Industeel

ArcelorMittal

SUPERGUIDE

User guide for Superplast® Mould Steels

User guide for Superplast® Mould Steels

Industeel

ArcelorMittal

User guide for Superplast® mould steels

Technical data and information are to the best of our knowledge at the time of printing. However, they may be subject to some slight variations due to our ongoing research programme on mould steel grades. Therefore, we suggest that information be verified at time of enquiry or order.
Furthermore, in service, real conditions are specific for each application. The data presented here are only for the purpose of description, and considered as guarantees when written formal approval has been delivered by our company.

Publisher: Industeel ArcelorMittal -56 rue Clémenceau-71200 LE CREUSOT

Editor: Valéry NGOMO
Setting: Clarisse TOURNEAU
Printing: SEIC Imprimerie-LE CREUSOT

English Edition 2014

Superplast® 2738 mod (SP 300)

Superplast® 2738 mod HH

Superplast® 400

Superplast® Stainless

Appendix

Hardness conversion table

Conversion factors

General Information

Product definition

Superplast® 2738mod is a mould steel designed by Industeel ArcelorMittal. Compared to standard grades (W1.2311, W1.2738), Superplast® 2738mod provides following benefits:

- Excellent through-hardening (uniform hardness)
- Consistent texturing (random and geometric)
- Consistent polishing (very low sulphur content)
- Reliable repair welding

Some applications of Superplast® 2738mod are:

- Plastic injection mould cores and cavities
- Large-size moulds for bumpers, dashboards, fenders, etc.
- Injection moulding, compression moulding, RIM moulding.

Chemical analysis (typical in weigth %)

C	S*	Mn	Ni	Cr	Mo	B
0.26	0.002	1.40	0.30	1.40	0.45	+

*** max : 0.007**

Cleanliness (ASTM E45)

	A	B	C	D
Thin	1.5	2.0	1.0	1.5
Heavy	1.0	1.0	0.5	1.0

A: sulphides | B: alumina | C: silicates | D: globular oxides

Product properties

Mechanical properties

Superplast® 2738mod is delivered quenched and tempered to 290 – 330 Brinell (HBW). Following data are provided for testing at quarter-thickness of a 400mm-thick block.

Hardness	Yield strength	Tensile strength	Elongation	Reduction of area
HBW	N/mm²	N/mm²	%	%
300	895	1000	16	60

Physical properties

Thanks to an original chemistry, Superplast® 2738mod has superior thermal characteristics. Thermal conductivity of Superplast® 2738mod is 20% higher than values for standard grades (W1.2738).

	25°C	100°C	200°C	300°C
Thermal expansion (10^{-6}/K)	-	11.0	12.5	12.8
Thermal conductivity (W/m/K)	42	41.0	39.0	38.0
Specific heat (J/Kg/K)	480	506	530	570
Yound modulus (kN/mm²)	205			

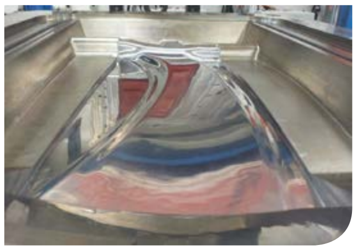
Hardness control

Wear resistance is usually proportional with hardness. In addition high and consistent hardness is especially important to avoid dents on parting lines.
Superplast® 2738mod provides very consistent hardness.

Key factors

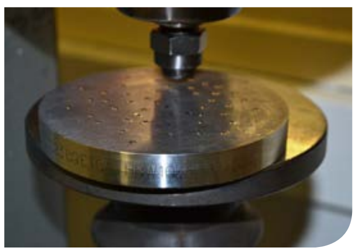
Surface preparation

All hardness test methods require smooth surfaces free of rust, oil, paint or protective coatings.



Gage repeatability and reproducibility

Prior to hardness testing, check the testing device using a reference block.



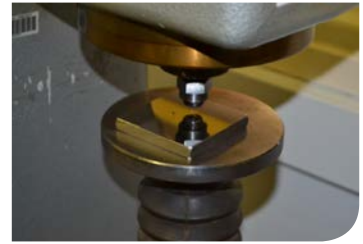
Hardness scales

It is common to test in one scale and report in another scale. Although conversion charts have some validity, established conversions do not always provide reliable information.

Popular hardness test methods

Brinell hardness testing (ISO 6506)

It measures the permanent width of indentation produced by a carbide indenter applied to a test specimen at a given load. Hardness of Superplast® 2738mod is measured by Brinell hardness test during manufacturing.



Diameter of indenter	Load	Plate thickness	Equipment
ϕ 5 mm	750 Kgf	≤ 5 mm	Brinella
ϕ 10 mm	3000 Kgf	> 5 mm	Brinella

Recommendation

The greatest source of error in Brinell testing is the measurement of the indentation. To ensure a reliable indentation reading, grind the surface with following grinding depths:

- 0.2 mm for plate thickness ≤ 5 mm
- 0.5 mm for plate thickness 5 - 40 mm
- 1 mm for plate thickness 40 - 80 mm
- 2 mm for plate thickness > 80 mm.

Grinding can be done with grit size 60 (or equivalent), followed by polishing (320 Grit paper).

Rockwell hardness testing (ISO 6508 / ASTM E-18)

It measures the permanent depth of indentation produced by a (diamond) indenter.

Recommendation

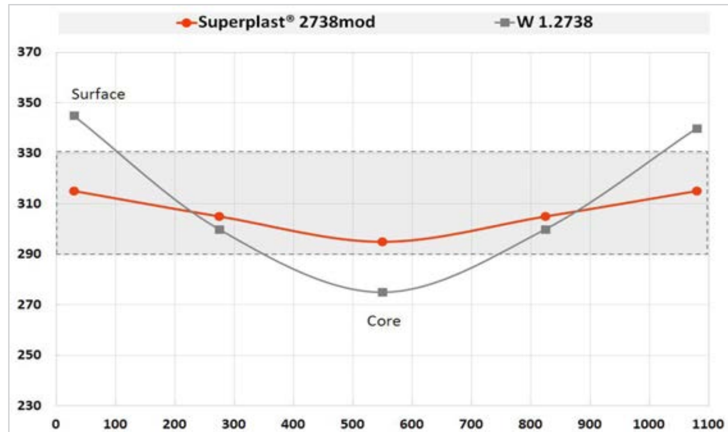
It is important to keep the specimen surface finish clean and decarburization from heat treatment should be removed. Surface preparation for Rockwell test usually requires a polishing finish finer than grit paper 600 (SPI B-1).

Rebound hardness test (DIN 50156)

Most commonly worldwide portable testers are based on the rebound technique. The device measures the Leeb hardness (HL). Superplast® 2738mod is controlled by the latest generation of portable testers EQUOTIP 3 (HLD or HLG).

Benefits of Superplast® 2738mod

- Thanks to an optimal balance of alloying content and high quality heat treatment, Superplast® 2738mod exhibits a very consistent hardness, even through large sections of blocks.
- Plates and blocks made of Superplast® 2738mod are carefully controlled by mill quality teams to ensure uniform hardness in accordance with customer's specification. Hardness is checked both with Equotip and Brinell devices.



Brinell hardness profile through 1100mm-thick blocks

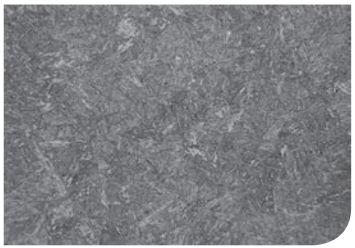
Machining

Machining is the most cost-intensive step in manufacturing moulds. It is therefore of utmost importance to optimize parameters that affect the machining performance: the workpiece material (steel grade), the cutting conditions and the machining operations.

Key factors

Workpiece material

The machinability of a given steel grade depends on its structure homogeneity (segregation), hardness and cleanliness. Superplast® 2738mod is more homogeneous than higher carbon standard grades, and exhibits a more consistent hardness.



Cutting conditions

The cutting tool (material, geometry) and the cutting strategy affect the machining cots and productivity. We have worked with tooling manufacturers to define optimal cutting conditions for Superplast® 2738mod.

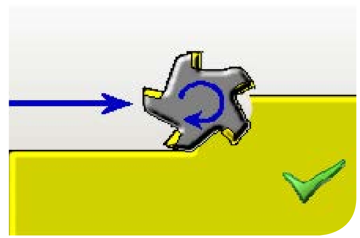
Milling Superplast® 2738mod

Recommendation

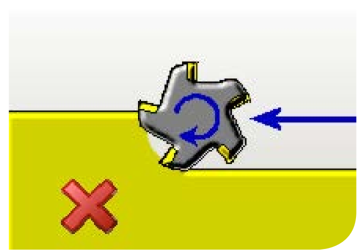
In order to achieve an adequate service life of cutting tools during milling of Superplast® 2738mod, down milling (climb milling) is recommended.

The advantages of climb milling are:

- Longer tool life (less flank wear).
- Better surface finish.
- Easier chip removal.



Climb milling (down milling)



Up milling (opposed milling)

Recommended cutting data for rough milling

Below are recommended cutting speeds and feeds both for conventional and high feed milling of Superplast® 2738mod. These data correspond to the operating range of selected cutting tools.

Dry machining	Grade for coated carbide inserts		Cutting parameters	
	ISO reference	SECO reference	Vc (m/min)	fz (mm/tooth)
Conven-tional	P20 - P30	MP2500	110 - 250	0.12 - 0.3
High feed	P30	MP2500	140 - 300	0.30 - 0.90

Recommendation

Please contact your local cutting tool supplier for full support on the selection of cutting tools and parameters.

Tool life test

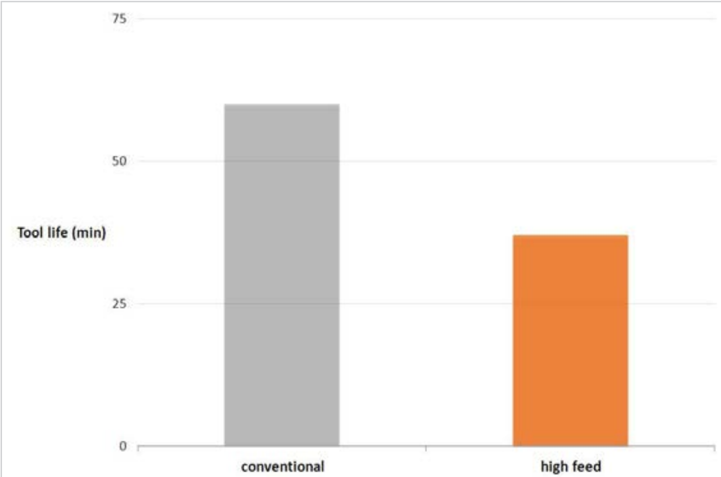
Milling tests were done to determine the cutting tool life using recommended cutting data.

Milling mode	Vc (m/min)	fz (mm)	Ap (mm)	Ae (mm)	Removal rate (cm3/min)
Conven-tional	200	0.2	3	25	79
High feed	300	0.6	0.7	28	140

Conventionnal milling (SECO tools)
cutter : R220.29-0040-06.4A
insert : RPHT 1204MOT-M15

High feed milling (SECO tools)
cutter : R220.21-0040-LP06.6A
insert : LPHW 1204MOT-D06

Tool life chart compares the cutting tool lifetimes achieved depending on the milling mode. The tool life criteria was milling duration to obtain a flank wear of 0.3 mm.



Milling tool life for conventional and high feed milling

Recommendation

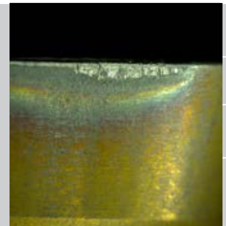
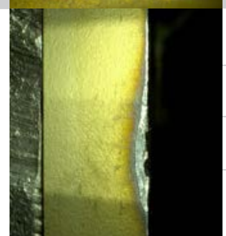
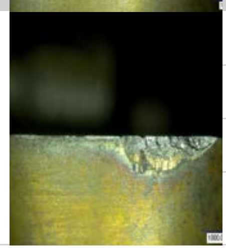
High feed milling is recommended for Superplast® 2738mod when higher productivity (metal removal rate) is required (with lower machining time).

Key characteristics of high feed milling are:

- Small cutting depth (Ap)
- Very high feed rate (fz)
- High cutting speed (Vc)

Troubleshooting

Below are some basic rules to deal with premature tool wear that might occur during milling operations.

Wear mechanism		Action and solutions
Flank wear		Check the tool operating range
		Reduce the cutting speed
		Reduce the feed rate
		Use a harder coated carbide grade
Crater wear		Check the tool operating range
		Reduce the cutting speed
		Reduce the feed rate
		Select an insert grade with alumina oxide Al_2O_3 coating
Cutting edge chipping		Use a tougher coated carbide grade
		Avoid using a coolant
		Check the cutter set-up
Cutting edge build-up		Increase the cutting speed
		Increase the feed rate
		Avoid using a coolant
		Change over to coated carbide grade

Deep hole drilling

Deep hole drilling is the machining of holes with a relatively large depth to diameter ratio. Usually any hole deeper than 5 times the drilled diameter can be considered as a deep hole. Deep-hole drilling systems are:

- Gun-drilling system
- Ejector system
- Single tube system (STS).

The selection of appropriate cutting data may be affected by following factors:

- Chip formation
- Cutting force (machine power)
- Tool life (length)
- Surface finish and tolerance.

Gun-drilling	Ejector drilling	STS drilling
Small diameters (≤ 40 mm)	Diameters ≥ 19 mm	Diameters ≥ 12 mm
Easily applied to machining centers with a pre-drilled hole for guidance.	Easily adapted to existing machines.	Requires special deep hole drilling machine.
Requires high coolant pressure.	Requires less fluid pressure than STS.	First choice for long series production.
		For materials where good chipbreaking is difficult to obtain.

Recommended cutting data for gun drilling

Solid carbide heads	Drill diameter, mm			
	1 – 3	3 – 6	6 – 12	12 – 40
Cutting speed Vc (m/min)	40 – 120			
Feed fn (mm/rev)	0.003-0.010	0.004-0.025	0.010-0.050	0.020-0.100

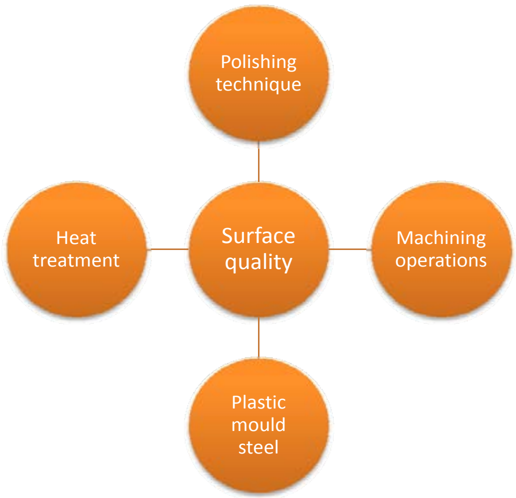
Recommended cutting data for STS / ejector drilling

Ground brazed heads Carbide P20 – P30	Drill diameter, mm			
	16 – 20	20 – 30	30 – 40	40- 60
Cutting speed Vc (m/min)	55 – 100			
Feed fn (mm/rev)	0.14-0.20	0.17-0.25	0.20-0.30	0.24-0.32

Solid drill head with indexable insert (coated carbide P15 – P50)	Drill diameter, mm	
	25 – 40	40 – 60
Cutting speed Vc (m/min)	55 – 110	
Feed fn (mm/rev)	0.10 – 0.40	0.20 – 0.45

Polishing

The condition of the mould cavity surface is crucial to the quality of the final part. It also affects the ease with which the molding can be released.
Whatever the function of polishing (functional or aesthetic), attention should be paid to factors that affect the quality of surface finish : the polishing method, the surface condition and the steel quality.



Key factors

Polishing technique: experience, skill and technique from the polisher are very important in achieving the desired result. Grit material, grit grade and polishing sequences should be carefully selected.

