of trial mouldings and the appropriate weight is determined.

Certain dimensions and weights, as also certain dimensional and weight variations (scatter), can be related to optimum processing conditions. With this knowledge, it is possible to base production control on weight and weight scatter.

Experience has shown that weight scatter should not exceed 0.6% (relative to the average weight of the moulding) if dimensional scatter is to be kept below 0.3%.

Tolerances

The dimensions of the moulding are important quality control characteristics. The dimensional scatter in manufacture of ± 3 s (or ± 3 v) must be less than the required production tolerance T_F.

Depending on application requirements, there are three tolerance ranges:

A general-purpose injection moulding
$T_F < 1\ \%$ at $\vartheta_W = 60\,°C$
B injection moulding of engineering components
$T_F < 0.6\,\%$ at $\vartheta_W = 90\,°C$
C injection moulding of precision components
$T_F < 0.3\%$ at $\vartheta_W = 120\,°C$

These data are valid for nominal dimensions > 10 mm, fig. 85.

For nominal dimensions < 10 mm, the linear relationship between tolerance and nominal dimension no longer applies. The percentage tolerance thus increases very rapidly below about 3 mm, fig. 86 (see also DIN 16 901).

5.3 Extrusion

The extrusion method is used mainly to process Hostaform into semi-finished products (round bars, flat bars, hollow profiles and sheets). The dimensions and permissible dimensional and shape variations of such profiles and their supply specifications are standardized in DIN 16 974, 16 975, 16 977 and 16 978.

These semi-finished products are frequently machined to make prototypes, pre-production runs or even production parts in small quantities [18].

In extruding Hostaform, the main points to note are the characteristically narrow melting temperature range and the rapidity with which freezing takes place.

5.3.1 Extruder and screw

Hostaform is extruded on conventional single-screw extruders. Twin-screw extruders are not suitable. Cooling or heating of the screw is not required.

Short-compression-zone screws have a suitable geometry for extruding Hostaform. Screw lengths of 25 D give the best results. Shorter screws frequently lead to surging.

Processing on vented extruders is not recommended.

Fig. 85 · Tolerance classes for the injection moulded dimensions of Hostaform components (IT 8 to IT 13 = ISA basic tolerances)

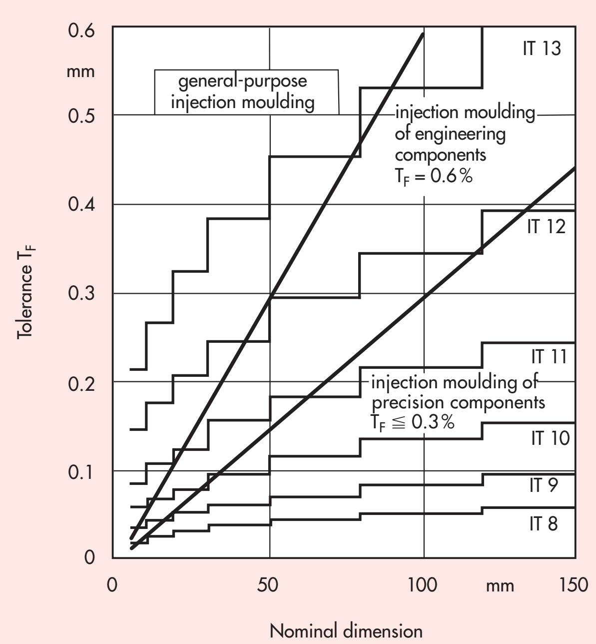
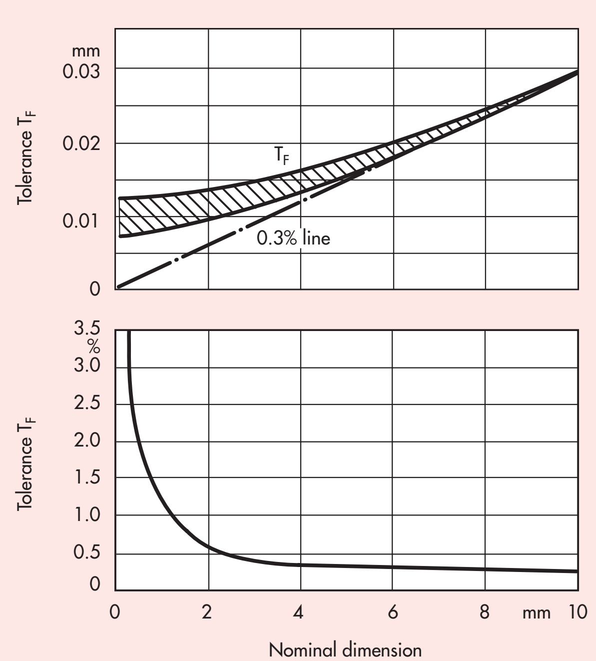


Fig. 86 · Production tolerance for Hostaform injection moulded precision components with small nominal dimensions



5.3.2 Material grades

For extrusion, the basic principle is to select a melt viscosity which will ensure that the plasticized material can be processed with maximum care. In most cases, this means the melt should be as highly viscous as possible, consistent with good homogenization. The Hostaform extrusion grades M30AE and M10AE are ideal materials for this purpose.

5.3.3 Extrusion of round bars

The design and mode of operation of an extrusion plant for round bars are shown in fig. 84. The difficulty of producing void-free round bars becomes greater with increase in diameter since uniform freezing of the extrudate throughout the cross-section is not possible.

Extrusion rate

To remove sufficient heat from the profile despite low thermal conductivity, not only is an effective cooling system essential but also a relatively low production rate. Experience shows that throughput rates of about 7-9 kg/h with single extrusion dies should not be exceeded.

To make full use of the considerably higher production rate of which the extruder is capable, round bars are frequently extruded with multi-orifice dies.

Back pressure

The extruded bar is deliberately retarded as it leaves the die by means of brake shoes or by a special haul-off system so that the freezing melt is placed under such high pressure that no voids are able to form and stresses due to volume contraction are largely avoided. The back pressure should be measured and controlled.

Cooling and melt temperature

On leaving the sizing device, the frozen outer skin of the profile must be thick enough to withstand the internal pressure applied. This is achieved by means of external cooling chambers and/or direct water cooling (see fig. 87). To shorten the cooling operation, it is advisable to choose a low melt temperature. For this reason, the temperatures normally used are 180–185 °C.

5.3.4 Extrusion of sheets and flat bars

For sheeting of about 1000 mm width, extruders with a screw diameter of 90 or 120 mm are used. The polishing rolls are chrome-plated and polished to a mirror finish and are heated with oil or superheated steam. With calendered sheeting, throughputs of about 100 kg/h can be achieved.

