



 BÖHLER



HOT WORK  
TOOL STEEL

HOT WORK TOOL STEEL

voestalpine BÖHLER Edelstahl GmbH & Co KG  
[www.voestalpine.com/boehler-edelstahl](http://www.voestalpine.com/boehler-edelstahl)

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ONE STEP AHEAD.

# FOR THE HIGHEST THERMAL LOAD

As the leading producer of tool steel worldwide voestalpine BÖHLER is focused on solving the most demanding customer problems when it comes to toolmaking. One of our top priorities here is hot work tool steels.

Hot work tool steels are alloyed tool steels for use in applications in which the surface temperature is generally above 200 °C. During the application the tool briefly comes into contact with hot material, the temperatures of which are well above 200 °C. Besides long term thermal load, there is the additional stress due to periodic change of temperature.

Tool steels for such applications have to be able to stand up to not only the universal mechanical and abrasive stress generally occurring in tool steels, they have to stand up to thermal load as well.







# SPECIAL STEELS IN TOP FORM

An optimal combination of both mechanical as well as metallurgical properties allows for:

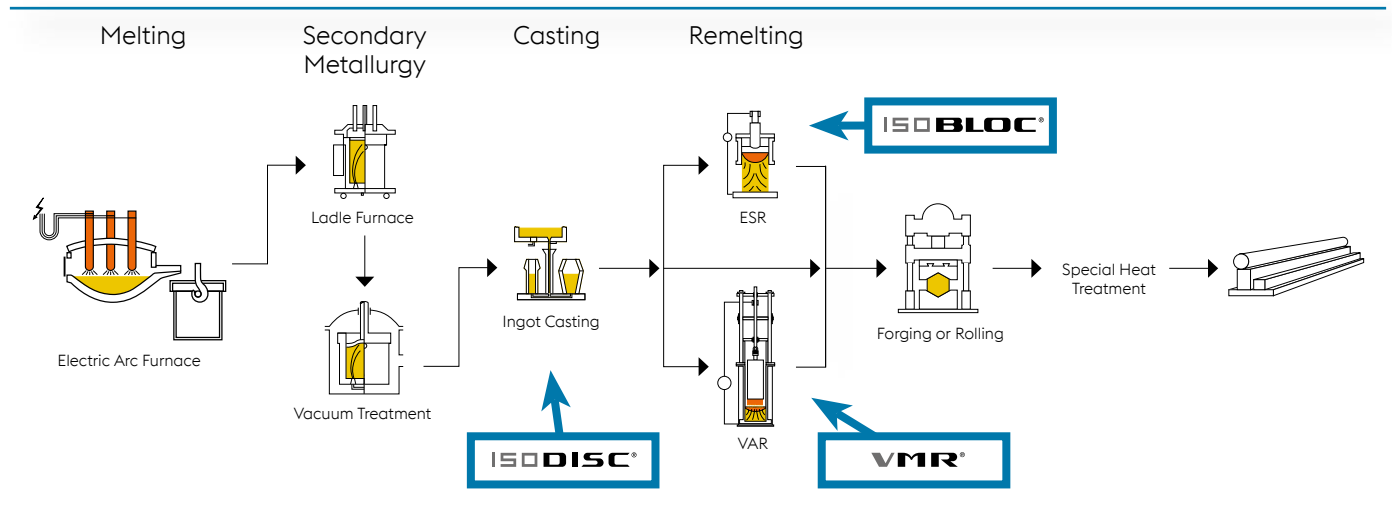
## In the production of the tool steel:

- » Easy machining and superior machinability
- » Safe and simple heat treatment
- » The best dimensional stability during heat treatment