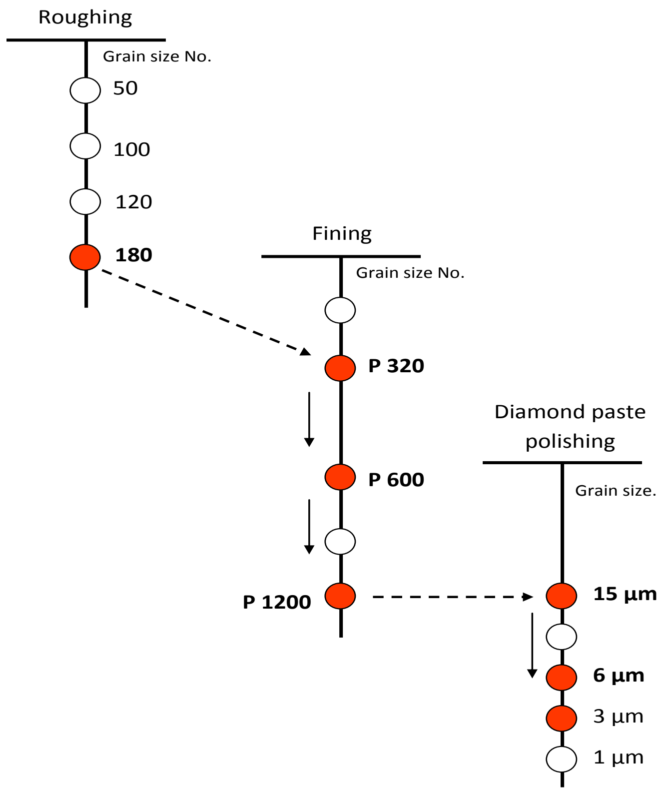
Machining operations prior polishing: sound milling and grinding steps are necessary pre-conditions for a high quality polish. Altered steel structure and hardness caused by local strain hardening will especially make difficult to achieve a good polishing quality.

Plastic mould steel: steel hardness, degree of purity and structure homogeneity affect the surface finishing. Thanks to a reduced segregation level compared to high carbon standard grades (W1.2738, W1.2311), a consistent hardness and a very good cleanliness, Superplast® 2738mod allows very good technical polishing.

Heat treatment: decarburization or recarburization during heat treatment may induce hardness variations, which will affect the polishing result.

Polishing Superplast® 2738mod

We can only do recommendations based on experience with customers and professional polishers.
Following sequences are typically suggested to obtain a good polishing result with Superplast® 2738mod.



Practical tips for polishing

Roughing (Grain size no. 180)

- Select the appropriate grinding wheel to avoid over-heating that may affect steel hardness and structure.
- Carefully clean the workpiece after each application of a compound, before the next compound is applied.
- Change direction during the operation to avoid scratches and unevenness.
- Work with one grain size in one direction, then with the next size in an angle of 45° until the surface does not exhibit anymore traces of the previous direction.

Fining (Grain size 200 - 1200)

- Only clean and unclogged tools should be used.
- Add ample coolant to prevent heating of the surface.
- With each change of grain, workpiece and hands have to be cleaned to prevent larger grains interfering with finer size.
- Pressure should be distributed uniformly. Scratches and cold-deformed layer from the preceding grain size have to be removed before switching to the next size.

Finishing (Diamond paste)

- Clean carefully workpiece and hands.
- Spend more time on the coarse steps before changing to the finer steps.
- Use as short time as possible when polishing with diamond paste.
- Polishing pressure should be adjusted to the hardness of the polishing tool and the grade of the paste.

DIN / ISO 1302	Roughness Ra µm	SPI	Grinding Polishing
N1	0.025	A-1	3 µm Diamond paste
N2	0.05	A-2	6 µm Diamond paste
N3	0.1	A-3	15 µm Diamond paste
N4	0.2	B-1	600 Grit paper
N5	0.4	B-2	400 Grit paper
N6	0.8	B-3	320 Grit paper
N7	1.6	C-1	600 Grit stone
N8	3.2	C-2	400 Grit stone
N9	6.3	C-3	320 Grit stone

Troubleshooting

The main problem caused by overpolishing is orange peel. Orange peel is an irregular texture caused by high polishing pressure during a prolonged time. If this phenomenon is observed during polishing, here are recommended actions:

- Stop polishing (continue to polish worsens orange peel)
- Remove the defective layer using the last grinding step prior to polishing
- Reduce polishing pressure and time

Orange peel on a mould cavity

Recommendation

A steel grade with high and consistent hardness will better withstand a high polishing pressure.

Texturing

Many plastic parts are textured for aesthetic or functional reasons. Among factors that affect the quality of texturing (or graining or etch graining), there is the mould steel quality. Thanks to its homogeneous structure and high cleanliness, Superplast® 2738mod provides reliable texturing.

Key factors

Texturing process: graining quality is affected by the type of etching solutions used (nitric acid, ferric chloride) and their characteristics (pH value, temperature, etc.). Know-how and experience of the engraving company are very important.

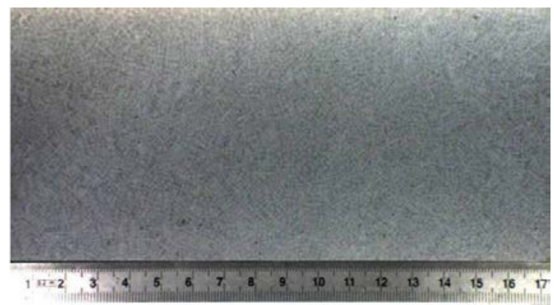
Surface condition: machining operations can modify the steel hardness by strain hardening. Repair welding also leads to microstructure and hardness variations that can impair the texturing quality.

Mould steel quality: segregation (structure heterogeneity) and inclusions (cleanliness) mainly affect the texturing quality. Compared to standard grades, Superplast® 2738mod has a much more homogeneous structure. Its cleanliness is also good, thanks to a vey low sulphur level.

Texturing Superplast® 2738mod

To evaluate the ability of Superplast® 2738mod to provide excellent results whatever the texturing pattern, tests have been done in association with MOLD TECH, a global leading texturing company.

Mold Tech reference	Type of texture	Depth (mm)
MT 9052	Fine	0.035
MT 21339	Geometric	0.150
MT 21339	Geometric	0.260
MT 21340	Leather	0.120



Macrograph of Superplast® 2738mod (acid test)

Fine (top) and leather textured surfaces of Superplast® 2738mod

Geometrical texturing of Superplast® 2738mod

Recommendation

For Mold Tech graining tests, surface finish of specimen was 400 grit paper. This is enough to achieve a good surface quality before starting the etch graining process.

Surface treatment

Main goals of surface treatment processes are:

- To improve the surface quality.
- To increase fatigue and wear resistance.
- To increase corrosion resistance.

Superplast® 2738mod is suitable for most surface treatment processes. Good results are especially achieved with laser hardening, chrome plating or nitriding.

Key factors

As there are many surface treatments, key factors that affect the surface treatment result will depend on each process. Surface hardness and case depth are common qualifying factors for all surface treatment processes.

Nitriding

Description

Nitriding is a thermochemical process used to enrich the surface layer of the workpiece with nitrogen. Steel absorbs nitrogen from the surrounding medium, at temperatures between 350 and 580°C.

Advantages of nitriding are:

- Nitrided parts yield extremely hard and wear-resistant layer
- Nitrided parts are free from distortion (treatment temperatures do not cause thermal microstructure transformations)
- The corrosion resistance of low alloy steels is increased, with good polishability
- Nitrided moulds are suitable for processing thermosets and such thermoplastics that are shaped at high mold temperatures.

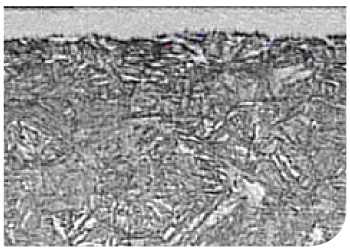
Recommendation

Alloying elements that are favorable to nitriding are chromium, aluminium and molybdenum. Thus the chemical composition of Superplast® 2738mod is perfectly adapted to nitriding process.

Nitriding Superplast® 2738mod

Gas and plasma nitriding are the main processes in plastic mouldmaking.

	Process parameters		Surface hardness	Diffusion zone	White layer
Nitriding	Tempe-rature	Time			
Gas	520°C	25 h.	814 HV10	0.38 mm	10 µm
Plasma	520°C	15 h.	861 HV10	0.32 mm	10 µm



Typical micrograph of a gas nitriding layer

Recommendation

To avoid softening of base metal, nitriding temperatures for Superplast® 2738mod should not exceed 520°C.

Hard chrome plating

Description

Hard chrome plating consists in electrolytically deposited layers of chromium in order to increase the surface hardness. Common thicknesses lie between 5 and 200 µm.

Benefits of hard chrome plating moulds are:

- Hard and wear-resistant layer
- High corrosion resistance
- Low coefficient of friction

Typical sequence of hard chrome plating

Visual examination (roughness Ra ≤ 0.2 µm)
Cleaning (chemical or electrochemical)
Air drying
Chrome plating
Water rinsing
Air drying
Polishing (if necessary)

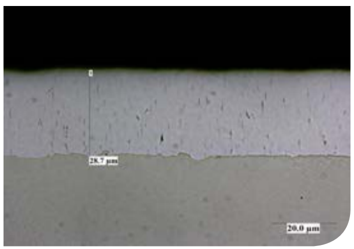
Hard chrome plating Superplast® 2738mod

Preparatory work
The surface to be chromium plated must be free of contaminants or grease from previous operations (machining).
Chemical or electrochemical cleaning can be done to remove grease.
A surface roughness Ra of 0.8 µm or less is recommended (Ra below 0.2 µm is even better).

Chromium plating bath

Following parameters are usually used for chromium plating of Superplast® 2738mod:

- Voltage: 6 – 8 V
- Current density: 20 – 50 A.dm^{-2}
- Bath temperature: 40 – 60°C
- Bath composition: chromic acid and sulfuric acid



Micrograph of hard chrome plated layer (hardness: 970 HV0.1 Kgf)

Recommendation

An amount of hydrogen can be absorbed during hard chrome plating, with detrimental effects. Degassing treatment is a non-mandatory option (450°C - 2 hours).

Induction hardening

Description

Induction hardening creates a hardened layer at the surface of the steel mould while maintaining an unaffected core microstructure. Parts to be treated are heated above the steel transformation range followed by immediate quenching.

Benefits of induction hardening are:

- A deep high surface hardness
- Increased wear resistance
- Increased fatigue strength
- No distortion of hardened parts

Hardening Superplast® 2738mod

Bars made of Superplast® 2738mod have been hardened by induction in order to determine the surface hardness achievable with this process.

Surface hardness	Case depth
52.7 – 53.6 HRC	2.87 mm

Recommendation

Tempering at low temperatures should be done following induction hardening in order to achieve the required hardness and for stress relieving (see tempering chart).

Laser hardening

Laser hardening is an impulse hardening using a high-energy laser as the heat source. Surface hardness levels achieved are similar to values obtained by induction hardening.

Benefits of laser hardening are:

- High surface hardness
- Increased wear resistance
- No distortion of hardened parts
- Minimal risk of crack
- Excellent accuracy and reproducibility

Recommendation

A surface finish of level N7 or finer is sometimes required on the surface to be laser hardened.

	Flame hardening	**Induction hardening**	**Laser hardening**
Case depth	max. 40 mm	max. 10 mm	max 1.5 mm
Reproducibility	good	very good	excellent
Dimensional stability	good	good	very good
Danger of cracking	high	low	very low
Polishing after treatment	usually required	usually required	usually unnecessary
Accuracy of heat source	medium	good	high

Welding

Welding is usually carried out on plastic moulds for maintenance (repair of worn parts) or original mouldmaking issues (repair of machining defects for example).
Therefore weldability of mould steels plays an important role. Thanks to its lower carbon content compared to high carbon grades (W1.2311, W1.2738), Superplast® 2738mod is optimized for welding.

The welding section provides key data to achieve good results following GTAW (TIG) welding of Superplast® 2738mod, especially when there are some demanding surface finish operations (polishing or texturing).

Key factors

Preparatory work

- Prepare the surface appropriately before welding. It must be clean and free of oxides, grease or oil residue.
- Remove any coatings (nitriding or chrome plating zones) by grinding or deplating.
- Cracks must be ground open to form a U-shaped cross section.

Welding procedure

- Preheat the mould before welding in order to minimise risk of stress cracks and to counteract increased hardening.
- Follow the preheating instruction for Superplast® 2738mod as the preheat temperature is specific to each steel grade.
- After welding cool the mould down, preferably covered.
- Carry out a post-weld heat treatment (PWHT) for stress relieving and hardness homogeneization.

Welding consumables

- Use a filler material with a similar chemical composition to the parent metal (and lower carbon content). It ensures uniform hardness and good surface quality.
- Use an electrode with as small diameter as possible for the work.

Welding gas

In GTAW process, the primary role of gas is to protect from the atmosphere:
- the molten pool
- the electrode
- the end of the filler material
- the heat affected zone (HAZ).

Gas has also an influence on:
- the arc heat input
- the welding speed
- the penetration depth and shape
- the surface finish.

Gases that can be used for welding of Superplast® 2738mod with GTAW are:
- Argon: versatile gas (GTAW of all types of metal alloys), and base constituent of welding gas mixtures
- Helium: increases the penetration depth and the welding speed, reduces ozone fumes.

Welding Superplast® 2738mod

Welding for polished and textured cavities

Process	Filler material	Preheating	Post-heating	PWHT
GTAW	SP300Weld-E	325°C	325°C-2h	550°C

Recommendation

The use of lower carbon rods (like SP300Weld-E) as filler material will guarantee the best result for polishing and etching following welding.
Another alternative filler material is DIN 25 CrMo 4 (F66S).

Welding without specific surface requirements

Filler material
The use of filler material suitable for the welding of high strength steels is recommended when there are no specific surface finish requirements.

Welding process	Suitable welding fillers by brand		
	Oerlikon	SAF	Thyssen
GTAW	OE-Ni 38 R	NERTAL 60	UNION I 1.2 Ni
SMAW	TENACITO 65	SAFDRY MD56	SH Schwartz 3KNi

Welding procedure

Process	Preheating	Post-heating	PWHT
GTAW	150°C	150°C-2h	550°C (not mandatory)
SMAW	150°C	150°C-2h	550°C (not mandatory)

Troubleshooting

Welding carbon steels can lead to cracks just after welding or a few hours later. Parameters that could lead to cold cracking are:

- Presence of hydrogen
- Heat affected zone (H.A.Z.)
- High residual stresses.

Following recommendations aim at reducing the risk of cold cracking during welding.

Parameters	Factors	Actions
Hydrogen	Process	Use a low hydrogen process (GTAW)
	Filler material	Dry the filler material
	Surface condition	Remove grease and other deposits before welding
Heat affected zone	Heat input	Follow preheating instructions
		Follow postheating instructions
	Base material	Use a base material with enhanced weldability
Residual stresses	Design	Decrease the notch effects
	Process	Use correct sequences
	Filler material	Use the appropriate filler material

Heat treatment

Superplast® 2738mod is delivered ready-for-use (quenched and tempered). As heat treatment may affect the steel characteristics, respect of basic rules is highly recommended.

Key factors

Efficient monitoring of the heat treatment with workload thermocouples at precisely preset locations.

Gradual heating to the required treatment temperature not to allow temperautre gradient within the workpiece.

Adequate soaking time to ensure homogeneous temperature distribution through the workpiece

Control cooling from the treatment temperature to room temperature.

Stress relieving

Sometimes some stresses may be put in the workpiece during machining (like rough machining with significant material removal). If stress relieving has to be carried out on Superplast® 2738mod, the temperature should be 30°C below the last tempering temperature so as to avoid a reduction in hardness.

Hardening

Heating: heat slowly the workpiece to the required hardening temperature to avoid temperature gradient (thermal stresses).