To produce sheeting with the minimum internal stress and with a high gloss surface, the two feed rolls should be heated to 130–135 °C and the delivery roll to 120–125 °C. Infrared heaters fitted additionally to the roller unit help to ensure uniform cooling, particularly in the edge regions of the sheet, and thus to produce an evenly stress-free profile. As a rule, the sheet edges are trimmed straight once the sheet has passed through the rolls.

Sheeting can also be produced by compression moulding. In this case, the material is preplasticized in an extruder, ejected into the heated compression mould, compressed, and then held at constant pressure and cooled to the demoulding temperature.

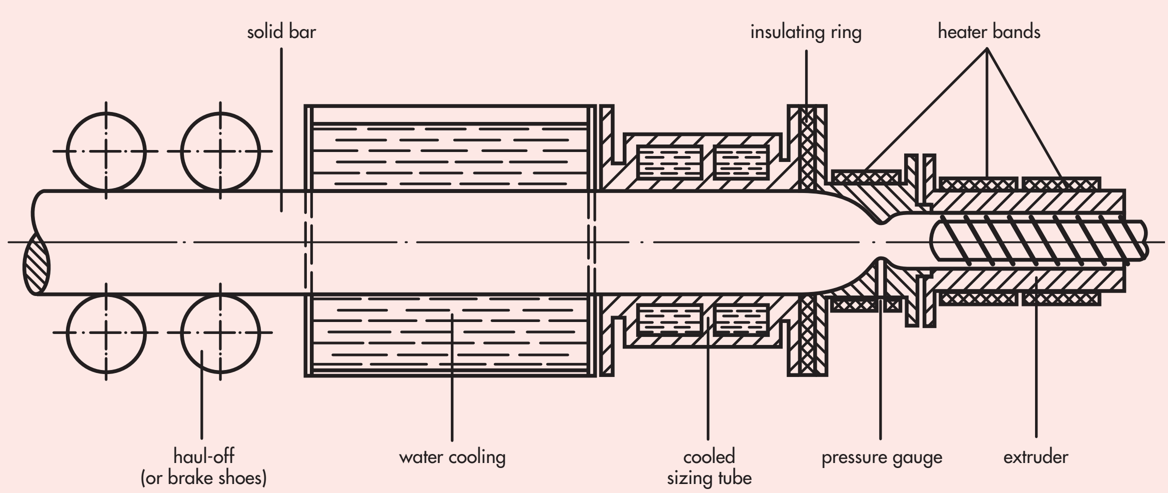
5.3.5 Extrusion of pipes and hallow profiles

Up to now, most extruded pipe has been 5–8 mm in outside diameter. It is used as casing for Bowden cables.

Pipes up to an outside diameter of 10–12 mm can be vacuum sized, whereas larger dimensions can be produced only by a combination of vacuum and internal pressure systems. These points must be borne in mind in designing the die and system of sizing.

A pipe extrusion line consists of an extruder with die, sizing device, quench bath, haul-off system and cutting and/or reel-up equipment.

Fig. 87 · Principle of a line for extruding round bars



5.3.6 Annealing

Despite all countermeasures, a certain amount of uneven cooling will take place over the cross-section and cause internal stresses which have to be relieved by a final heat treatment. This annealing treatment is usually carried out in air or nitrogen (circulating air oven) or in liquids (waxes, oils) at 140 °C for a period of 10 min per mm wall thickness or diameter. To avoid possible formation of stresses as a result of heating up or cooling down, both operations should be carried out slowly and evenly. The times required for these operations are added to the annealing time.

Example: round bar 100 mm diameter

Annealing:	
100 (mm) x 10 (min/mm)	= 1000 min
	≙ 16 h 40 min
Heating the loaded oven from cold	= 3 h 20 min
Cooling the oven to 40 to 50°C	≈ 6 h
Total annealing	26 h

5.4 Extrusion blow moulding

General

This is a two-stage process. The first stage comprises the production by extrusion of an inflatable preform, the second, blow moulding and cooling the article in the mould.

For extrusion blow moulding, plastics with a relatively high melt strength are required. Hostaform C 2521 is suitable for the production of small hollow mouldings up to a maximum capacity of 1 litre.

The shrinkage of Hostaform blow moulded articles is between 2 and 4%.

Machine and mould

Hostaform containers up to a capacity of 5 litres are produced on blow moulding machines without a melt accumulator, ie the tubular parison is extruded continuously. Larger blow moulded articles require machines with an accumulator head in which the plastic melt collects until the required shot volume has been obtained and is then extruded relatively quickly.

To plasticize the material, slow-running, single-screw extruders fitted with screws between 20 and 25 D in length are suitable.

Processing

On discharge from the head, the plasticized material should have a temperature of about 185 °C. At this point, sagging can be limited by judicious lowering of the temperature (but not below 170 °C). To obtain uniform axial wall thickness distribution, it is necessary, particularly with non-cylindrical shapes because of different radial blow ratios, to provide programme control of parison wall thickness in the axial direction. When processing Hostaform, the die must be adequately heated in the orifice region (≧ 170 °C) since otherwise temperature variations in the parison wall will cause irregular parison swell and continuous operation will be interrupted.

Well-formed, blow-moulded containers with a smooth finish are obtained only when the mould is maintained at about 90 °C.

When production ceases, the screw must be run until it is completely empty, ie until no more plasticized material comes out, before the extruder is switched off. When production is to be resumed, the predetermined temperature settings should be raised by about 20 °C for the initial startup period. When these higher temperature values have been reached, it is necessary to wait at least 15 min before the extruder drive is switched on. Only in this way can cooled material – particularly in the adaptor between the extruder and head – be plasticized sufficiently. When the extruder is started, granules should be fed in slowly (half of the visible screw region in the feed opening should be covered) until the parison emerges. The temperatures can then be returned immediately to the established production settings, and the material fed in as usual.

When changing from another thermoplastic to Hostaform, "purging" clean with Hostaform may cost more than a strip-down and clean of the machine.

If the previous material was PVC, the machine should in any case be thoroughly cleaned since PVC splits off hydrochloric acid and polyacetal is not resistant to this.

5.5 Injection blow moulding

General

Injection blow moulding – like extrusion blow moulding – is a two-stage process. The first stage consists in injection moulding an inflatable preform in a mould comprising a cavity and core rod. The second stage involves transferring the preform to a blow mould where it is blown into the finished product and cooled, fig. 88.