## In use:

- » Long and uniform tool life time
- » Maximum security against failure

## Production routes for BÖHLER hot work tool steels





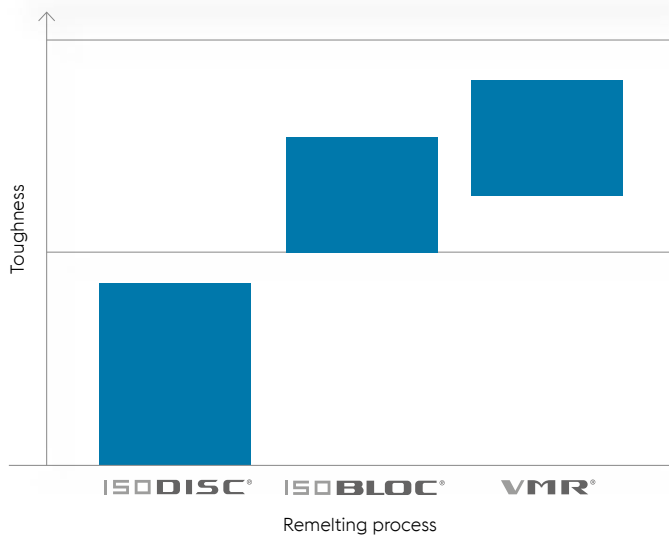
Property	Definition	Benefits
<b>Hot toughness</b>	The resistance of a material to crack formation and crack growth. The toughness of hot work tool steels increases as the temperature rises.	On tools with deep engraving at cross-sectional variations and edges high mechanical stress can develop, leading to thermal cracks. An increase in toughness <b>thus reduces the risk of crack formation</b> and contributing greatly to <b>resistance to crack formation</b> .
<b>Hot strength</b>	The ability of a material to absorb stress without deformation. If the microstructure changes due to the high temperatures, the strength at room temperature and subsequently the strength at service temperature decreases.	With sufficient strength even at high temperatures the security <b>against deformation</b> of the tools increases.
<b>Retention of hardness</b>	The resistance of a material to softening at elevated temperatures.	With sufficiently good tempering properties <b>sufficient working hardness</b> even at high temperatures will be guaranteed.
<b>Hot wear resistance</b>	The resistance to loss of material on surfaces brought about by mechanical causes.	With sufficient hot wear resistance the <b>risk of erosion</b> is reduced.
<b>Thermal shock resistance</b>	The ability of material to stand periodic loads due to cyclic temperature changes.	The reticular heat checking formed on the surfaces due to change in temperature <b>are delayed</b> .
<b>Thermal conductivity</b>	The speed at which heat from a single point spreads throughout the material.	On the one hand, with high thermal conductivity the temperature gradient leading to thermal stress is reduced. On the other hand, the damaging temperature is transported away from the surface. This brings about a <b>reduction in deformations, heat checking and gross cracking</b> .

For the most part these properties are characterized by metallurgic features and thus are regulated during the melting of the hot work tool steel. Our experience and on-going research lead to the continuous improvement of these metallurgic properties through advancements and further developments in the melting and remelting processes.

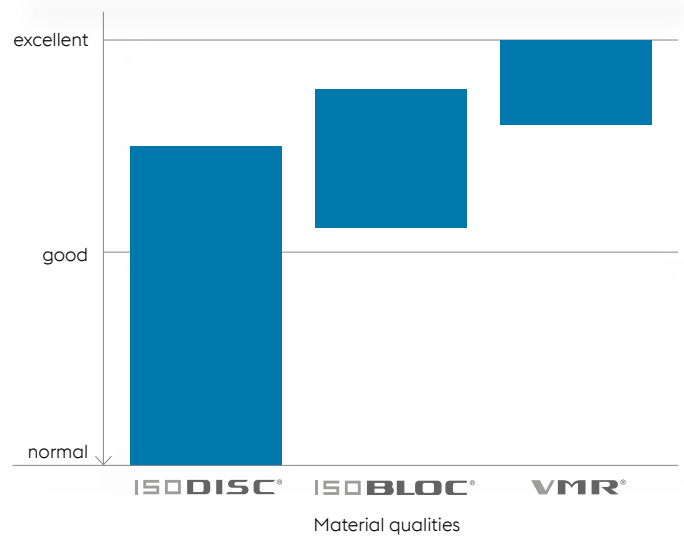




### Remelting process vs. toughness



### Cleanliness (K0 acc. to DIN 50602)\*



\* Cleanliness (K0 acc. to DIN 50602) depending on the melting and remelting process

# COMPARISON OF STEEL PROPERTIES

## Qualitative comparison of the major steel properties

This table is intended to support the steel choice. It does not, however, take into account the various load conditions imposed by the different types of applications. Our technical consultancy staff will be glad to assist you in any questions concerning the use and processing of steels.

BÖHLER grade	High temperature strength	High temperature toughness	High temperature wear resistance	Machinability
<b>BÖHLER W300</b> <b>ISODISC®</b>	★★	★★★	★★	★★★★★
<b>BÖHLER W300</b> <b>ISOBLOC®</b>	★★	★★★★	★★	★★★★★
<b>BÖHLER W302</b> <b>ISODISC®</b>	★★★	★★★	★★★	★★★★★
<b>BÖHLER W302</b> <b>ISOBLOC®</b>	★★★	★★★★	★★★	★★★★★
<b>BÖHLER W303</b> <b>ISODISC®</b>	★★★★	★★★	★★★★	★★★★★
<b>BÖHLER W320</b> <b>ISODISC®</b>	★★★	★★	★★★	★★★★★
<b>BÖHLER W350</b> <b>ISOBLOC®</b>	★★★	★★★★★	★★★	★★★★★
<b>BÖHLER W360</b> <b>ISOBLOC®</b>	★★★★★	★★★★	★★★★★	★★★★★
<b>BÖHLER W400</b> <b>VMR®</b>	★★	★★★★★	★★	★★★★
<b>BÖHLER W403</b> <b>VMR®</b>	★★★★	★★★★	★★★★	★★★★
<b>BÖHLER W720</b> <b>VMR®</b>	Maraging steels (ageing temperature about 480 °C), in this form not comparable with the heat treatable steels.			
<b>BÖHLER W722</b> <b>VMR®</b>				