Austenitising: once the workpiece surface has reached the hardening temperature, a soaking time should be applied in order to obtain a homogeneous temperature distribution throughout the section. Avoid excessive soaking times that may increase the steel grain size (which deteriorates mechanical properties).

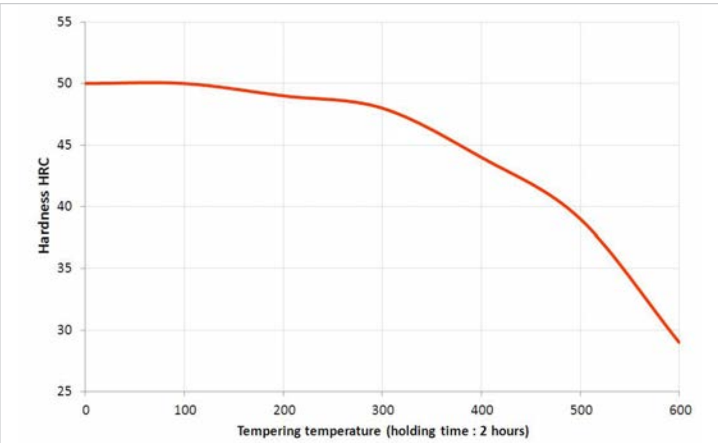
Quenching: following austenitisation cool the workpiece in the appropriate cooling medium. As cooling induces thermal stresses, the speed of cooling should not be higher than necessary. For Superplast® 2738mod, when parts are cooled to 100°C, they should be directly transferred into a furnace at a temperature of 100 - 150°C. This prevents possible quench cracks to develop.

Tempering

The specified hardness is usually achieved by a tempering treatment. The appropriate tempering temperature can be estimated from the tempering chart.
Heating to the tempering temperature should take place slowly. The usual soaking time is 1 hour for every 25 mm wall thickness, with a minimum of 2 hours.

Heat treating Superplast® 2738mod

	Temperature	Soaking time	Cooling
Stress relieving	525°C	1 hour per 25mm	Furnace
Hardening	900°C	30 min. per 25mm	Oil, vacuum, polymer
Tempering	see chart	1 hour per 25 mm	Air



Recommendation

The tempering chart has been designed with samples of section 50 mm x 50 mm. Please consult our technical team for further assistance on heat treatment.

General Information

Product definition

Superplast® 2738mod HH is a mould steel designed by Industeel ArcelorMittal. Compared to standard grades (W1.2311, W1.2738), Superplast® 2738mod HH provides following benefits:

- Excellent through-hardening (uniform hardness)
- Consistent texturing (random and geometric)
- Consistent polishing (very low sulphur content)
- Reliable repair welding

Some applications of Superplast® 2738mod HH are:

- Plastic injection mould cores and cavities
- Large-size moulds for bumpers, dashboards, fenders, etc.
- Injection moulding, compression moulding, RIM moulding.

Chemical analysis (typical in weigth %)

C	S*	Ni	Cr	Mo	V	B
0.26	0.002	0.30	1.70	0.52	0.05	added

*** max : 0.007**

Cleanliness (ASTM E45)

	A	B	C	D
Thin	1.5	2.0	1.0	1.5
Heavy	1.0	1.0	0.5	1.0

A: sulphides | B: alumina | C: silicates | D: globular oxides

Product properties

Mechanical properties

Superplast® 2738mod HH is delivered quenched and tempered to 330 - 360 Brinell (HBW). Following data are provided for testing at quarter-thickness of a 400mm-thick block.

Hardness	Yield strength	Tensile strength	Elongation	Reduction of area
HBW	N/mm²	N/mm²	%	%
345	940	1100	15	55

Physical properties

Thanks to an original chemistry, Superplast® 2738mod HH has superior thermal characteristics. Thermal conductivity of Superplast® 2738mod HH is 15% higher than values for standard grades (W1.2738 HH).

	25°C	100°C	200°C	300°C
Thermal expansion (10^{-6}/K)	-	11.0	12.6	13.1
Thermal conductivity (W/m/K)	40.0	39.0	38.0	36.0
Specific heat (J/Kg/K)	470	500	530	570
Yound modulus (kN/mm²)	205			

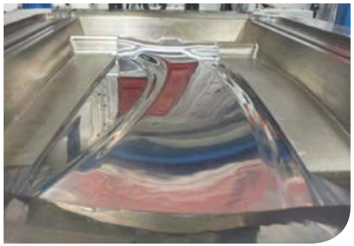
Hardness control

Wear resistance is usually proportional with hardness. In addition high and consistent hardness is especially important to avoid wear on parting lines.
Superplast® 2738mod HH provides very consistent hardness.

Key factors

Surface preparation

All hardness test methods require smooth surfaces free of rust, oil, paint or protective coatings. Adequate surface finish depends on the test method.



Gage repeatability and reproducibility

Prior to hardness testing, check the testing device using a reference block. Periodic maintenance checks of the testing device are also recommended.

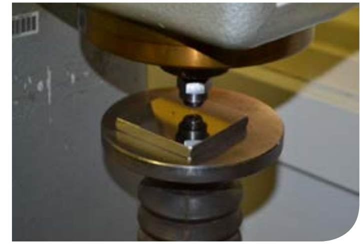
Hardness scales

It is common to test in one scale and report in another scale. Although conversion charts have some validity, established conversions may or may not always provide reliable information (see conversion charts in appendix).

Popular hardness test methods

Brinell hardness testing (ISO 6506)

It measures the permanent width of indentation produced by a carbide indenter applied to a test specimen at a given load. Plates of Superplast® 2738mod HH are usually controlled by means carbide indenters.



Diameter of indenter	Load	Plate thickness	Equipment
ϕ 5 mm	750 Kgf	≤ 5 mm	Brinella
ϕ 10 mm	3000 Kgf	> 5 mm	Brinella

Recommendation

The greatest source of error in Brinell testing is the measurement of the indentation. To ensure a reliable indentation reading, grind the surface with following grinding depths:

- 0.2 mm for plate thickness ≤ 5 mm
- 0.5 mm for plate thickness 5 - 40 mm
- 1 mm for plate thickness 40 - 80 mm
- 2 mm for plate thickness > 80 mm.

Grinding can be done with grit size 60 (or equivalent), followed by polishing (320 Grit paper).

Rockwell hardness testing (ISO 6508 / ASTM E-18)

It measures the permanent depth of indentation produced by a (diamond) indenter. Superplast® 2738mod HH is controlled at our R&D centre with a conical indenter and a load of 150 Kgf (HRC).

Recommendation

It is important to keep the specimen surface finish clean and decarburization from heat treatment should be removed.
Surface preparation for Rockwell test usually requires a polishing finish finer than grit paper 600 (SPI B-1).

Rebound hardness test (DIN 50156)

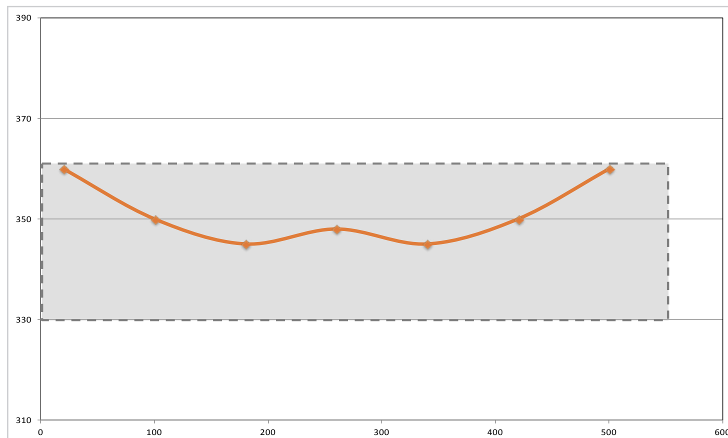
Most commonly worldwide portable testers are based on the rebound technique. The device measures the Leeb hardness (HL). Superplast® 2738mod HH is controlled by the latest generation of portable testers EQUOTIP 3 (HLD or HLG).

Recommendation

Our plates are usually controlled by means of Equotip HLG for thickness ≥ 40 mm. Surface preparation is similar to the one done for Brinell control.
You should never perform an average of hardness values measured in Brinell and values in HLG converted in Brinell.

Benefits of Superplast® 2738mod HH

- Thanks to an optimal balance of alloying content and high quality heat treatment, Superplast® 2738mod HH exhibits a very consistent hardness, even through large sections of blocks.
- Plates and blocks made of Superplast® 2738mod HH are carefully controlled by mill quality teams to ensure uniform hardness in accordance with customer's specification. Hardness is checked both with Equotip and Brinell devices.



Brinell hardness profile through 540mm-thick block

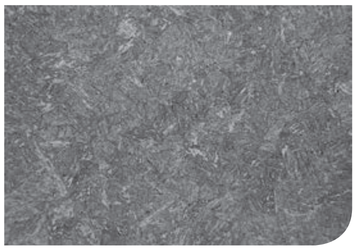
Machining

Machining is the most cost-intensive step in manufacturing moulds. It is therefore of utmost importance to optimize parameters that affect the machining performance: the workpiece material (steel grade), the cutting conditions and the machining operations.

Key factors

Workpiece material

The machinability of a given steel grade depends on its structure homogeneity (segregation), hardness and cleanliness. Superplast® 2738mod HH is more homogeneous than higher carbon standard grades, and exhibits a more consistent hardness.



Cutting conditions

The cutting tool (material, geometry) and the cutting strategy affect the machining cots and productivity. We have worked with tooling manufacturers to define optimal cutting conditions for Superplast® 2738mod HH.

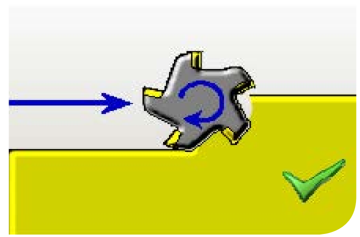
Milling Superplast® 2738mod HH

Recommendation

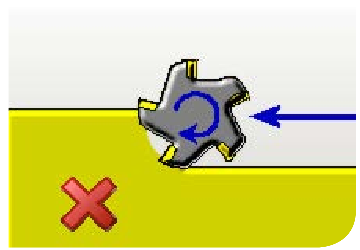
In order to achieve an adequate service life of cutting tools during milling of Superplast® 2738mod HH, down milling (climb milling) is recommended.

The advantages of climb milling are:

- Longer tool life (less flank wear).
- Better surface finish.
- Easier chip removal.



Climb milling (down milling)



Up milling (opposed milling)

Recommended cutting data for rough milling

Below are recommended cutting speeds and feeds both for conventional and high feed milling of Superplast® 2738mod. HH These data correspond to the operating range of selected cutting tools.

Dry machining	Grade for coated carbide inserts		Cutting parameters	
	ISO reference	SECO reference	Vc (m/min)	fz (mm/tooth)
Conven-tional	P20 - P30	MP2500	110 - 250	0.12 - 0.30
High feed	P30	MP2500	200 - 300	0.40- 0.90

Recommendation

Please contact your local cutting tool supplier for full support on the selection of cutting tools and parameters.

Tool life test

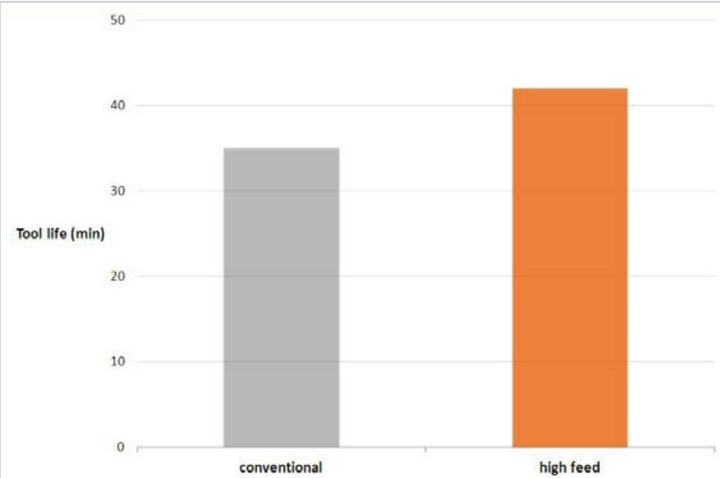
Milling tests were done to determine the cutting tool life using recommended cutting data.

Milling mode	Vc (m/min)	fz (mm)	Ap (mm)	Ae (mm)	Removal rate (cm3/min)
Conven-tional	200	0.2	3	20	73
High feed	300	0.6	0.6	25	81

Conventionnal milling (SECO tools)
cutter : R220.29-0040-06.4A
insert : RPHT 1204MOT-M15

High feed milling (SECO tools)
cutter : R220.21-0040-LP06.6A
insert : LPHW 1204MOT-D06

Tool life chart compares the cutting tool lifetimes achieved depending on the milling mode. The tool life criteria was milling duration to obtain a flank wear of 0.3 mm.



Milling tool life for conventional and high feed milling

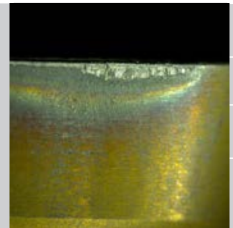
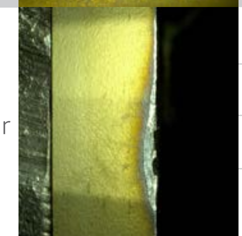
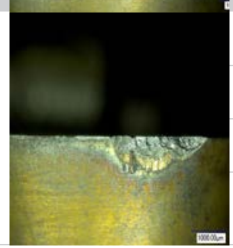
Recommendation

High feed milling is recommended for Superplast® 2738mod HH as it increases both metal removal rate and tool life.
Key characteristics of high feed milling are:

- Small cutting depth (Ap)
- Very high feed rate (fz)
- High cutting speed (Vc)

Troubleshooting

Below are some basic rules to deal with premature tool wear that might occur during milling operations.

Wear mechanism		Action and solutions
Flank wear		Check the tool operating range
		Reduce the cutting speed
		Reduce the feed rate
		Use a harder coated carbide grade
Crater wear		Check the tool operating range
		Reduce the cutting speed
		Reduce the feed rate
		Select an insert grade with alumina oxide Al2O3 coating
Cutting edge chipping		Use a tougher coated carbide grade
		Avoid using a coolant
		Check the cutter set-up
Cutting edge build-up		Increase the cutting speed
		Increase the feed rate
		Avoid using a coolant
		Change over to coated carbide grade

Deep hole drilling

Deep hole drilling is the machining of holes with a relatively large depth to diameter ratio. Usually any hole deeper than 5 times the drilled diameter can be considered as a deep hole. Deep-hole drilling systems are:

- Gun-drilling system
- Ejector system
- Single tube system (STS).

The selection of appropriate cutting data may be affected by following factors:

- Chip formation
- Cutting force (machine power)
- Tool life (length)
- Surface finish and tolerance.

Gun-drilling	Ejector drilling	STS drilling
Small diameters (≤ 40 mm)	Diameters ≥ 19 mm	Diameters ≥ 12 mm
Easily applied to machining centers with a pre-drilled hole for guidance.	Easily adapted to existing machines.	Requires special deep hole drilling machine.
Requires high coolant pressure.	Requires less fluid pressure than STS.	First choice for long series production.
		For materials where good chipbreaking is difficult to obtain.