An important feature of injection blow moulding is that it allows scrap-free production of containers. In addition, the process has a number of other advantages such as

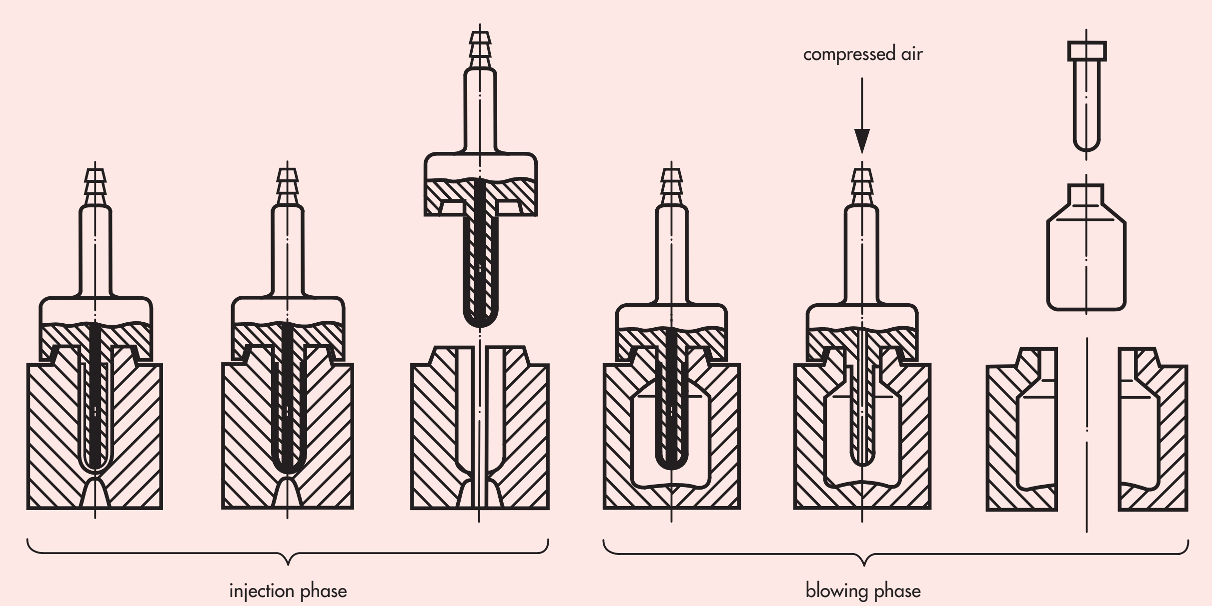
– high dimensional accuracy
– uniform wall thickness
– minimal weight and volume variation
– no weld lines
– optimum surface quality
– improved mechanical properties.

These advantages generally ensure minimum material requirement and optimum finished-part properties.

However, the advantages have to be weighed against the limitation that containers with an offset opening, additional openings or blow moulded handles cannot be produced by injection moulding. This also holds true for bottles with extreme cross-sections or longitudinal sections, for example flat rectangular cross-sections with a side ratio of a:b > 1:2.5 [9]. Because of its high rigidity and impact strength, Hostaform is suitable for the manufacture of containers subject to internal pressure. The main use of Hostaform in injection blow moulding is to produce aerosol containers.

Hostaform C 2521 has proved an ideal grade for injection blow moulding.

Fig. 88 · Basic principle of injection blow moulding



5.6 Assembly of mouldings and semi-finished products

With the present drive towards efficient, low-cost manufacture of plastics assemblies, the actual technique of assembly has become increasingly important. For manufacturing and fabrication reasons, it is often necessary to produce the component parts separately and then assemble them as required. Hostaform mouldings can be joined efficiently to produce assemblies with good resistance to mechanical stress. Various assembly methods are suitable and these are described in detail in our series of publications entitled "Design · Calculations · Applications". In series B "Design of technical mouldings", the following brochures have so far appeared on this subject:

B.3.1 Design calculations for snapfit joints in plastic parts
B.3.2 Fastening with metal screws
B.3.3 Plastic parts with integrally moulded threads
B.3.4 Design calculations for pressfit joints
B.3.5 Integral hinges in engineering plastics
B.3.7 Ultrasonic welding and assembly of engineering plastics

Publications in this series are available on request.

Hot-plate welding

Hot-plate welding has proved a successful method of joining Hostaform injection moulded components, irrespective of pigment or additive content. This method is particularly suitable for joints which are to be mechanically stressed, for large joints, or for components whose particular shape precludes the use of other methods.

The surfaces to be joined are brought up to temperature by light contact with a PTFE-coated hot plate and are then welded together under pressure. The hot-plate temperature should be between 220 and 240 °C. The heating up time is about 5–30 s, depending on the shape of the component and, of course, the melt viscosity of the particular Hostaform component being used. When joining the heated surfaces, it is an advantage to use a welding pressure control system in which welding pressure is automatically controlled by travel path when the mating surfaces reach a predetermined distance apart (≈ 0.5 to 1.5 mm).

Friction welding

Another low-cost method of joining injection moulded components is friction welding. With this method, it is essential for the joint faces to be rotationally symmetrical.

Experience so far has shown that frictional speeds between 100 and 300 m/min at contact pressures of 0.2 to 0.5 N/mm^2 give successful results. The optimum conditions must be determined for each particular component; these vary with the geometry of the component, the type of joint, the construction of the drive device and the grade of material used.

Riveting

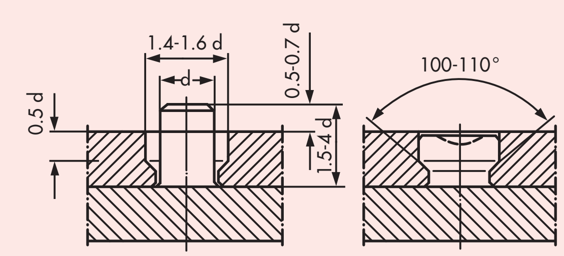
To join Hostaform components with each other or with parts made from other materials, hot riveting and ultrasonic riveting are suitable methods.

Hot riveting

In hot riveting, a PTFE-coated tool is brought up to a temperature of about 220 to 230 °C. In the first stage, the rivet is preheated with the tool and in the following stage, the head is formed with a cold heading tool, fig. 89.

With appropriately designed riveting tools, several rivets can be closed in one operation.

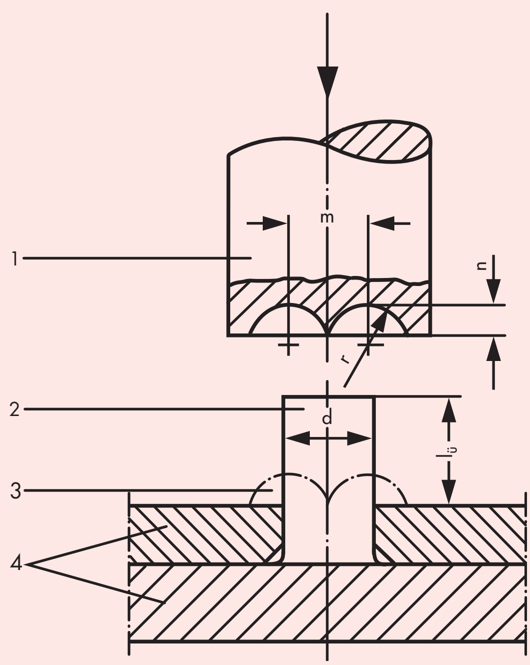
Fig. 89 · Initial dimensions for hot riveting



Ultrasonic riveting

In ultrasonic riveting, the ultrasonic horn acts additionally as a heading tool (fig. 90). Ultrasonically riveted joints are low in stress, have high mechanical load-bearing capacity and are less sensitive to temperature changes. In contrast to cold-riveted joints, they have no noticeable "memory" and thus have good long-term properties. Ultrasonic riveting provides the advantage of short cycle times.

Fig. 90 · Initial dimensions for ultrasonic riveting



1. ultrasonic horn
2. rivet shank
3. head shape
4. parts to be riveted together

Typical values
$l_ü$ = 0.4-1.6 d
m = 0.75-1.0 d
n = 0.25-0.5 d
r ≈ 0.5 d

Adhesive bonding

Conventional adhesive systems

Because of its high solvent resistance, Hostaform is not readily bonded with conventional adhesives. Joints made with pressure-sensitive adhesives are the only type possible. To obtain high-strength bonds, the surfaces must be pretreated. Suitable options include mordant solutions, primer coats or corona discharge.

After thorough surface pretreatment, the following adhesive systems can be used:

Type of adhesive	Base
Contact adhesives	polychlorobutadiene with isocyanate crosslinking agents
Two-component adhesives	epoxy resin polyurethane nitrile rubber/phenolic resin methacrylate
Hot-melt adhesives	vinyl copolymers
One-component polymerizable adhesive	cyanoacrylate

Bonds obtained with these adhesive systems have sufficient strength for many applications.

5.7 Surface decoration

Consumer taste and publicity needs are not always fully satisfied by the pigmentation of plastics or by the possibility of obtaining two-colour mouldings in the injection moulding process. There is in addition a demand for plastic products which, for decorative and/or information purposes, are given a printed, painted or hot stamped finish. Flock coating and metallizing of the surface are further special types of finish supplied.

5.7.1 General surface requirements

To attain an aesthetically pleasing decorative effect, it is essential for the mouldings to have a smooth, flawless surface. Irregularities or scratches, weld lines or other surface defects are not as a rule obliterated by surface decoration but remain visible on the decorated surface and detract from its appearance. This should be taken into account by exercising care in polishing the mould and by maintaining optimum processing conditions (mould and melt temperature, injection pressure, injection rate).

With nearly all mouldings, the surfaces are likely to be soiled and so generally speaking a cleaning process should precede surface decoration. Numerous solvents such as paint thinners or trichloroethylene are suitable for this purpose.

A special surface pretreatment is frequently necessary, and may be either chemical or mechanical. Decorative materials applied onto an untreated surface should in any case be given a heat treatment either as they are applied (hot stamping foil) or after application (primers, printing inks).

5.7.1.1 Mechanical pretreatment

Roughening the moulding surface by sandblasting, grinding etc. induces a surface activation and aids adhesion of subsequently applied decorative materials. This method is very costly and therefore is hardly ever used.

5.7.1.2 Acid etching

The same effect is achieved by controlled slight etching of the surface of the moulding in an acid bath. Here again the surface is roughened and takes on a matt appearance. Afterwards the parts must be thoroughly rinsed in warm water at 60 °C. After air drying, the surface can be readily wetted.

5.7.1.3 Primers

Primers are included among coatings which will adhere to Hostaform mouldings without surface pretreatment but unlike hot stamping foils or printing inks, primers are used only as aids to decoration, ie adhesion promoters for topcoats.

5.7.1.4 Physical pretreatment

Pretreatments commonly used for other plastics such as flame treatment or exposure to corona discharge are unsuitable for Hostaform because they bring hardly any improvement in adhesion.

5.7.2 Painting

Conventional topcoat systems are used and the choice of system depends on the paint properties required, eg weathering resistance, chemical resistance, scratch resistance etc.

5.7.3 Vacuum metallizing

By this process, a mirror-finish, metallized surface can be imparted to Hostaform mouldings. The various operations required are as follows:

– Pretreatment

The surfaces to be metallized are first cleaned and degreased, followed by mechanical delustring or preferably acid etching as described in section 5.7.1.2. The primer treatment discussed above also produces satisfactory results.

– Base coating

The quality of adhesion of the evaporated metal depends mainly on the suitability of the basecoat applied to the surface to be metallized. The two-component, polyisocyanate-based lacquers developed specially for vacuum metallizing have proved very good. After application, they are cured in a drying oven.

– Vacuum metallizing

Evaporation of the desired metal onto the article is carried out under the usual conditions for this method.

– Topcoating

The evaporated metal layer is very sensitive to mechanical damage. To protect it from scratches, a colourless or transparent topcoat is applied.

5.7.4 Electroplating

Hostaform mouldings can be coated with a conducting metal layer then electroplated by the usual electrochemical method. The surface may be roughened by the etching process described.

It is not possible to obtain firm adhesion of the metal layer to the plastic and for this reason the coating has to be of at least sufficient thickness to be self-supporting.

5.7.5 Hot stamping

Hot stamping of Hostaform mouldings is a frequently employed method of decoration because pretreatment of the surface is unnecessary. However, the surface must be clean.

The popularity of this method is reflected in the large number of hot stamping foils at present on the market which are suitable for Hostaform. The choice of foil depends on the stamping method to be used (positive stamping, negative stamping, large-area stamping, relief stamping, reciprocating press, rotary press with cylindrical or flat die, stamping with brass or silicone rubber dies), the properties required of the stamping (scratch and abrasion resistance, chemical resistance, weathering resistance) and of course the shade required, including surface finish (glossy, matt). This great variety of choice makes it impossible to give general recommendations on suitable foils and stamping conditions. For example, the required temperature of the stamping die can vary between 100 and 200 °C, depending on the type of foil. Stamping equipment must have accurate control systems for pressure, temperature and die dwell. A uniform contact pressure is particularly important. Exact setting of the stamping die is not in itself sufficient. Care must also be taken to ensure that the moulding is firmly and evenly supported. Soft supports such as rubber are unsuitable. High contact pressure, short dwell times and high temperature are the preferred processing conditions. Flat surfaces are of course easier to stamp than domed surfaces, solid parts easier than hollow. In certain cases, preliminary trials may be required.