Recommended cutting data for gun drilling

Solid carbide heads	Drill diameter, mm			
	1 - 3	3 - 6	6 - 12	12 - 40
Cutting speed Vc (m/min)	40 - 120			
Feed fn (mm/rev)	0.003-0.010	0.004-0.025	0.010-0.050	0.020-0.100

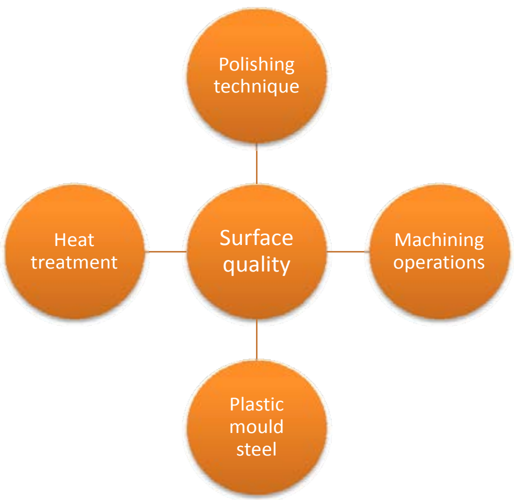
Recommended cutting data for STS / ejector drilling

Ground brazed heads Carbide P20 - P30	Drill diameter, mm			
	16 - 20	20 - 30	30 - 40	40- 60
Cutting speed Vc (m/min)	55 - 100			
Feed fn (mm/rev)	0.14-0.20	0.17-0.25	0.20-0.30	0.24-0.32

Solid drill head with indexable insert (coated carbide P15 - P50)	Drill diameter, mm	
	25 - 40	40 - 60
Cutting speed Vc (m/min)	55 - 110	
Feed fn (mm/rev)	0.10 - 0.40	0.20 - 0.45

Polishing

The condition of the mould cavity surface is crucial to the quality of the final part. It also affects the ease with which the molding can be released.
Whatever the function of polishing (functional or aesthetic), attention should be paid to factors that affect the quality of surface finish : the polishing method, the surface condition and the steel quality.



Key factors

Polishing technique: experience, skill and technique from the polisher are very important in achieving the desired result. Grit material, grit grade and polishing sequences should be carefully selected.

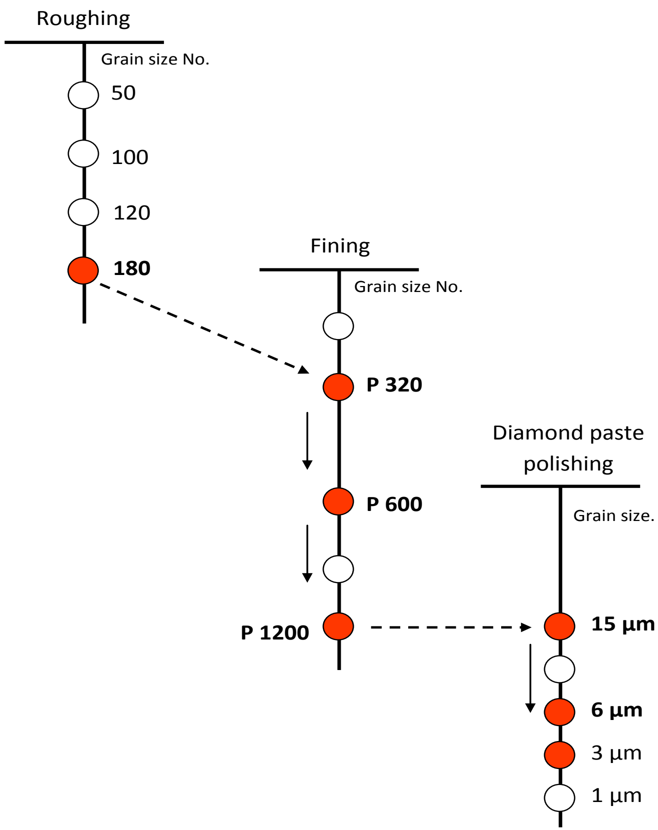
Machining operations prior polishing: sound milling and grinding steps are necessary pre-conditions for a high quality polish. Altered steel structure and hardness caused by local strain hardening will especially make difficult to achieve a good polishing quality.

Plastic mould steel: steel hardness, degree of purity and structure homogeneity affect the surface finishing. Thanks to a reduced segregation level compared to high carbon standard grades (W1.2738 HH), a consistent hardness and a very good cleanliness, Superplast® 2738mod HH allows very good technical polishing.

Heat treatment: decarburization or recarburization during heat treatment may induce hardness variations, which will affect the polishing result.

Polishing Superplast® 2738mod HH

We can only do recommendations based on experience with customers and professional polishers.
Following sequences are typically suggested to obtain a good polishing result with Superplast® 2738mod HH.



Practical tips for polishing

<u>Roughing (Grain size no. 180)</u>

- Select the appropriate grinding wheel to avoid over-heating that may affect steel hardness and structure.
- Carefully clean the workpiece after each application of a compound, before the next compound is applied.
- Change direction during the operation to avoid scratches and unevenness.
- Work with one grain size in one direction, then with the next size in an angle of 45° until the surface does not exhibit anymore traces of the previous direction.

<u>Fining (Grain size 200 – 1200)</u>

- Only clean and unclogged tools should be used.
- Add ample coolant to prevent heating of the surface.
- With each change of grain, workpiece and hands have to be cleaned to prevent larger grains interfering with finer size.
- Pressure should be distributed uniformly. Scratches and cold-deformed layer from the preceding grain size have to be removed before switching to the next size.

Finishing (Diamond paste)

- Clean carefully workpiece and hands.
- Spend more time on the coarse steps before changing to the finer steps.
- Use as short time as possible when polishing with diamond paste.
- Polishing pressure should be adjusted to the hardness of the polishing tool and the grade of the paste.

DIN / ISO 1302	Roughness Ra µm	SPI	Grinding Polishing
N1	0.025	A-1	3 µm Diamond paste
N2	0.05	A-2	6 µm Diamond paste
N3	0.1	A-3	15 µm Diamond paste
N4	0.2	B-1	600 Grit paper
N5	0.4	B-2	400 Grit paper
N6	0.8	B-3	320 Grit paper
N7	1.6	C-1	600 Grit stone
N8	3.2	C-2	400 Grit stone
N9	6.3	C-3	320 Grit stone

Troubleshooting

The main problem caused by overpolishing is orange peel. Orange peel is an irregular texture caused by high polishing pressure during a prolonged time. If this phenomenon is observed during polishing, here are recommended actions:

- Stop polishing (continue to polish worsens orange peel)
- Remove the defective layer using the last grinding step prior to polishing
- Reduce polishing pressure and time

Orange peel on a mould cavity

Recommendation

A steel grade with high and consistent hardness will better withstand a high polishing pressure.

Texturing

Many plastic parts are textured for aesthetic or functional reasons. Among factors that affect the quality of texturing (or graining or etch graining), there is the mould steel quality. Thanks to its homogeneous structure and high cleanliness, Superplast® 2738mod HH provides reliable texturing performance.

Key factors

Texturing process: graining quality is affected by the type of etching solutions used (nitric acid, ferric chloride) and their characteristics (pH value, temperature, etc.). Know-how and experience of the engraving company are very important.

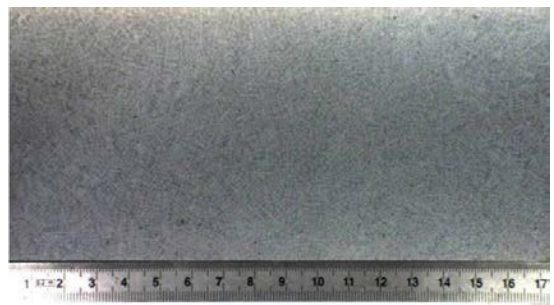
Surface condition: machining operations can modify the steel hardness by strain hardening. Repair welding also leads to microstructure and hardness variations that can impair the texturing quality.

Mould steel quality: segregation (structure heterogeneity) and inclusions (cleanliness) mainly affect the texturing quality. Compared to standard grades, Superplast® 2738mod HH has a much more homogeneous structure. Its cleanliness is also good, thanks to a vey low sulphur level.

Texturing Superplast® 2738mod HH

To evaluate the ability of Superplast® 2738mod HH to provide excellent results whatever the texturing pattern, tests have been done in association with MOLD TECH, a global leading texturing company.

Mold Tech reference	Type of texture	Depth (mm)
MT 9052	Fine	0.035
MT 21339	Geometric	0.150
MT 21339	Geometric	0.260
MT 21340	Leather	0.120



Macrograph of Superplast® 2738mod HH (acid test)

Fine (top) and leather textured surfaces of Superplast® 2738mod HH

Geometrical texturing of Superplast® 2738mod HH

Recommendation

For *Mold Tech* graining tests, surface finish of specimen was 400 grit paper. This is enough to achieve a good surface quality before starting the etch graining process.

Surface treatment

Main goals of surface treatment processes are:

- To improve the surface quality.
- To increase fatigue and wear resistance.
- To increase corrosion resistance.

Superplast® 2738mod HH is suitable for most surface treatment processes. Good results are especially achieved with laser hardening, chrome plating or nitriding.

Key factors

As there are many surface treatments, key factors that affect the surface treatment result will depend on each process. Surface hardness and case depth are common qualifying factors for all surface treatment processes.

Nitriding

Description

Nitriding is a thermochemical process used to enrich the surface layer of the workpiece with nitrogen. Steel absorbs nitrogen from the surrounding medium, at temperatures between 350 and 580°C.

Advantages of nitriding are:

- Nitrided parts yield extremely hard and wear-resistant layer
- Nitrided parts are free from distortion (treatment temperatures do not cause thermal microstructure transformations)
- The corrosion resistance of low alloy steels is increased, with good polishability
- Nitrided moulds are suitable for processing thermosets and such thermoplastics that are shaped at high mold temperatures (glass fibre resins for example).

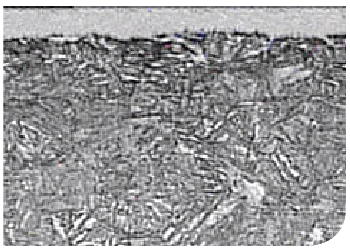
Recommendation

Alloying elements that are favorable to nitriding are chromium, aluminium and molybdenum. Thus the chemical composition of Superplast® 2738mod HH is perfectly adapted to nitriding process.

Nitriding Superplast® 2738mod HH

Gas and plasma nitriding are the main processes in plastic mouldmaking.

	Process parameters		Surface hardness	Diffusion zone	White layer
Nitriding	Tempe-rature	Time			
Gas	520°C	25 h.	814 HV10	0.36 mm	10 µm
Plasma	520°C	15 h.	861 HV10	0.32 mm	10 µm



Typical micrograph of a gas nitriding layer

Recommendation

To avoid softening of base metal, nitriding temperatures for Superplast® 2738mod HH should not exceed 530°C.

Hard chrome plating

Description

Hard chrome plating consists in electrolytically deposited layers of chromium in order to increase the surface hardness. Common thicknesses lie between 5 and 30 µm.

Benefits of hard chrome plating moulds are:
- Hard and wear-resistant layer
- High corrosion resistance
- Low coefficient of friction

Typical sequence of hard chrome plating

Visual examination (roughness Ra ≤ 0.2 µm)
Cleaning (chemical or electrochemical)
Air drying
Chrome plating
Water rinsing
Air drying
Polishing (if necessary)

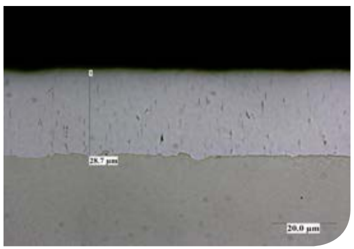
Hard chrome plating Superplast® 2738mod HH

Preparatory work
The surface to be chromium plated must be free of contaminants or grease from previous operations (machining).
Chemical or electrochemical cleaning can be done to remove grease.
A surface roughness Ra of 0.8 µm or less is recommended (Ra below 0.2 µm is even better).

Chromium plating bath

Following parameters are usually used for chromium plating of Superplast® 2738mod HH:

- Voltage: 6 – 8 V
- Current density: 20 – 50 A.dm^{-2}
- Bath temperature: 40 – 60°C
- Bath composition: chromic acid and sulfuric acid



Micrograph of hard chrome plated layer (hardness: 970 HV0.1 Kgf)

Recommendation

An amount of hydrogen can be absorbed during hard chrome plating, with detrimental effects. Degassing treatment is a non-mandatory option (450°C - 2 hours).

Induction hardening

Description

Induction hardening creates a hardened layer at the surface of the steel mould while maintaining an unaffected core microstructure. Parts to be treated are heated above the steel transformation range followed by immediate quenching.

Benefits of induction hardening are:

- A deep high surface hardness
- Increased wear resistance
- Increased fatigue strength
- No distortion of hardened parts

Hardening Superplast® 2738mod HH

Bars made of Superplast® 2738mod have been hardened by induction in order to determine the surface hardness achievable with this process.

Surface hardness	Case depth
52.7 – 53.6 HRC	3.30 mm

Recommendation

Tempering at low temperatures should be done following induction hardening in order to achieve the required hardness and for stress relieving.

Laser hardening

Laser hardening is an impulse hardening using a high-energy laser as the heat source. Surface hardness levels achieved are similar to values obtained by induction hardening.

Benefits of laser hardening are:

- High surface hardness
- Increased wear resistance
- No distortion of hardened parts
- Minimal risk of crack
- Excellent accuracy and reproducibility

Recommendation

A surface finish of level N7 or finer is sometimes required on the surface to be laser hardened.

	Flame hardening	Induction hardening	Laser hardening
Case depth	max. 40 mm	max. 10 mm	max 1.5 mm
Reproducibility	good	very good	excellent
Dimensional stability	good	good	very good
Danger of cracking	high	low	very low
Polishing after treatment	usually required	usually required	usually unnecessary
Accuracy of heat source	medium	good	high

Welding

Welding is usually carried out on plastic moulds for maintenance (repair of worn parts) or original mouldmaking issues (repair of machining defects for example).
Therefore weldability of mould steels plays an important role. Thanks to its lower carbon content compared to high carbon grades (W1.2311, W1.2738), Superplast® 2738mod HH is optimized for welding.

The welding section provides key data to achieve good results following GTAW (TIG) welding of Superplast® 2738mod HH, especially when there are some demanding surface finish operations (polishing or texturing).

Key factors

Preparatory work

- Prepare the surface appropriately before welding. It must be clean and free of oxides, grease or oil residue.
- Remove any coatings (nitriding or chrome plating zones) by grinding or deplating.
- Cracks must be ground open to form a U-shaped cross section.

Welding procedure

- Preheat the mould before welding in order to minimise risk of stress cracks and to counteract increased hardening.
- Follow the preheating instruction for Superplast® 2738mod HH as the preheat temperature is specific to each steel grade.
- After welding cool the mould down, preferably covered.
- Carry out a post-weld heat treatment (PWHT) for stress relieving and hardness homogeneization.

Welding consumables

- Use a filler material with a similar chemical composition to the parent metal (and lower carbon content). It ensures uniform hardness and good surface quality.
- Use an electrode with as small diameter as possible for the work.

Welding gas

In GTAW process, the primary role of gas is to protect from the atmosphere:

- the molten pool
- the electrode
- the end of the filler material
- the heat affected zone (HAZ).

Gas has also an influence on:

- the arc heat input
- the welding speed
- the penetration depth and shape
- the surface finish.

Gases that can be used for welding of Superplast® 2738mod HH with GTAW are:

- Argon: versatile gas (GTAW of all types of metal alloys), and base constituent of welding gas mixtures
- Helium: increases the penetration depth and the welding speed, reduces ozone fumes.

Welding Superplast® 2738mod HH

Welding for polished and textured cavities

Process	Filler material	Preheating	Post-heating	PWHT
GTAW	SP300Weld-E	325°C	325°C-2h	550°C

Recommendation

The use of lower carbon rods (like SP300Weld-E) as filler material will guarantee the best result for polishing and etching following welding.
Another alternative filler material is DIN 25 CrMo 4 (F66S).

Welding without specific surface requirements

Filler material
The use of filler material suitable for the welding of high strength steels is recommended when there are no specific surface finish requirements.

Welding process	Suitable welding fillers by brand		
	Oerlikon	SAF	Thyssen
GTAW	OE-Ni 38 R	NERTAL 60	UNION I 1.2 Ni
SMAW	TENACITO 65	SAFDRY MD56	SH Schwartz 3KNi

Welding procedure

Process	Preheating	Post-heating	PWHT
GTAW	150°C	150°C-2h	550°C (not mandatory)
SMAW	150°C	150°C-2h	550°C (not mandatory)

Troubleshooting

Welding carbon steels can lead to cracks just after welding or a few hours later. Parameters that could lead to cold cracking are:

- Presence of hydrogen
- Heat affected zone (H.A.Z.)
- High residual stresses.

Following recommendations aim at reducing the risk of cold cracking during welding.

Parameters	Factors	Actions
Hydrogen	Process	Use a low hydrogen process (GTAW)
	Filler material	Dry the filler material
	Surface condition	Remove grease and other deposits before welding
Heat affected zone	Heat input	Follow preheating instructions
		Follow postheating instructions
	Base material	Use a base material with enhanced weldability
Residual stresses	Design	Decrease the notch effects
	Process	Use correct sequences
	Filler material	Use the appropriate filler material

Heat treatment

Superplast® 2738mod HH is delivered ready-for-use (quenched and tempered). As heat treatment may affect the steel characteristics, respect of basic rules is highly recommended.

Stress relieving

Sometimes some stresses may be put in the workpiece during machining (like rough machining with significant material removal). If stress relieving has to be carried out on Superplast® 2738mod HH, the temperature should be 30°C below the last tempering temperature so as to avoid a reduction in hardness.

Hardening

Heating: heat slowly the workpiece to the required hardening temperature to avoid temperature gradient (thermal stresses).

Austenitising: once the workpiece surface has reached the hardening temperature, a soaking time should be applied in order to obtain a homogeneous temperature distribution throughout the section. Avoid excessive soaking times that may increase the steel grain size (which deteriorates mechanical properties).

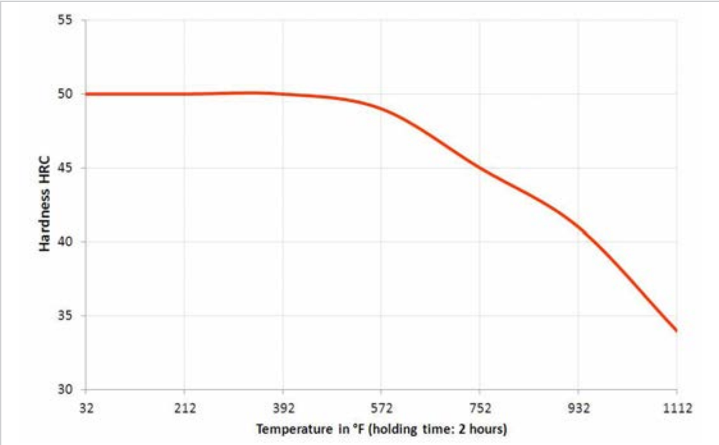
Quenching: following austenitisation cool the workpiece in the appropriate cooling medium. As cooling induces thermal stresses, the speed of cooling should not be higher than necessary. For Superplast® 2738mod HH, when parts are cooled to 100°C, they should be directly transferred into a furnace at a temperature of 100 - 150°C. This prevents possible quench cracks to develop.

Tempering

The specified hardness is usually achieved by a tempering treatment. The appropriate tempering temperature can be estimated from the tempering chart.
Heating to the tempering temperature should take place slowly. The usual soaking time is 1 hour for every 25 mm wall thickness, with a minimum of 2 hours.

Heat treating Superplast® 2738mod HH

	Temperature	Soaking time	Cooling
Stress relieving	525°C	1 hour per 25mm	Furnace
Hardening	900°C	30 min. per 25mm	Oil, vacuum, polymer
Tempering	see chart	1 hour per 25 mm	Air



Recommendation

The tempering chart has been designed with samples of section 50 mm x 50 mm. Please consult our technical team for further assistance on heat treatment.

General Information

Product definition

Superplast® 400 is a mould steel designed by Industeel ArcelorMittal. Compared to standard grade W1.2711, Superplast® 400 provides following benefits:

- Higher through-hardening (uniform hardness)
- More consistent texturing (random and geometric)
- More reliable repair welding
- Higher thermal conductivity

Some applications of Superplast® 400 are:

- Plastic injection mould cores and cavities
- Large-size moulds for fenders, bumpers
- Injection and compression moulding of reinforced resins

Chemical analysis (typical in weigth %)

C	S*	Mn	Ni	Cr	Mo	V	B
0.26	0.002	1.20	0.75	2.0	0.60	0.07	+

*** max : 0.007**

Cleanliness (ASTM E45)

	A	B	C	D
Thin	1.5	2.0	1.0	1.5
Heavy	1.0	1.0	0.5	1.0

A: sulphides | B: alumina | C: silicates | D: globular oxides

Product properties

Mechanical properties

Superplast® 400 is delivered quenched and tempered to 350-380 Brinell (HBW). Following data are provided for testing at quarter-thickness of a 400mm-thick block.

Hardness	Yield strength	Tensile strength	Elongation	Reduction of area
HBW	N/mm^2	N/mm^2	%	%
370	1000	1215	15	55

Physical properties

Thanks to an original chemistry, Superplast® 400 has superior thermal characteristics. Thermal conductivity of Superplast® 400 is 10% higher than values for standard grades (W1.2714).

	25°C	100°C	200°C	300°C
Thermal expansion (10^{-6}/K)	-	10.8	11.2	12.9
Thermal conductivity (W/m/K)	38.0	37.5	36.0	36.0
Specific heat (J/Kg/K)	460	500	530	560
Yound modulus (kN/mm^2)	205			

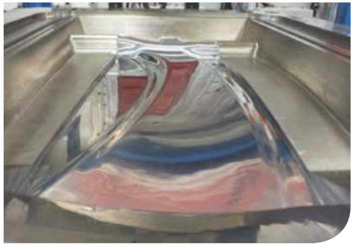
Hardness control

Wear resistance is usually proportional with hardness. In addition high and consistent hardness is especially important to avoid dents on parting lines.
It is therefore important to control hardness according to the required specification. Superplast® 400 provides very consistent hardness.

Key factors

Surface preparation

All hardness test methods require smooth surfaces free of rust, oil, paint or protective coatings. Adequate surface finish depends on the test method.

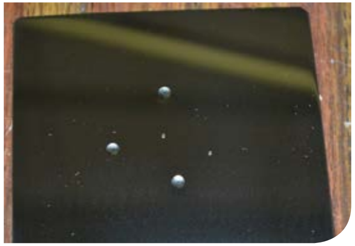


Gage repeatability and reproducibility

Prior to hardness testing, check the testing device using a reference block. Periodic maintenance checks of the testing device are also recommended.

Hardness scales

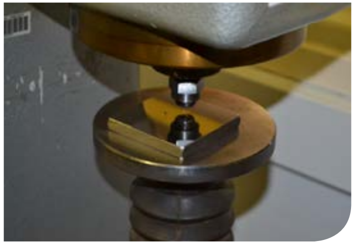
It is common to test in one scale and report in another scale. Although conversion charts have some validity, established conversions do not always provide reliable information.



Popular hardness test methods

Brinell hardness testing (ISO 6506)

It measures the permanent width of indentation produced by a carbide indenter applied to a test specimen at a given load. Plates of Superplast® 400 are usually controlled by means of carbide indenters.



Diameter of indenter	Load	Plate thickness	Equipment
ϕ 5 mm	750 Kgf	≤ 5 mm	Brinella
ϕ 10 mm	3000 Kgf	> 5 mm	Brinella

Recommendation

The greatest source of error in Brinell testing is the measurement of the indentation. To ensure a reliable indentation reading, grind the surface with following grinding depths:

- 0.2 mm for plate thickness ≤ 5 mm
- 0.5 mm for plate thickness 5 - 40 mm
- 1 mm for plate thickness 40 - 80 mm
- 2 mm for plate thickness > 80 mm.

Grinding can be done with grit size 60 (or equivalent), followed by polishing (320 Grit paper).

Rockwell hardness testing (ISO 6508 / ASTM E-18)

It measures the permanent depth of indentation produced by a (diamond) indenter. Superplast® 400 is controlled at R&D centre with a conical diamond indenter and a load of 150Kgf (HRC).

Recommendation

It is important to keep the specimen surface finish clean and decarburization from heat treatment should be removed.
Surface preparation for Rockwell test usually requires a polishing finish finer than grit paper 600 (SPI B-1).

Rebound hardness test (DIN 50156)

Most commonly worldwide portable testers are based on the rebound technique. The device measures the Leeb hardness (HL). Superplast® 400 is usually controlled by the latest generation of portable testers EQUOTIP 3 (HLD or HLG).

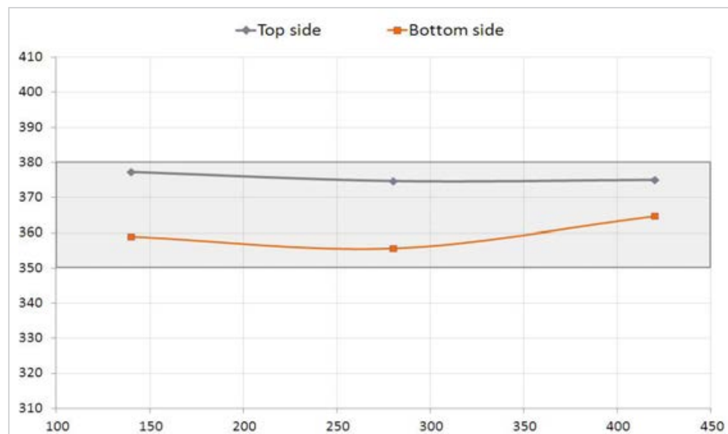
Recommendation

Our plates are usually controlled by means of Equotip HLG for thickness ≥ 40 mm. Surface preparation is similar to the one done for Brinell control.
You should never perform an average of hardness values measured in Brinell and values in HLG converted in Brinell.

Benefits of Superplast® 400

- Thanks to an optimal balance of alloying content and high quality heat treatment, Superplast® 400 exhibits a very consistent hardness, even through large sections of blocks.

- Plates and blocks made of Superplast® 400 are carefully controlled by mill quality teams to ensure uniform hardness in accordance with customer's specification. Hardness is checked both with Equotip and Brinell devices.



Brinell hardness profile through 560mm-thick blocks

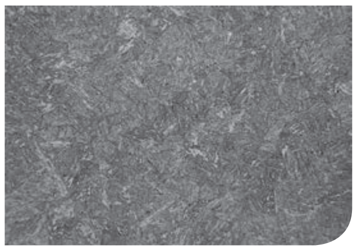
Machining

Machining is the most cost-intensive step in manufacturing moulds. It is therefore of utmost importance to optimize parameters that affect the machining performance: the workpiece material (steel grade), the cutting conditions and the machining operations.

Key factors

Workpiece material

The machinability of a given steel grade depends on its structure homogeneity (segregation), hardness and cleanliness. Superplast® 400 is more homogeneous than higher carbon standard grades, and exhibits a more consistent hardness.



Cutting conditions

The cutting tool (material, geometry) and the cutting strategy affect the machining cots and productivity. We have worked with tooling manufacturers to define optimal cutting conditions for Superplast® 400.

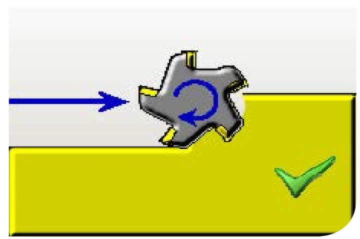
Milling Superplast® 400

Recommendation

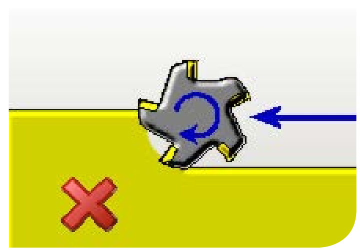
In order to achieve an adequate service life of cutting tools during milling of Superplast® 400, down milling (climb milling) is recommended.

The advantages of climb milling are:

- Longer tool life (less flank wear).
- Better surface finish.
- Easier chip removal.



Climb milling (down milling)



Up milling (opposed milling)

Recommended cutting data for rough milling

Below are recommended cutting speeds and feeds both for conventional and high feed milling of Superplast® 400. These data correspond to the operating range of selected cutting tools.

Dry machining	Grade for coated carbide inserts		Cutting parameters	
	ISO 513 reference	SECO reference	Vc (m/min)	fz (mm/tooth)
Conven-tional	P20 - P30	MP1500	120 - 200	0.15 - 0.30
High feed	P30	MP3000	140 - 250	0.30 - 0.90

Recommendation

Please contact your local cutting tool supplier for full support on the selection of cutting tools and parameters.

Tool life test

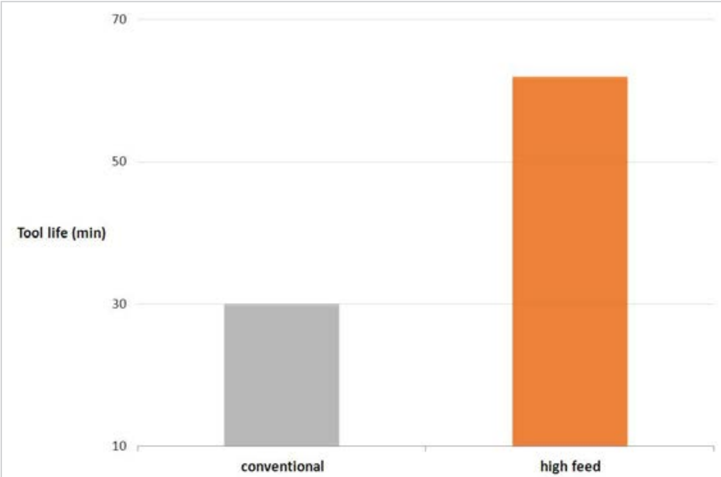
Milling tests were done to determine the cutting tool life using recommended cutting data.

Milling mode	Vc (m/min)	fz (mm)	Ap (mm)	Ae (mm)	Removal rate (cm3/min)
Conven-tional	175	0.2	3	15	68
High feed	180	0.6	0.6	18	77

Conventionnal milling (SECO tools)
cutter : R220.29-0040-06.4A
insert : RPHT 1204MOT-M15

High feed milling (SECO tools)
cutter : R220.21-0040-LP06.6A
insert : LPHW 1204MOT-D06

Tool life chart compares the cutting tool lifetimes achieved depending on the milling mode. The tool life criteria was milling duration to obtain a flank wear of 0.3 mm.



Milling tool life for conventional and high feed milling

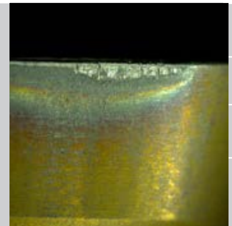
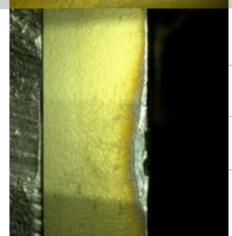
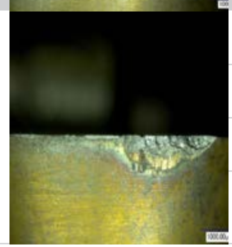
Recommendation

High feed milling is recommended for Superplast® 400 as tool life is significantly increased compared to conventional milling. Key characteristics of high feed milling are:

- Small cutting depth (Ap)
- Very high feed rate (fz)
- High cutting speed (Vc)

Troubleshooting

Below are some basic rules to deal with premature tool wear that might occur during milling operations.

Wear mechanism		Action and solutions
Flank wear		Check the tool operating range
		Reduce the cutting speed
		Reduce the feed rate
		Use a harder coated carbide grade
Crater wear		Check the tool operating range
		Reduce the cutting speed
		Reduce the feed rate
		Select an insert grade with alumina oxide Al_2O_3 coating
Cutting edge chipping		Use a tougher coated carbide grade
		Avoid using a coolant
		Check the cutter set-up
Cutting edge build-up		Increase the cutting speed
		Increase the feed rate
		Avoid using a coolant
		Change over to coated carbide grade

Deep hole drilling

Deep hole drilling is the machining of holes with a relatively large depth to diameter ratio. Usually any hole deeper than 5 times the drilled diameter can be considered as a deep hole. Deep-hole drilling systems are:

- Gun-drilling system
- Ejector system
- Single tube system (STS).