It is always advisable to consult the foil manufacturer.

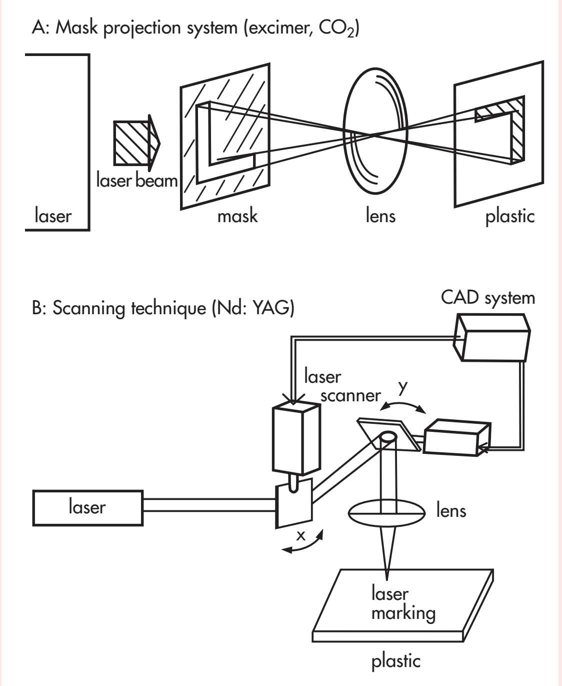
Lists of suppliers of the primers, printing inks and stamping foils mentioned above are available on request.

5.7.6 Laser marking

A relatively new, contactless method for applying text, patterns and symbols of all kinds on the surface of plastics involves marking with a laser beam [22]. This is a "clean" process requiring no surface pretreatment, colour pastes or solvents; the moulded parts cannot be contaminated or damaged by it. Laser marking is fast, uncomplicated, extremely flexible in terms of changing fonts and characters and can be readily integrated into production units.

There are two methods for laser marking polymers: the mask projection system (fig. 91 A) and the scanning system (fig. 91 B). Which of these is the most appropriate method will depend on the job at hand, the required results and the type of material. Each process requires its own special equipment.

Fig. 91 · Diagrams showing basic principles of laser marking processes for plastic



Mask projection system

In this process, the laser beam initiates a photochemical reaction of the pigments or additives on the plastic surface. The result is a marking which may be light or dark, depending on the base colour. Marking is carried out through a metal or ceramic mask. For a change of character, the mask must be changed. Excimer or CO_2 lasers are suitable for the mask projection process.

Scanning system

In this process, a laser beam passed through a system of mirrors "writes" the required marking on the plastic. The marking in the plastics surface is produced by foaming or burning an extremely thin layer or by bleaching out pigments. By varying the intensity of the laser beam, a thinner marking can be produced or a thicker one that is slightly raised from the surface. The particular advantage of this process is its high flexibility. Changes, modifications, serial numbers etc. present no problem. The required marking data are entered in a PC program which controls the laser unit. This process operates with an Nd: YAG laser.

Laser marking of Hostaform mouldings

Extensive trials have already been carried out with laser marking of Hostaform mouldings. In table 3 special colours for laser marking with the appropriate marking colours are listed.

5.8 CAMPUS plastics data base

In conjunction with other material manufacturers, Ticona has helped to set up a standardized plastics data base which is available on diskette.

The data base contains values which

– have been measured in standard tests on test specimens prepared by standard methods

– have been carefully chosen to describe the property profiles of plastics with sufficient accuracy to form the basis for material selection.

®CAMPUS = registered trademark of CWFG, Frankfurt am Main, Germany

Table 3: Laser marking of Hostaform C

		Colour	Marking Nd:YAG laser 1064 mm	Marking Excimer laser 351 nm
Hostaform	10/9005	black	white	
	80/9006	dark blue	white	
	60/9007	dark brown	white	
	70/9008	green	pale green	
	80/9009	blue	pale blue	
	30/9010	gray	white	
	40/9011	crimson	pink	
	80/9012	violet	pale violet	
Hostaform	20/9001	white		black
	20/9002	ivory		black
	40/9003	red		white
	50/9004	yellow		gray
Hostaform	10/9101	near-black	blue	
	10/9102	near-black	green	
	10/9103	near-black	yellow	
	10/9104	near-black	red	

6. Recycling Hostaform

Hostaform can be recycled in various ways – some of which have limitations.

Material recycling

Sprues, rejects etc. can be processed as regrind in blends with virgin material. This includes the common practice of feeding sprues directly back into the injection moulding machine. It is important to ensure, however, that regrind is dry, clean and dust-free since otherwise processing stability is reduced. The addition of regrind can also impair feed behaviour.

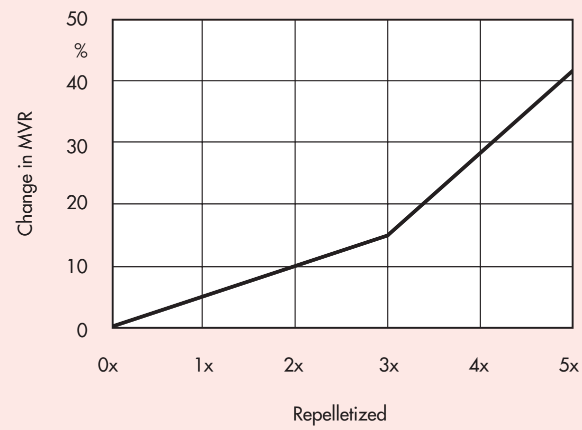
The use of regrind is not recommended for high-quality engineering parts.

Hostaform waste can also be remelted and repelletized but attention must be paid in this case to some specific requirements resulting from its chemical structure. Polymer-type purity and cleanliness of the waste material are particularly important in this process. In practice, this places some limitations on the use of recompounding as a recycling option.

When a material has passed through the recycling loop several times, some deterioration in properties may occur due to degradation and consequently there are restrictions on the possible uses for recycled material. This applies particularly to material produced wholly or partly from post-consumer waste. Quality assurance conforming to ISO 9001, which can be achieved in the production of virgin material, is not really possible with these POM recyclates.

Multiple processing can lead to material degradation. This is shown by an increase in the volume flow rate MVR which is an index for reduction in molecular weight, fig. 92. An increase in MVR is accompanied by a loss in thermal stability and frequently in toughness as well.