The selection of appropriate cutting data may be affected by following factors:

- Chip formation
- Cutting force (machine power)
- Tool life (length)
- Surface finish and tolerance.

Gun-drilling	Ejector drilling	STS drilling
Small diameters (≤ 40 mm)	Diameters ≥ 19 mm	Diameters ≥ 12 mm
Easily applied to machining centers with a pre-drilled hole for guidance.	Easily adapted to existing machines.	Requires special deep hole drilling machine.
Requires high coolant pressure.	Requires less fluid pressure than STS.	First choice for long series production.
		For materials where good chipbreaking is difficult to obtain.

Recommended cutting data for gun drilling

Solid carbide heads	Drill diameter, mm			
	1 - 3	3 - 6	6 - 12	12 - 40
Cutting speed Vc (m/min)	40 - 120			
Feed fn (mm/rev)	0.003-0.010	0.004-0.025	0.010-0.050	0.020-0.100

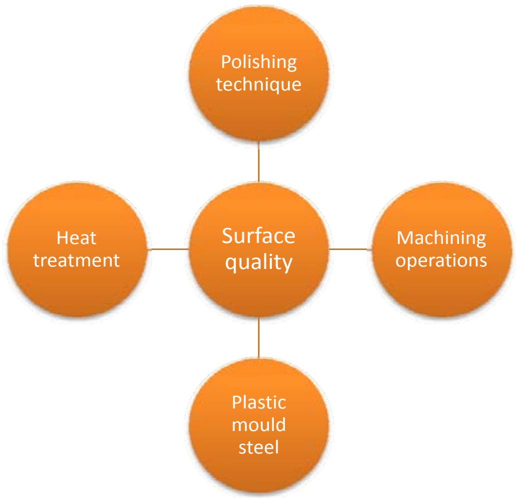
Recommended cutting data for STS / ejector drilling

Ground brazed heads Carbide P20 - P30	Drill diameter, mm			
	16 - 20	20 - 30	30 - 40	40- 60
Cutting speed Vc (m/min)	55 - 100			
Feed fn (mm/rev)	0.14-0.20	0.17-0.25	0.20-0.30	0.24-0.32

Solid drill head with indexable insert (coated carbide P15 - P50)	Drill diameter, mm	
	25 - 40	40 - 60
Cutting speed Vc (m/min)	55 - 110	
Feed fn (mm/rev)	0.10 - 0.40	0.20 - 0.45

Polishing

The condition of the mould cavity surface is crucial to the quality of the final part. It also affects the ease with which the molding can be released.
Whatever the function of polishing (functional or aesthetic), attention should be paid to factors that affect the quality of surface finish : the polishing method, the surface condition and the steel quality.



Key factors

Polishing technique: experience, skill and technique from the polisher are very important in achieving the desired result. Grit material, grit grade and polishing sequences should be carefully selected.

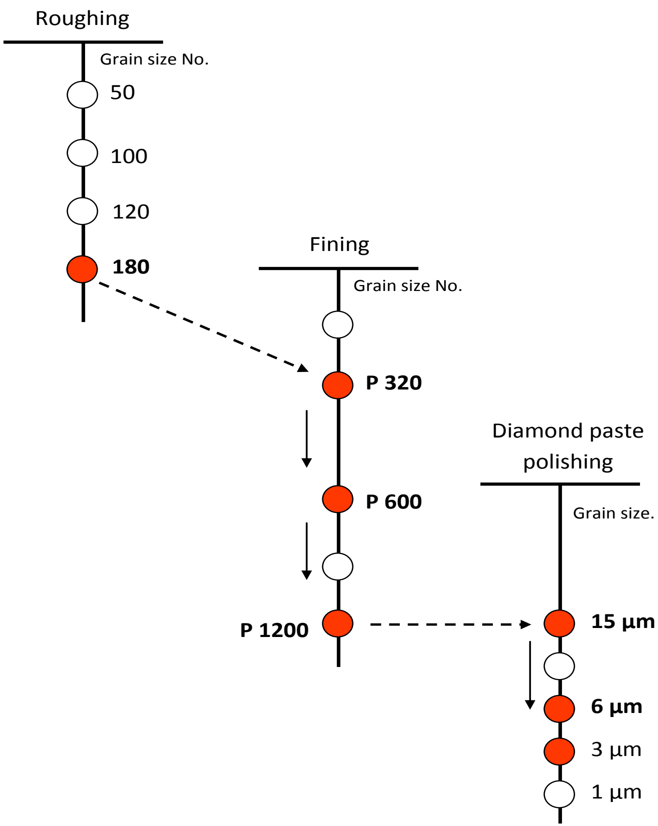
Machining operations prior polishing: sound milling and grinding steps are necessary pre-conditions for a high quality polish. Altered steel structure and hardness caused by local strain hardening will especially make difficult to achieve a good polishing quality.

Plastic mould steel: steel hardness, degree of purity and structure homogeneity affect the surface finishing. Thanks to a reduced segregation level compared to high carbon standard grades (W1.2714), a consistent hardness and a very good cleanliness, Superplast® 400 allows very good technical polishing.

Heat treatment: decarburization or recarburization during heat treatment may induce hardness variations, which will affect the polishing result.

Polishing Superplast® 400

We can only do recommendations based on experience with customers and professional polishers.
Following sequences are typically suggested to obtain a good polishing result with Superplast® 400.



Practical tips for polishing

Roughing (Grain size no. 180)

- Select the appropriate grinding wheel to avoid over-heating that may affect steel hardness and structure.
- Carefully clean the workpiece after each application of a compound, before the next compound is applied.
- Change direction during the operation to avoid scratches and unevenness.
- Work with one grain size in one direction, then with the next size in an angle of 45° until the surface does not exhibit anymore traces of the previous direction.

Fining (Grain size 200 - 1200)

- Only clean and unclogged tools should be used.
- Add ample coolant to prevent heating of the surface.
- With each change of grain, workpiece and hands have to be cleaned to prevent larger grains interfering with finer size.
- Pressure should be distributed uniformly. Scratches and cold-deformed layer from the preceding grain size have to be removed before switching to the next size.

Finishing (Diamond paste)

- Clean carefully workpiece and hands.
- Spend more time on the coarse steps before changing to the finer steps.
- Use as short time as possible when polishing with diamond paste.
- Polishing pressure should be adjusted to the hardness of the polishing tool and the grade of the paste.

DIN / ISO 1302	Roughness Ra µm	SPI	Grinding Polishing
N1	0.025	A-1	3 µm Diamond paste
N2	0.05	A-2	6 µm Diamond paste
N3	0.1	A-3	15 µm Diamond paste
N4	0.2	B-1	600 Grit paper
N5	0.4	B-2	400 Grit paper
N6	0.8	B-3	320 Grit paper
N7	1.6	C-1	600 Grit stone
N8	3.2	C-2	400 Grit stone
N9	6.3	C-3	320 Grit stone

Troubleshooting

The main problem caused by overpolishing is orange peel. Orange peel is an irregular texture caused by high polishing pressure during a prolonged time. If this phenomenon is observed during polishing, here are recommended actions:

- Stop polishing (continue to polish worsens orange peel)
- Remove the defective layer using the last grinding step prior to polishing
- Reduce polishing pressure and time

Orange peel on a mould cavity

Recommendation

Thanks to its high and consistent hardness, Superplast®400 may better withstand a high polishing pressure.

Texturing

Many plastic parts are textured for aesthetic or functional reasons. Among factors that affect the quality of texturing (or graining or etch graining), there is the mould steel quality. Thanks to its homogeneous structure and high cleanliness, Superplast® 400 provides reliable texturing performance.

Key factors

Texturing process: graining quality is affected by the type of etching solutions used (nitric acid, ferric chloride) and their characteristics (pH value, temperature, etc.). Know-how and experience of the engraving company are very important.

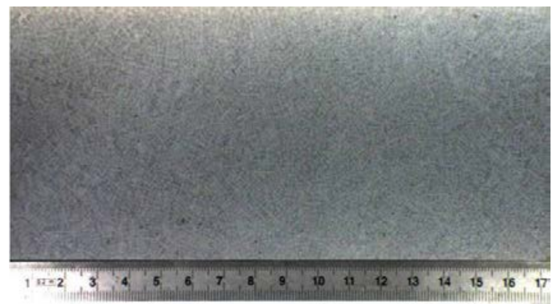
Surface condition: machining operations can modify the steel hardness by strain hardening. Repair welding also leads to microstructure and hardness variations that can impair the texturing quality.

Mould steel quality: segregation (structure heterogeneity) and inclusions (cleanliness) mainly affect the texturing quality. Compared to standard grades, Superplast® 400 has a much more homogeneous structure. Its cleanliness is also good, thanks to a vey low sulphur level.

Texturing Superplast® 400

To evaluate the ability of Superplast® 400 to provide excellent results whatever the texturing pattern, tests have been done in association with MOLD TECH, a global leading texturing company.

Mold Tech reference	Type of texture	Depth (mm)
MT 9052	Fine	0.035
MT 21340	Leather	0.120



Macrograph of Superplast® 400 (acid test)

Fine (top) and leather textured surfaces of Superplast® 400

Recommendation

For Mold Tech graining tests, surface finish of specimen was 400 grit paper. This is enough to achieve a good surface quality before starting the etch graining process.

Surface treatment

Main goals of surface treatment processes are:

- To improve the surface quality.
- To increase fatigue and wear resistance.
- To increase corrosion resistance.

Superplast® 400 is suitable for most surface treatment processes. Good results are especially achieved with laser hardening, chrome plating or nitriding.

Key factors

As there are many surface treatments, key factors that affect the surface treatment result will depend on each process. Surface hardness and case depth are common qualifying factors for all surface treatment processes.

Nitriding

Description

Nitriding is a thermochemical process used to enrich the surface layer of the workpiece with nitrogen. Steel absorbs nitrogen from the surrounding medium, at temperatures between 350 and 580°C.

Advantages of nitriding are:

- Nitrided parts yield extremely hard and wear-resistant layer
- Nitrided parts are free from distortion (treatment temperatures do not cause thermal microstructure transformations)
- The corrosion resistance of low alloy steels is increased, with good polishability
- Nitrided moulds are suitable for processing thermosets and such thermoplastics that are shaped at high mold temperatures.

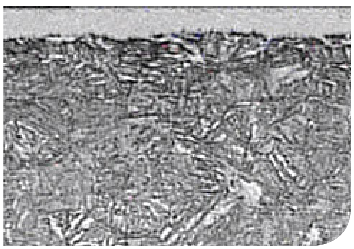
Recommendation

Alloying elements that are favorable to nitriding are chromium, aluminium and molybdenum. Thus the chemical composition of Superplast® 400 is perfectly adapted to nitriding process.

Nitriding Superplast® 400

Gas and plasma nitriding are the main processes in plastic mouldmaking.

	Process parameters		Surface hardness	Diffusion zone	White layer
Nitriding	Tempe-rature	Time			
Gas	520°C	25 h.	875 HV10	0.34 mm	11 µm
Plasma	520°C	15 h.	900 HV10	0.25 mm	7 µm



Typical micrograph of a gas nitriding layer

Recommendation

To avoid softening of base metal, nitriding temperatures for Superplast® 400 should not exceed 540°C.

Hard chrome plating

Description

Hard chrome plating consists in electrolytically deposited layers of chromium in order to increase the surface hardness. Common thicknesses lie between 5 and 30 µm.

Benefits of hard chrome plating moulds are:

- Hard and wear-resistant layer
- High corrosion resistance
- Low coefficient of friction

Typical sequence of hard chrome plating

Visual examination (roughness Ra ≤ 0.2 µm)
Cleaning (chemical or electrochemical)
Air drying
Chrome plating
Water rinsing
Air drying
Polishing (if necessary)

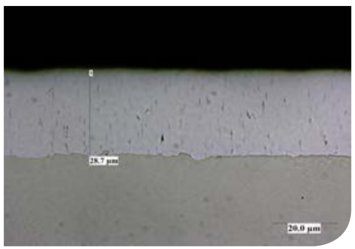
Hard chrome plating Superplast® 400

Preparatory work
The surface to be chromium plated must be free of contaminants or grease from previous operations (machining).
Chemical or electrochemical cleaning can be done to remove grease.
A surface roughness Ra of 0.8 µm or less is recommended (Ra below 0.2 µm is even better).

Chromium plating bath

Following parameters are usually used for chromium plating of Superplast® 400:

- Voltage: 6 – 8 V
- Current density: 20 – 50 $A.dm^{-2}$
- Bath temperature: 40 – 60°C
- Bath composition: chromic acid and sulfuric acid



Micrograph of hard chrome plated layer (hardness: 970 HV0.1 Kgf)

Recommendation

An amount of hydrogen can be absorbed during hard chrome plating, with detrimental effects. Degassing treatment is a non-mandatory option (450°C - 2 hours).

Induction hardening

Description

Induction hardening creates a hardened layer at the surface of the steel mould while maintaining an unaffected core microstructure. Parts to be treated are heated above the steel transformation range followed by immediate quenching.

Benefits of induction hardening are:

- A deep high surface hardness
- Increased wear resistance
- Increased fatigue strength
- No distortion of hardened parts

Hardening Superplast® 400

Bars made of Superplast® 400 have been hardened by induction in order to determine the surface hardness achievable with this process.

Surface hardness	Case depth
53.5 – 53.9 HRC	3.02 mm

Recommendation

Tempering at low temperature should be done following induction hardening in order to achieve the required hardness and for stress relieving.

Laser hardening

Laser hardening is an impulse hardening using a high-energy laser as the heat source. Surface hardness levels achieved are similar to values obtained by induction hardening.

Benefits of laser hardening are:

- High surface hardness
- Increased wear resistance
- No distortion of hardened parts
- Minimal risk of crack
- Excellent accuracy and reproducibility

Recommendation

A surface finish of level N7 or finer is sometimes required on the surface to be laser hardened.

	Flame hardening	**Induction hardening**	**Laser hardening**
Case depth	max. 40 mm	max. 10 mm	max 1.5 mm
Reproducibility	good	very good	excellent
Dimensional stability	good	good	very good
Danger of cracking	high	low	very low
Polishing after treatment	usually required	usually required	usually unnecessary
Accuracy of heat source	medium	good	high

Welding

Welding is usually carried out on plastic moulds for maintenance (repair of worn parts) or original mouldmaking issues (repair of machining defects for example).
Therefore weldability of mould steels plays an important role. Thanks to its lower carbon content compared to high carbon grades (W1.2711, W1.2714), Superplast® 400 is optimized for welding.

The welding section provides key data to achieve good results following GTAW (TIG) welding of Superplast® 400, especially when polishing and texturing are required.

Key factors

Preparatory work

- Prepare the surface appropriately before welding. It must be clean and free of oxides, grease or oil residue.
- Remove any coatings (nitriding or chrome plating zones) by grinding or deplating.
- Cracks must be ground open to form a U-shaped cross section.

Welding procedure

- Preheat the mould before welding in order to minimise risk of stress cracks and to counteract increased hardening.
- Follow the preheating instruction for Superplast® 400 as the preheat temperature is specific to each steel grade.
- After welding cool the mould down, preferably covered.
- Carry out a post-weld heat treatment (PWHT) for stress relieving and hardness homogeneization.

Welding consumables

- Use a filler material with a similar chemical composition to the parent metal (and lower carbon content). It ensures uniform hardness and good surface quality.
- Use an electrode with as small diameter as possible for the work.

Welding gas

In GTAW process, the primary role of gas is to protect from the atmosphere:

- the molten pool
- the electrode
- the end of the filler material
- the heat affected zone (HAZ).

Gas has also an influence on:

- the arc heat input
- the welding speed
- the penetration depth and shape
- the surface finish.

Gases that can be used for welding of Superplast® 400 with GTAW are:

- Argon: versatile gas (GTAW of all types of metal alloys), and base constituent of welding gas mixtures
- Helium: increases the penetration depth and the welding speed, reduces ozone fumes.