Fig. 92 · Change in the volume flow rate (MVR) of polyacetals as a function of multiple processing



Feedstock recycling

Another recycling option is feedstock recycling, in which waste plastics are broken down into their constituent monomers for reuse as feedstock in new polymerization processes. Virgin material results from this process and so there is no loss in quality, unlike with recyclates. Although Hostaform has a structure which makes it particularly suitable for this option, the process is not at present being exploited industrially owing to an absence of the necessary logistics for collecting the used parts and for economic reasons.

6

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8. Photo supplement showing typical applications

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Basic grades

Proven standard grades for injection moulding, extrusion and blow moulding

Photos 1-4:
Modern, heavy-duty kitchen tap components consist of three materials: metal, ceramics and Hostaform C 9021

Photo 5:
Dial switch disk for current meter made from Hostaform C 9021 with engaging springs, snapfit hooks and dial bar

Photo 6:
More than 20 components made from Hostaform C 9021 and C 9021 GV 3/20 for a modern gas meter

Photo 7:
Directional control valve blocks made from Hostaform C 9021 with integrally moulded snapfit hooks for straightforward assembly

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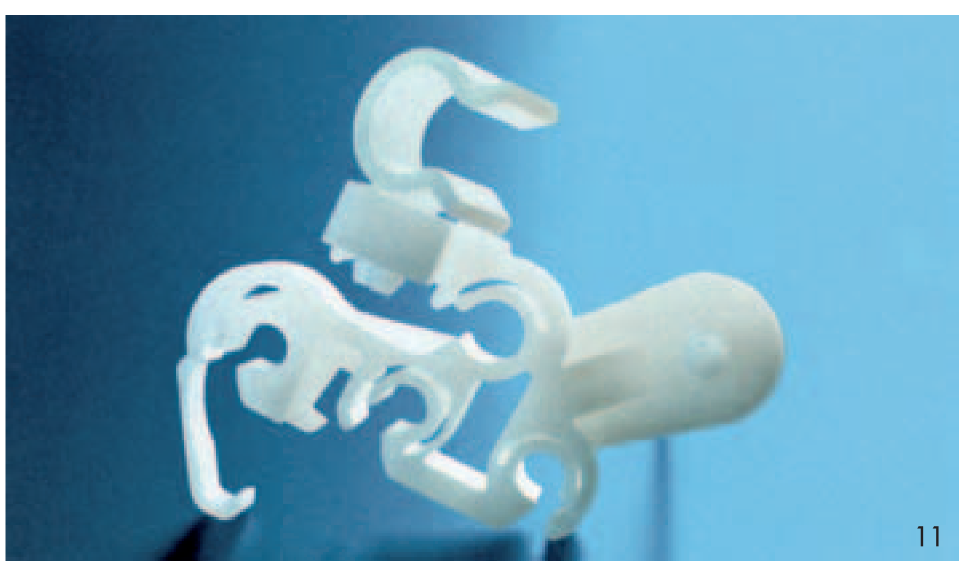
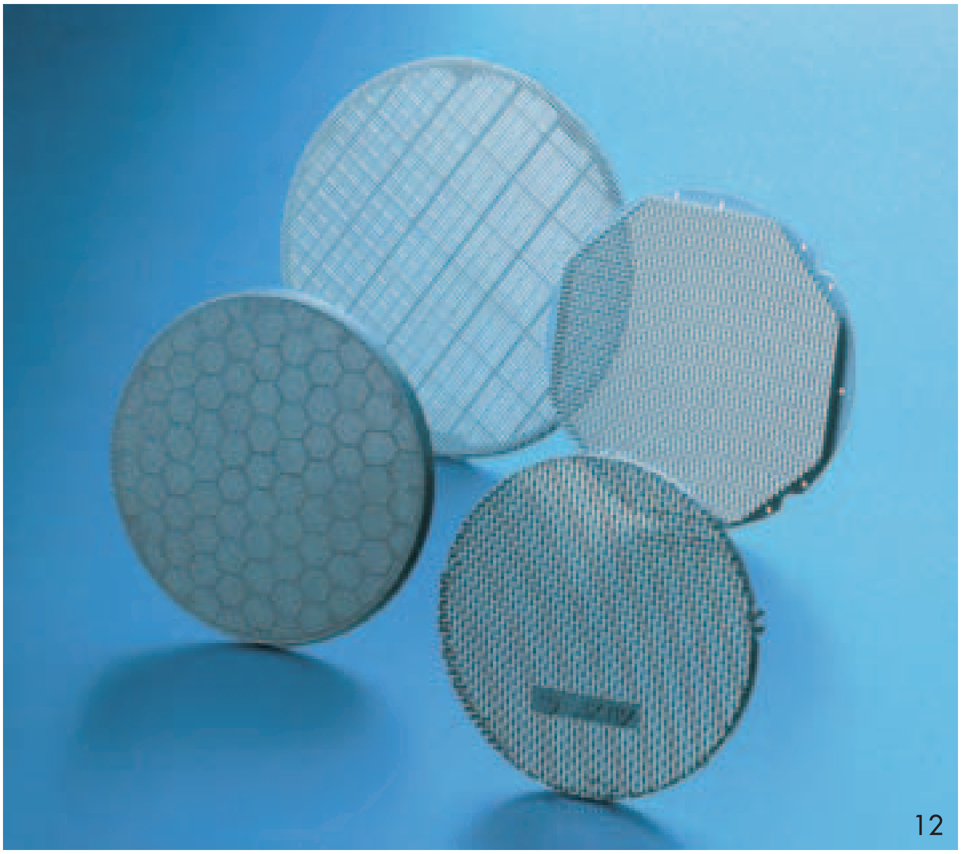
Photo 8:
Perfume container – inner parts with integrally moulded spring, engaging and snapfit elements made from Hostaform C 9021

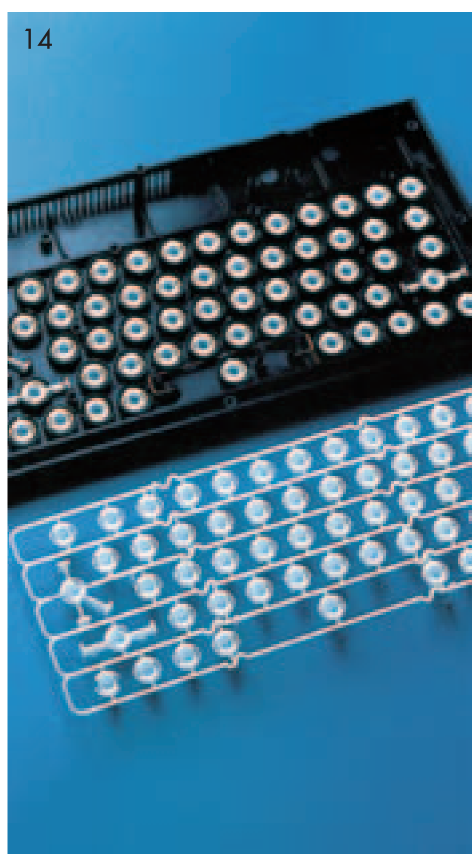
Photo 9:
Truck door handles made from UV-stabilized Hostaform C 2521 are of robust design appropriate to the application

Photo 10:
Drive wheels with internal toothing made from Hostaform C 2521 for a motor mower

Photo 11:
Automotive clip made from Hostaform C 2521 with various spring and snapfit elements designed to hold cables and pipelines and fix the clip to the car







Easyflowing grades

These are distinguished mainly by their high melt flow rates and meet all requirements of modern injection moulding technology.