Welding Superplast® 400

Welding for polished and textured cavities

Process	Filler material	Preheating	Post-heating	PWHT
GTAW	SP300Weld-E	325°C	325°C-2h	550°C

Recommendation

The use of lower carbon rods (like SP300Weld-E) as filler material will guarantee the best result for polishing and etching following welding.
Another alternative filler material is DIN 25 CrMo 4 (F66S).

Welding without specific surface requirements

Filler material
The use of filler material suitable for the welding of high strength steels is recommended when there are no specific surface finish requirements.

Welding process	Suitable welding fillers by brand		
	Oerlikon	SAF	Thyssen
GTAW	OE-Ni 38 R	NERTAL 60	UNION I 1.2 Ni
SMAW	TENACITO 65	SAFDRY MD56	SH Schwartz 3KNi

Welding procedure

Process	Preheating	Post-heating	PWHT
GTAW	150°C	150°C-2h	550°C (not mandatory)
SMAW	150°C	150°C-2h	550°C (not mandatory)

Troubleshooting

Welding carbon steels can lead to cracks just after welding or a few hours later. Parameters that could lead to cold cracking are:

- Presence of hydrogen
- Heat affected zone (H.A.Z.)
- High residual stresses.

Following recommendations aim at reducing the risk of cold cracking during welding.

Parameters	Factors	Actions
Hydrogen	Process	Use a low hydrogen process (GTAW)
	Filler material	Dry the filler material
	Surface condition	Remove grease and other deposits before welding
Heat affected zone	Heat input	Follow preheating instructions
		Follow postheating instructions
	Base material	Use a base material with enhanced weldability
Residual stresses	Design	Decrease the notch effects
	Process	Use correct sequences
	Filler material	Use the appropriate filler material

Heat treatment

Superplast® 400 is delivered ready-for-use (quenched and tempered). As heat treatment may affect the steel characteristics, respect of basic rules is highly recommended.

Stress relieving

Sometimes some stresses may be put in the workpiece during machining (like rough machining with significant material removal). If stress relieving has to be carried out on Superplast® 400, the temperature should be 30°C below the last tempering temperature so as to avoid a reduction in hardness.

Hardening

Heating: heat slowly the workpiece to the required hardening temperature to avoid temperature gradient (thermal stresses).

Austenitising: once the workpiece surface has reached the hardening temperature, a soaking time should be applied in order to obtain a homogeneous temperature distribution throughout the section. Avoid excessive soaking times that may increase the steel grain size (which deteriorates mechanical properties).

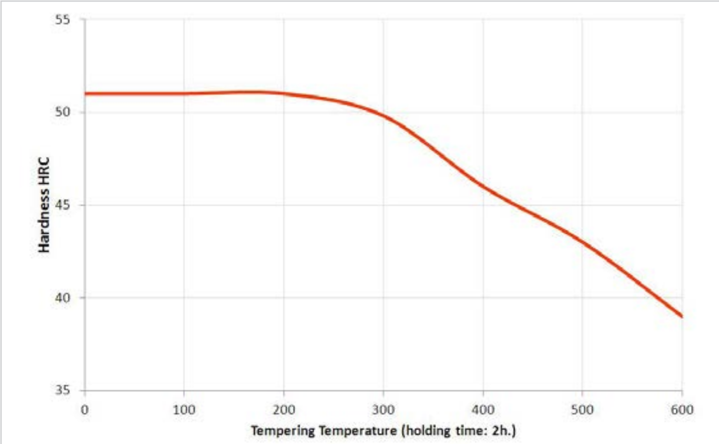
Quenching: following austenitisation cool the workpiece in the appropriate cooling medium. As cooling induces thermal stresses, the speed of cooling should not be higher than necessary. For Superplast® 400, when parts are cooled to 100°C, they should be directly transferred into a furnace at a temperature of 100 - 150°C. This prevents possible quench cracks to develop.

Tempering

The specified hardness is usually achieved by a tempering treatment. The appropriate tempering temperature can be estimated from the tempering chart.
Heating to the tempering temperature should take place slowly. The usual soaking time is 1 hour for every 25 mm wall thickness, with a minimum of 2 hours.

Heat treating Superplast® 400

	Temperature	Soaking time	Cooling
Stress relieving	525°C	1 hour per 25mm	Furnace
Hardening	900°C	30 min. per 25mm	Oil, vacuum, polymer
Tempering	see chart	1 hour per 25 mm	Air



Recommendation

The tempering chart has been designed with samples of section 50 mm x 50 mm. Please consult our technical team for further assistance on heat treatment.

General Information

Product definition

Superplast® Stainless is a corrosion-resistant holder steel. Compared to standard grade W1.2085, Superplast® Stainless provides following benefits:

- Excellent machinability
- Consistent hardness
- Uniform microstructure
- High thermal conductivity
- High dimensional stability

Some applications of Superplast® Stainless are:

- Plastic injection mould holders and support plates
- Chemically aggressive and acid-releasing plastics
- Injection moulding, rubber injection moulding, extrusion.

Chemical analysis (typical in weigth %)

C	Mn	S	Ni	Cr	N
0.07	1.40	0.12	0.50	12.0	added

Cleanliness (ASTM E45)

	A	B	C	D
Thin	1.5	2.0	1.0	1.5
Heavy	1.0	1.0	0.5	1.0

A: sulphides | B: alumina | C: silicates | D: globular oxides

Product properties

Mechanical properties

Superplast® Stainless is delivered quenched and tempered to 290 – 330 Brinell (HBW). Following data are provided for testing at quarter-thickness of a 100mm-thick block.

Hardness	Yield strength	Tensile strength	Elongation	Reduction of area
HBW	N/mm²	N/mm²	%	%
310	890	1000	15	55

Physical properties

Thanks to an original chemistry, Superplast® Stainless has superior thermal characteristics. Thermal conductivity of Superplast® Stainless is 20% higher than values for standard grade W1.2085.

	25 °C	100 °C	200 °C	300 °C
Thermal expansion (10^{-6}/K)	-	10.6	10.7	10.9
Thermal conductivity (W/m/K)	27.4	28.3	28.2	28.0
Specific heat (J/Kg/K)	460	490	520	570
Yound modulus (kN/mm²)	205			

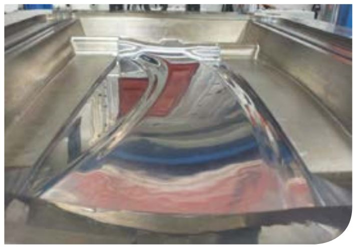
Hardness control

Wear resistance is usually proportional with hardness. In addition high and consistent hardness is especially important to avoid trouble during machining.
It is therefore important to control hardness accordingto the required specification. Superplast® Stainless provides consistent hardness.

Key factors

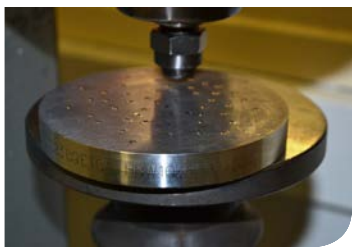
Surface preparation

All hardness test methods require smooth surfaces free of rust, oil, paint or protective coatings. Adequate surface finish depends on the test method.



Gage repeatability and reproducibility

Prior to hardness testing, check the testing device using a reference block. Periodic maintenance checks of the testing device are also recommended.



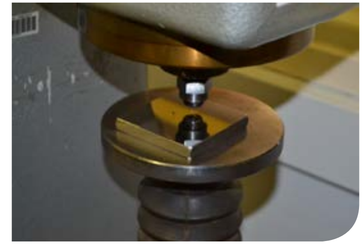
Hardness scales

It is common to test in one scale and report in another scale. Although conversion charts have some validity, established conversions do not always provide reliable information.

Popular hardness test methods

Brinell hardness testing (ISO 6506)

It measures the permanent width of indentation produced by a carbide indenter applied to a test specimen at a given load. Plates of Superplast® Stainless manufactured by mills are usually controlled by means of carbide indenters.



Diameter of indenter	Load	Plate thickness	Equipment
ϕ 5 mm	750 Kgf	≤ 5 mm	Brinella
ϕ 10 mm	3000 Kgf	> 5 mm	Brinella

Recommendation

The greatest source of error in Brinell testing is the measurement of the indentation. To ensure a reliable indentation reading, grind the surface with following grinding depths:

- 0.2 mm for plate thickness ≤ 5 mm
- 0.5 mm for plate thickness 5 - 40 mm
- 1 mm for plate thickness 40 - 80 mm
- 2 mm for plate thickness > 80 mm.

Grinding can be done with grit size 60 (or equivalent), followed by polishing (320 Grit paper).

Rockwell hardness testing (ISO 6508 / ASTM E-18)

It measures the permanent depth of indentation produced by a (diamond) indenter. Superplast® Stainless is controlled at our R&D centre with a conical diamond indenter and a load of 150 Kgf (HRC).

Recommendation

It is important to keep the specimen surface finish clean and decarburization from heat treatment should be removed.
Surface preparation for Rockwell test usually requires a polishing finish finer than grit paper 600 (SPI B-1).

Rebound hardness test (DIN 50156)

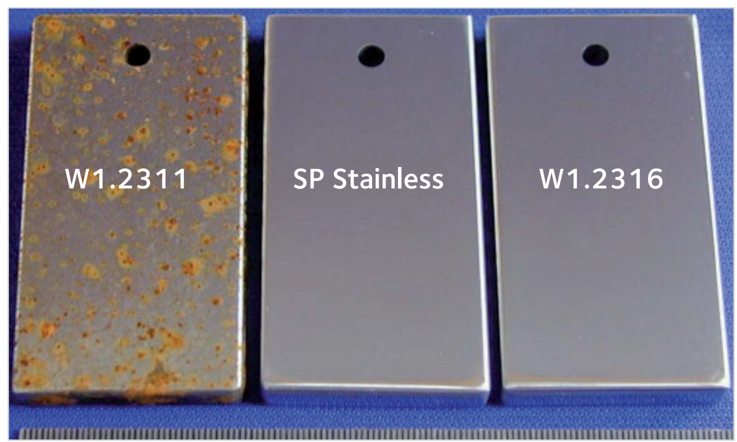
Most commonly worldwide portable testers are based on the rebound technique. The device measures the Leeb hardness (HL). Superplast® 2738mod is controlled by the latest generation of portable testers EQUOTIP 3 (HLD or HLG).

Recommendation

Our plates are usually controlled by means of Equotip HLG for thickness ≥ 40 mm. Surface preparation is similar to the one done for Brinell control.
You should never perform an average of hardness values measured in Brinell and values in HLG converted in Brinell.

Benefits of Superplast® Stainless

- Superplast® Stainless has been developed to provide better machinability than standard grade W1.2085. Milling tests have shown cutting tool life can be increased by 75% when milling Superplast® Stainless compared to W1.2085.
- Thanks to high chromium content and reduced carbon content, Superplast® Stainless exhibits corrosion resistance similar to grade W1.2085.



Sample following corrosion resistance test

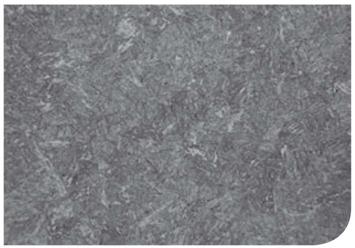
Machining

Machining is the most cost-intensive step in manufacturing moulds. It is therefore of utmost importance to optimize parameters that affect the machining performance: the workpiece material (steel grade), the cutting conditions and the machining operations.

Key factors

Workpiece material

The machinability of a free machining steel depends on its structure and hardness. Thanks to an optimal addition of sulphur and a consistent hardness, Superplast® Stainless is designed to offer the best in machining.



Cutting conditions

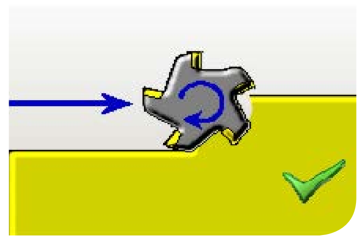
The cutting tool (material, geometry) and the cutting strategy affect the machining cots and productivity. We have worked with tooling manufacturers to define optimal cutting conditions for Superplast® Stainless.

Milling Superplast® Stainless

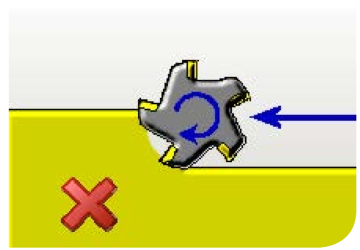
Recommendation

In order to achieve an adequate service life of cutting tools during milling of Superplast® Stainless, down milling (climb milling) is recommended.
The advantages of climb milling are:

- Longer tool life (less flank wear).
- Better surface finish.
- Easier chip removal.



Climb milling (down milling)



Up milling (opposed milling)

Recommended cutting data for rough milling

Below are recommended cutting speeds and feeds both for conventional and high feed milling of Superplast® Stainless. These data correspond to the operating range of selected cutting tools.

Dry machining	Grade for coated carbide inserts		Cutting parameters	
	ISO reference	SECO reference	Vc (m/min)	fz (mm/tooth)
Conven-tional	P30 – P40	T350M	100 – 300	0.12 - 0.80
High feed	P20 – P30	MP3000	100 – 300	0.80 - 3.00

Recommendation

Please contact your local cutting tool supplier for full support on the selection of cutting tools and parameters.

Tool life test

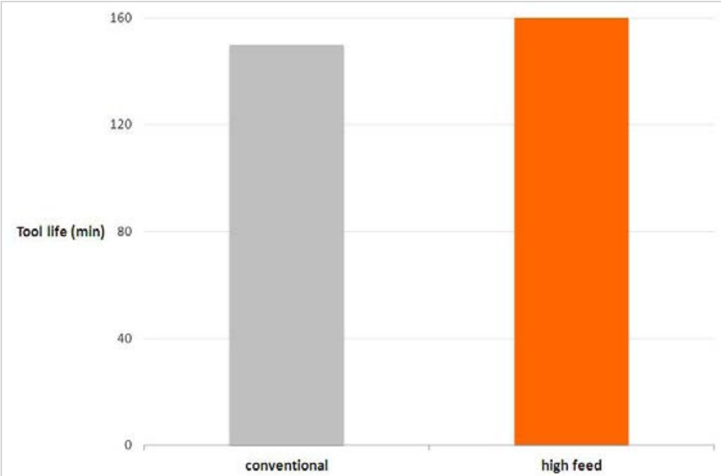
Milling tests were done to determine the cutting tool life using recommended cutting data.

Milling mode	Vc (m/min)	fz (mm)	Ap (mm)	Ae (mm)	Removal rate (cm3/min)
Conven-tional	200	0.75	0.5	39	81
High feed	100	2.50	1.0	13	85

Conventionnal milling (SECO tools)
cutter : R220.29-0040-06.4A
insert : RPHT 1204MOT-M15

High feed milling (SECO tools)
cutter : R220.21-0040-LP06.6A
insert : LPHW 1204MOT-D06

Tool life chart compares the cutting tool lifetimes achieved depending on the milling mode. The tool life criteria was milling duration to obtain a flank wear of 0.3 mm.



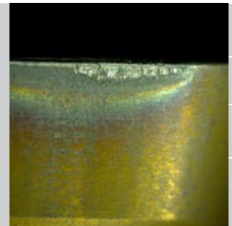
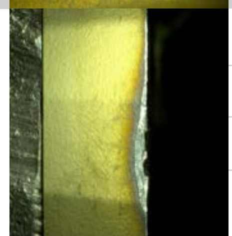
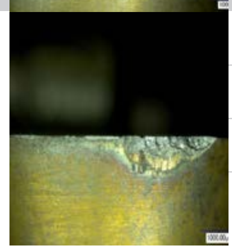
Milling tool life for conventional and high feed milling

Recommendation

Superplast® Stainless provides high cutting tool life both for conventional and high feed milling.

Troubleshooting

Below are some basic rules to deal with premature tool wear that might occur during milling operations.

Wear mechanism		Action and solutions
Flank wear		Check the tool operating range
		Reduce the cutting speed
		Reduce the feed rate
		Use a harder coated carbide grade
Crater wear		Check the tool operating range
		Reduce the cutting speed
		Reduce the feed rate
		Select an insert grade with alumina oxide Al2O3 coating
Cutting edge chipping		Use a tougher coated carbide grade
		Avoid using a coolant
		Check the cutter set-up
Cutting edge build-up		Increase the cutting speed
		Increase the feed rate
		Avoid using a coolant
		Change over to coated carbide grade

Deep hole drilling

Deep hole drilling is the machining of holes with a relatively large depth to diameter ratio. Usually any hole deeper than 5 times the drilled diameter can be considered as a deep hole. Deep-hole drilling systems are:

- Gun-drilling system
- Ejector system
- Single tube system (STS).

The selection of appropriate cutting data may be affected by following factors:

- Chip formation
- Cutting force (machine power)
- Tool life (length)
- Surface finish and tolerance.

Gun-drilling	Ejector drilling	STS drilling
Small diameters (≤ 40 mm)	Diameters ≥ 19 mm	Diameters ≥ 12 mm
Easily applied to machining centers with a pre-drilled hole for guidance.	Easily adapted to existing machines.	Requires special deep hole drilling machine.
Requires high coolant pressure.	Requires less fluid pressure than STS.	First choice for long series production.
		For materials where good chipbreaking is difficult to obtain.

Recommended cutting data for gun drilling

Solid carbide heads	Drill diameter, mm			
	1 – 3	3 – 6	6 – 12	12 – 40
Cutting speed Vc (m/min)	40 – 120			
Feed fn (mm/rev)	0.003-0.008	0.004-0.025	0.010-0.040	0.020-0.100

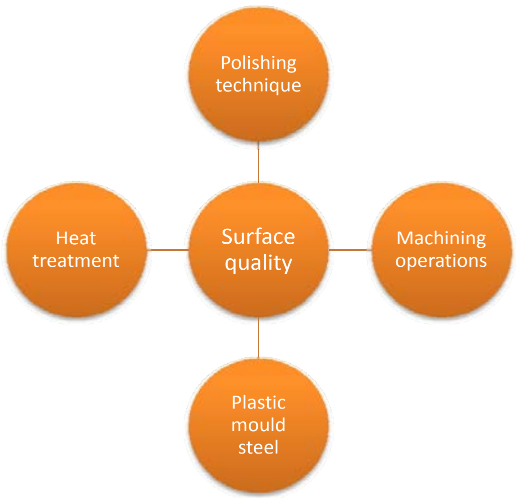
Recommended cutting data for STS / ejector drilling

Ground brazed heads Carbide P20 – P30	Drill diameter, mm			
	16 – 20	20 – 30	30 – 40	40- 60
Cutting speed Vc (m/min)	50 – 100			
Feed fn (mm/rev)	0.16-0.20	0.18-0.25	0.22-0.30	0.24-0.36

Solid drill head with indexable insert (coated carbide P15 – P50)	Drill diameter, mm	
	25 – 40	40 – 60
Cutting speed Vc (m/min)	40 – 110	
Feed fn (mm/rev)	0.10 – 0.40	0.20 – 0.45

Polishing

Whatever the function of polishing (functional or aesthetic), attention should be paid to factors that affect the quality of surface finish : the polishing method, the surface condition and the steel quality.



Key factors

Polishing technique: experience, skill and technique from the polisher are very important in achieving the desired result. Grit material, grit grade and polishing sequences should be carefully selected.

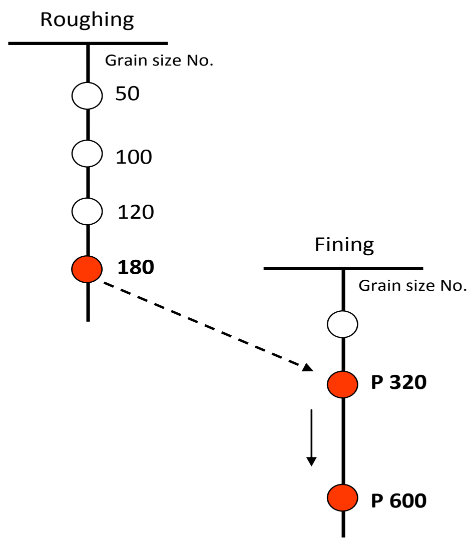
Machining operations prior polishing: sound milling and grinding steps are necessary pre-conditions for a high quality polish. Altered steel structure and hardness caused by local strain hardening will especially make difficult to achieve a good polishing quality.

Plastic mould steel: steel hardness, degree of purity and structure homogeneity affect the surface finishing. As sulphur is intentionnally added to achieve an excellent machinability, Superplast® Stainless is limited to technical polishing with low requirements.

Heat treatment: decarburization or recarburization during heat treatment may induce hardness variations, which will affect the polishing result.

Polishing Superplast® Stainless

We can only do recommendations based on experience with customers and professional polishers.
Following sequences are typically suggested to obtain a good polishing result with Superplast® Stainless.



Practical tips for polishing

Roughing (Grain size no. 180)

- Select the appropriate grinding wheel to avoid over-heating that may affect steel hardness and structure.
- Carefully clean the workpiece after each application of a compound, before the next compound is applied.
- Change direction during the operation to avoid scratches and unevenness.
- Work with one grain size in one direction, then with the next size in an angle of 45° until the surface does not exhibit anymore traces of the previous direction.

Fining (Grain size 200 - 1200)

- Only clean and unclogged tools should be used.
- Add ample coolant to prevent heating of the surface.
- With each change of grain, workpiece and hands have to be cleaned to prevent larger grains interfering with finer size.
- Pressure should be distributed uniformly. Scratches and cold-deformed layer from the preceding grain size have to be removed before switching to the next size.

Finishing (Diamond paste)

- Clean carefully workpiece and hands.
- Spend more time on the coarse steps before changing to the finer steps.
- Use as short time as possible when polishing with diamond paste.
- Polishing pressure should be adjusted to the hardness of the polishing tool and the grade of the paste.

DIN / ISO 1302	Roughness Ra µm	SPI	Grinding Polishing
N1	0.025	A-1	3 µm Diamond paste
N2	0.05	A-2	6 µm Diamond paste
N3	0.1	A-3	15 µm Diamond paste
N4	0.2	B-1	600 Grit paper
N5	0.4	B-2	400 Grit paper
N6	0.8	B-3	320 Grit paper
N7	1.6	C-1	600 Grit stone
N8	3.2	C-2	400 Grit stone
N9	6.3	C-3	320 Grit stone

Troubleshooting

The main problem caused by overpolishing is orange peel. Orange peel is an irregular texture caused by high polishing pressure during a prolonged time. If this phenomenon is observed during polishing, here are recommended actions:

- Stop polishing (continue to polish worsens orange peel)
- Remove the defective layer using the last grinding step prior to polishing
- Reduce polishing pressure and time

Recommendation

Superplast® Stainless should be limited to technical polishing with low surface finish requirements (maximum SPI B3 or 320 Grit paper).

Welding

Welding is usually carried out on plastic moulds for maintenance (repair of worn parts) or original mouldmaking issues (repair of machining defects for example).
Therefore weldability of mould steels plays an important role. Superplast® Stainless can be repaired by welding provided some safepractice.

The welding section provides key data to achieve good results following GTAW (TIG) welding of Superplast® Stainless.

Key factors

Preparatory work

- Prepare the surface appropriately before welding. It must be clean and free of oxides, grease or oil residue.
- Remove any coatings (nitriding or chrome plating zones) by grinding or deplating.
- Cracks must be ground open to form a U-shaped cross section.

Welding procedure

- Preheat the mould before welding in order to minimise risk of stress cracks and to counteract increased hardening.
- Follow the preheating instruction for Superplast® Stainless as the preheat temperature is specific to each steel grade.
- After welding cool the mould down, preferably covered.
- Carry out a post-weld heat treatment (PWHT) for stress relieving and hardness homogeneization.

Welding consumables

- Use a filler material with a similar chemical composition to the parent metal (and lower carbon content). It ensures uniform hardness and good surface quality.
- Use an electrode with as small diameter as possible for the work.

Welding gas

In GTAW process, the primary role of gas is to protect from the atmosphere:

- the molten pool
- the electrode
- the end of the filler material
- the heat affected zone (HAZ).

Gas has also an influence on:

- the arc heat input
- the welding speed
- the penetration depth and shape
- the surface finish.

Gases that can be used for welding of Superplast® Stainless with GTAW are:

- Argon: versatile gas (GTAW of all types of metal alloys), and base constituent of welding gas mixtures
- Helium: increases the penetration depth and the welding speed, reduces ozone fumes.

Welding Superplast® Stainless

Welding parameters

Process	Gas tungsten arc welding (GTAW)
Filler material	AWS type ER410 NiMo
Filler diameter	2.4 mm (recommended to limit dilution)
Preheating temperature	100 - 150°C
Interpass temperature	Between 100°C and 150°C
Heat input	Maximum 1.5 kJ/mm
PWHT	530°C - 2 hours

Recommendation

Due to the high sulphur content of Superplast® Stainless, you should limit the heat input and the dilution of the weld pool to avoid hot cracking.

Welding consumables

Below are indicated some filler materials suitable for welding of Superplast® Stainless (non exhaustive list).

Brand	Thermanit 13/04 Si				
Classification	DIN 8556		EN 12072	AWS A 5.9	W-Nr.
	SG-X 3 CrNi 13-4		G 13 4	ER410Ni-Mo	1.4351
Typical analysis (%)	C	Si	Cr	Ni	Mo
	0.03	0.8	13.0	4.7	0.5

Brand	Böhler CN 13/4-IG				
Classification	EN 12072	AWS A5.9	W-Nr.		
	W 13 4	ER410Ni-Mo	1.4351 (mod)		
Typical analysis (%)	C	Si	Cr	Ni	Mo
	0.02	0.7	12.3	4.7	0.5

Troubleshooting

Welding carbon steels can lead to cracks just after welding or a few hours later. Parameters that could lead to cold cracking are:

- Presence of hydrogen
- Heat affected zone (H.A.Z.)
- High residual stresses.

Following recommendations aim at reducing the risk of cold cracking during welding.

Parameters	Factors	Actions
Hydrogen	Process	Use a low hydrogen process (GTAW)
	Filler material	Dry the filler material
	Surface condition	Remove grease and other deposits before welding
Heat affected zone	Heat input	Follow preheating instructions
		Follow postheating instructions
	Base material	Use a base material with enhanced weldability
Residual stresses	Design	Decrease the notch effects
	Process	Use correct sequences
	Filler material	Use the appropriate filler material

Heat treatment

Superplast® Stainless is delivered ready-for-use (quenched and tempered). As heat treatment may affect the steel characteristics, respect of basic rules is highly recommended.

Key factors

Efficient monitoring of the heat treatment with workload thermocouples at precisely preset locations.

Gradual heating to the required treatment temperature not to allow temperature gradient within the workpiece.

Adequate soaking time to ensure homogeneous temperature distribution through the workpiece

Control cooling from the treatment temperature to room temperature.

Stress relieving

Sometimes some stresses may be put in the workpiece during machining (like rough machining with significant material removal). If stress relieving has to be carried out on Superplast® Stainless, the temperature should be 30°C below the last tempering temperature so as to avoid a reduction in hardness.

Hardening

Heating: heat slowly the workpiece to the required hardening temperature to avoid temperature gradient (thermal stresses).

Austenitising: once the workpiece surface has reached the hardening temperature, a soaking time should be applied in order to obtain a homogeneous temperature distribution throughout the section. Avoid excessive soaking times that may increase the steel grain size (which deteriorates mechanical properties).

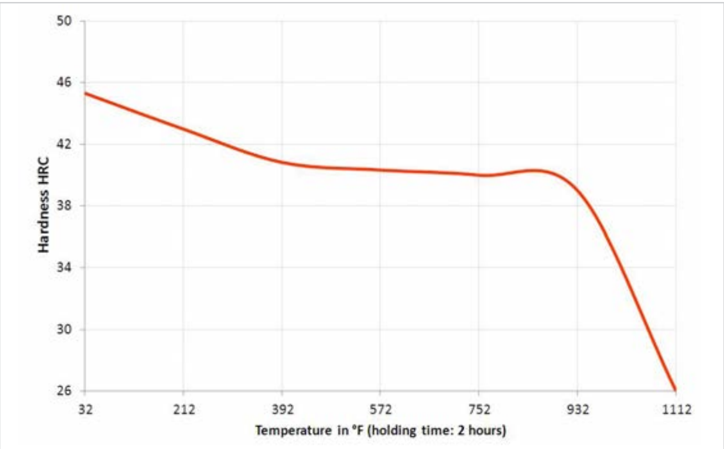
Quenching: following austenitisation cool the workpiece in the appropriate cooling medium. As cooling induces thermal stresses, the speed of cooling should not be higher than necessary. For Superplast® Stainless, when parts are cooled to 100°C, they should be directly transferred into a furnace at a temperature of 100 - 150°C. This prevents possible quench cracks to develop.

Tempering

The specified hardness is usually achieved by a tempering treatment. The appropriate tempering temperature can be estimated from the tempering chart.
Heating to the tempering temperature should take place slowly. The usual soaking time is 1 hour for every 25 mm wall thickness, with a minimum of 2 hours.

Heat treating Superplast® Stainless

	Temperature	Soaking time	Cooling
Stress relieving	525°C	1 hour per 25mm	Furnace
Hardening	900°C	30 min. per 25mm	Oil, vacuum, polymer
Tempering	see chart	1 hour per 25 mm	Air



Recommendation

The tempering chart has been designed with samples of section 50 mm x 50 mm. Please consult our technical team for further assistance on heat treatment.

Hardness Conversion Table

Conversion table ISO 18265:2004

Vickers HV	Brinell HBW	Rockwell HRC	Tensile strength MPa
270	266	26.2	845
280	276	27.7	877
290	286	29.1	909
300	296	30.5	940
310	306	31.8	972
320	316	33.1	1 003
330	326	34.3	1 035
340	336	35.4	1 070
350	345	36.5	1 097
360	355	37.6	1 128
370	365	38.6	1 159
380	375	39.6	1 189
390	385	40.6	1 220
400	395	41.5	1 250
410	405	42.4	1 281
420	414	43.2	1 311
430	424	44.1	1 341
440	434	44.9	1 371
450	444	45.7	1 401
460	453	46.4	1 430
470	463	47.2	1 460
480	473	47.9	
490	482	48.6	

Conversion table ASTM E140-07

Vickers HV	Brinell HBW	Rockwell HRC
279	264	27
286	271	28
294	279	29
302	286	30
310	294	31
318	301	32
327	311	33
336	319	34
345	327	35
354	336	36
363	344	37
372	353	38
382	362	39
392	371	40
402	381	41
412	390	42
423	400	43
434	409	44
446	421	45
458	432	46
471	443	47
484	455	48
498	469	49

Appendix

Conversion factors

Length

From	To	Multiply by
Meters, m	Micrometers, µm	1000000
Meters, m	Inches, in	39.37
Meters, m	Feet, ft	3.281

Energy

From	To	Multiply by
Joules, J	Foot pounds, ft lbf	0.7376
Joules, J	British thermal unit, Btu	9.478×10^{-4}
Joules, J	Kilowatt hours, kW h	2.78×10^{-7}

Pressure

From	To	Multiply by
Megapascals, MPa	Bars, bar	10
Megapascals, MPa	Pounds per sq. inch, lb/in^2	145.04
Megapascals, MPa	Newton per sq. mm, N/mm^2	1

Thermal conductivity

From	To	Multiply by
W/mK	Btu in/h/ft² °F	7.028
W/mK	Btu / h ft °F	0.5777
W/mK	cal / cm s °C	2.39×10^{-3}

Milling

From	To	Multiply by
m/min	SFM (Surface Feet per Minute)	3.28
mm/min	IPM (Inches per Minute)	0.04
SFM	m/min	0.30
IPM	mm/min	25.4

T (°F) = 1.8 * T (°C) + 32
T (K) = T (°C) + 273.1