Photo 12:
Speaker grille with complicated moulding geometry made from extremely easyflowing Hostaform C 27021 and Hostaform C 52021

Photo 13:
Fuel supply system with parts made from easyflowing Hostaform C 13031

Photo 14:
Key guides made from easyflowing Hostaform for the keyboard of a PC system

Photo 15:
Base plate with more than 100 parts made from Hostaform C 13021, produced by outsert moulding for a video recorder

Photo 16:
Clips made from easyflowing Hostaform C 13021 for fastening pipelines and cables in automotive manufacture

Photo 17:
Spring plate made from very easyflowing Hostaform C 27021

Photo 18:
Rotating and sliding elements made from UV-stabilized, easyflowing Hostaform C 13031 for vertical blinds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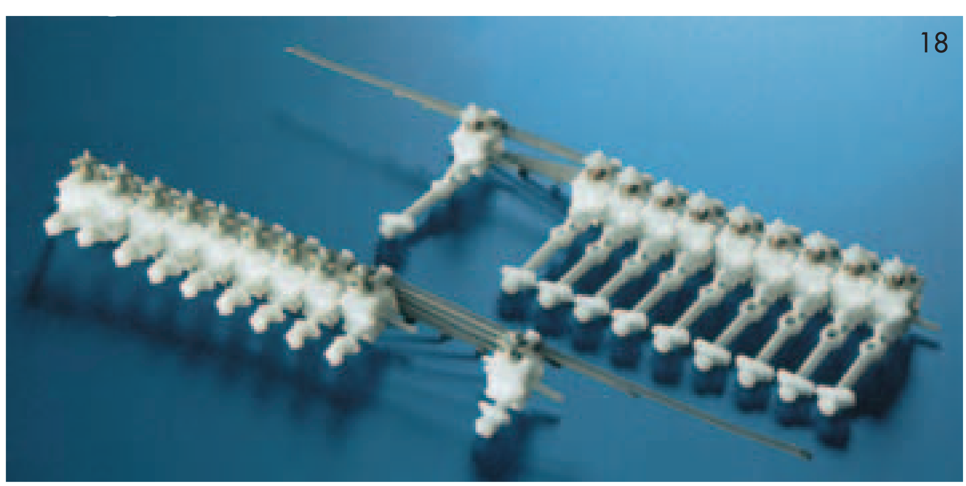
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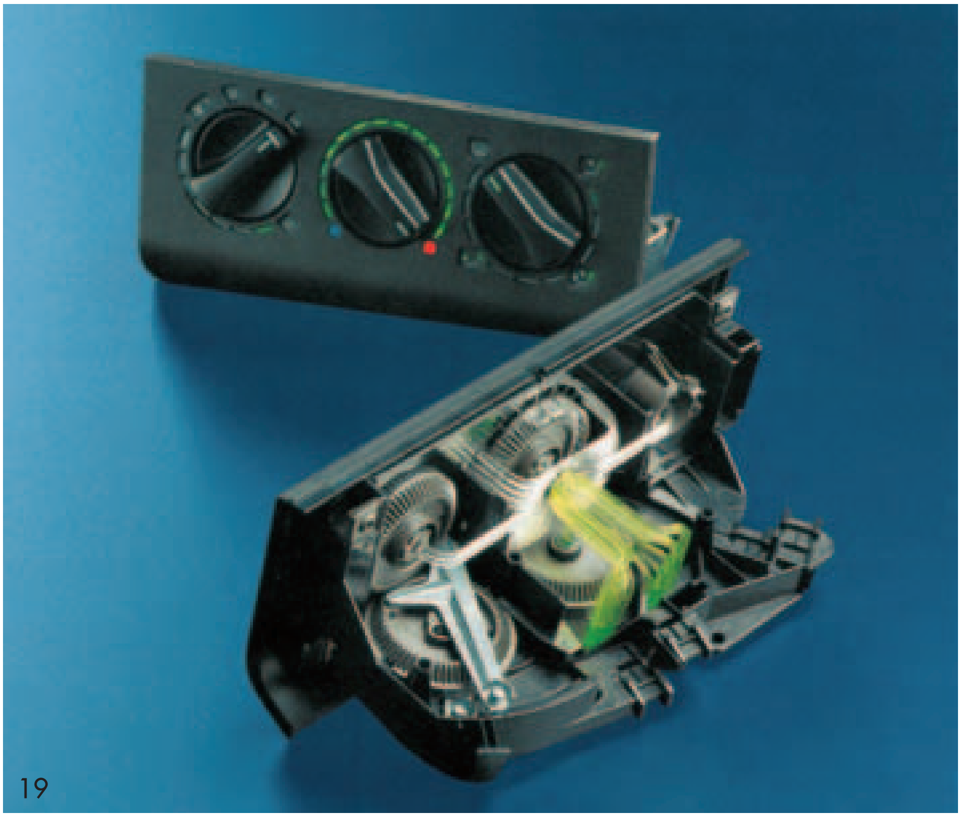

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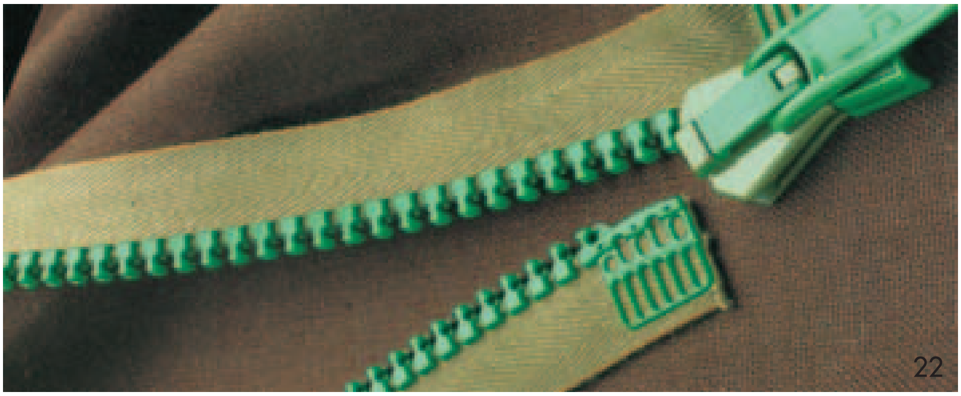

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Grades with improved slip properties

These are modified with additives which improve slip properties and/or abrasion resistance.

Photo 19:
Bevel wheels made from molybdenum-disulphide-modified Hostaform C 9021 M in an automotive ventilation/heating system

Photo 20:
Circuit breaker (modular design) with gearwheels precision moulded from slip-modified Hostaform C 9021 K

Photo 21:
Gearwheel assembly made from Hostaform C 9021 G for a towel dispenser

Photo 22:
Zip fastener with injection moulded plastic teeth made from the special grade Hostaform C 13021 RM

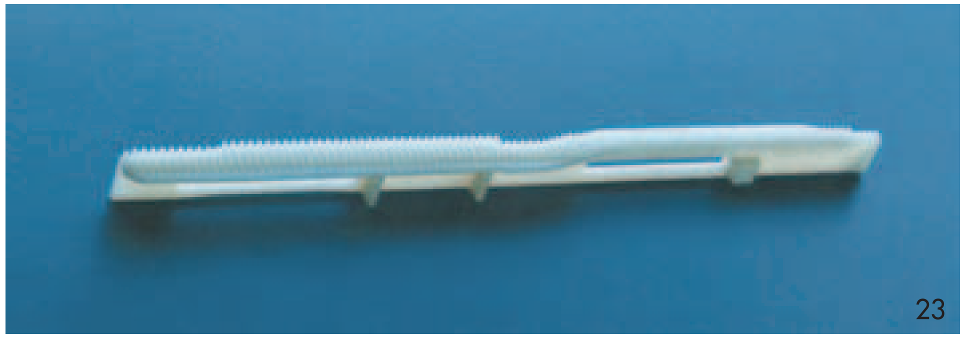
Glass-fibre/glass-sphere-reinforced grades

In these grades, glass fibres or glass spheres are used as reinforcing materials.

Photo 23:
Toothed rack measuring 190 x 9 x 11 mm, injection moulded from 30%-glass-sphere-reinforced Hostaform C 9021 GV 3/30

Photo 24:
Toothed ring made from Hostaform C 9021 GV 3/30 – true-running and distortion-free
o.d. = 135 mm
i.d. = 100 mm

Photo 25:
Pump with parts made from Hostaform C 9021 GV 1/30 for an automotive windshield (screen) washer unit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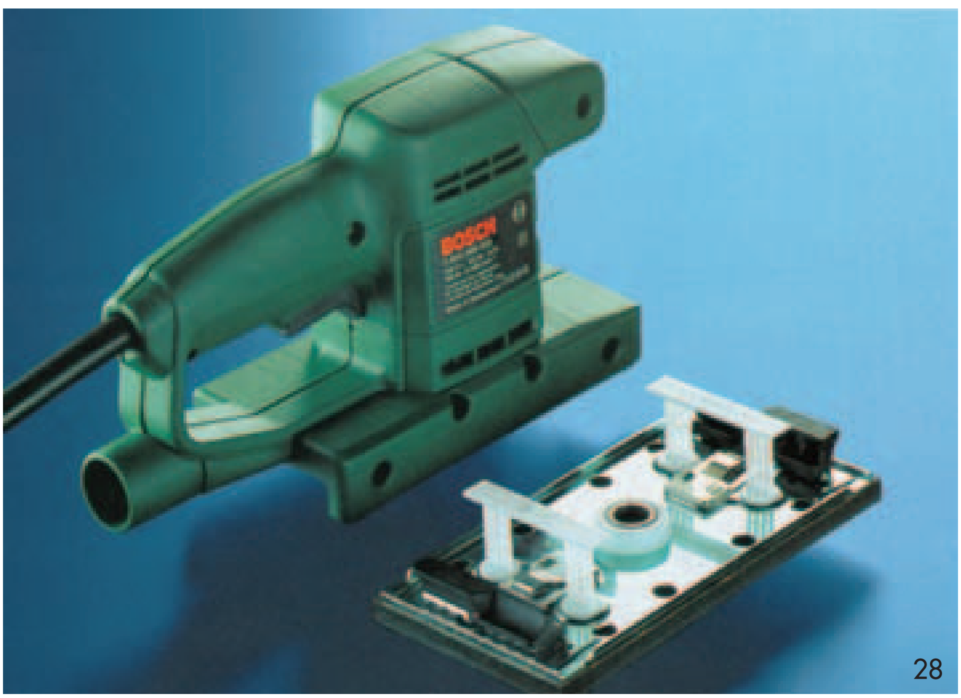

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Impact-modified grades

These grades are blends with elastomers and have higher impact strength than the basic grades.

Photo 26:
Parts of a conveyor system for garment blanks in the clothing industry: garment carrier and pulley made from Hostaform S 9063, other parts made from C 13021 and C 2521

Photo 27:
Automotive aerial bushing made from impact-resistant, easyflowing Hostaform S 27063

Photo 28:
Orbital sander plate with outsert moulded components made from Hostaform S 9063

Photo 29:
Flexible adjusting ring made from high-impact Hostaform S 27064 for trimming-depth adjustment on an electric shaver

Photo 30:
High-load-bearing belt fasteners made from high-impact, high-weld-strength Hostaform S 9244; hinged flap with snap-in projections made from extremely easyflowing Hostaform C 52021

Laser marking of Hostaform

This is a fast, clean, noncontact process which offers a high degree of flexibility and produces very good results.

Photo 31: Money box made from very easyflowing Hostaform C 27021

Photo 32: Hair collector for an electric shaver, laser-marked with text, codes, safety symbols and the company logo

Photo 33: Laser-marked fountain pen top made from very easyflowing Hostaform C 27021 (two-colour injection moulding)

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9. Subject index

Notice to users:

To the best of our knowledge, the information contained in this publication is accurate, however we do not assume any liability whatsoever for the accuracy and completeness of such information. The information contained in this publication should not be construed as a promise or guarantee of specific properties of our products.

Further, the analysis techniques included in this publication are often simplifications and, therefore, approximate in nature. More vigorous analysis techniques and prototype testing are strongly recommended to verify satisfactory part performance. Anyone intending to rely on any recommendation or to use any equipment, processing technique or material mentioned in this publication should satisfy themselves that they can meet all applicable safety and health standards.

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