# CHEMICAL ANALYSIS



BÖHLER grade	Chemical composition in %								Standards		
	C	Si	Mn	Cr	Mo	Ni	V	Others	DIN / EN	AISI	AFNOR
<b>BÖHLER W300</b> <sup>1</sup> <b>ISOBLOC</b> ®	0.38	1.10	0.40	5.00	1.30	-	0.40	-	<1.2343> X38CrMoV5-1	H11	Z38CDV5
<b>BÖHLER W302</b> <sup>1</sup> <b>ISOBLOC</b> ®	0.39	1.10	0.40	5.20	1.30	-	0.95	-	<1.2344> X40CrMoV5-1	H13	Z40CDV5
<b>BÖHLER W303</b> <b>ISODISC</b> ®	0.38	0.40	0.40	5.00	2.80	-	0.55	-	<1.2367> X38CrMoV5-3	-	-
<b>BÖHLER W320</b> <b>ISODISC</b> ®	0.31	0.30	0.35	2.90	2.80	-	0.50	-	<1.2365> 32CrMoV12-28 (X32CrMoV3 3)	H10	32DCV28
<b>BÖHLER W350</b> <b>ISOBLOC</b> ®	0.38	0.20	0.55	5.00	1.75	-	0.55	-	-	-	-
<b>BÖHLER W360</b> <b>ISOBLOC</b> ®	0.50	0.20	0.25	4.50	3.00	-	0.55	-	-	-	-
<b>BÖHLER W400</b> <b>VMR</b> ®	0.37	0.20	0.25	5.00	1.30	-	0.45	-	1.2340 ~ X37CrMoV5-1	~ H11	Z36CDV5 ~ Z38CDV5
<b>BÖHLER W403</b> <b>VMR</b> ®	0.38	0.20	0.25	5.00	2.80	-	0.65	-	~ 1.2367 ~ X38CrMoV5-3	-	~ Z38CDV5-3
<b>BÖHLER W720</b> <b>VMR</b> ®	max. 0.005	max. 0.05	max. 0.10	-	5.00	18.50	-	Co = 9.00 Ti = 0.70 Al = 0.10	~1.2709	-	-
<b>BÖHLER W722</b> <sup>2</sup> <b>VMR</b> ®	max. 0.005	max. 0.05	max. 0.05	-	4.90	18.00	-	Co = 9.30 Ti = 1.00	<1.2709 >	-	-

<sup>1</sup> also available in ISODISC quality

<sup>2</sup> Special grade, please enquire before ordering





BÖHLER grade	Applications	
<b>BÖHLER W300</b> <sup>1</sup> <b>ISOBLOC</b> ®	Primarily for the processing of light metal alloys	Highly stressed hot work tools, such as mandrels, dies and containers for metal tube and rod extrusion.
<b>BÖHLER W302</b> <sup>1</sup> <b>ISOBLOC</b> ®		Hot extrusion tools, die casting tools, forming dies, die inserts, hot shear blades.
<b>BÖHLER W303</b> <b>ISODISC</b> ®		Tools for the manufacture of hollows, tools for the manufacture of screws, nuts, rivets and bolts.
<b>BÖHLER W320</b> <b>ISODISC</b> ®	Primarily for the processing of heavy metal alloys	
<b>BÖHLER W350</b> <b>ISOBLOC</b> ®	Primarily for the processing of light metal alloys	
<b>BÖHLER W360</b> <b>ISOBLOC</b> ®	Primarily for the processing of heavy metal and light metal alloys	Dies and punches in warm and hot forging. Tooling for high speed presses. Toughness-critical cold work applications. Extrusion tooling, e.g. dies. Core pins and inserts in die-casting dies. Specific applications in the plastic processing sector.
<b>BÖHLER W400</b> <b>VMR</b> ®	Primarily for the processing of light metal alloys	Highly stressed hot work tools, such as mandrels, dies and containers for metal tube and rod extrusion. Die casting tools, forming dies, die inserts, hot shear blades.
<b>BÖHLER W403</b> <b>VMR</b> ®		Hot extrusion tools, tools for the manufacture of hollows, tools for the manufacture of screws, nuts, rivets and bolts.
<b>BÖHLER W720</b> <b>VMR</b> ®	Hot and cold work tool steel for long-time service up to abt. 450 °C. Tools for hydrostatic presses, cold extrusion tools, cold heading and embossing tools, moulds for the plastic industry, die casting tools for aluminium and zinc alloys, hot pressing tools, cold pilger mandrels.	
<b>BÖHLER W722</b> <b>VMR</b> ®	Cold heading and embossing tools, cold extrusion tools, casings, shear plates, moulds for the plastic industry, die casting tools for aluminium and zinc alloys, hot pressing tools.	

<sup>1</sup> also available in ISODISC quality

# HIGH PRESSURE DIE CASTING PROCESS

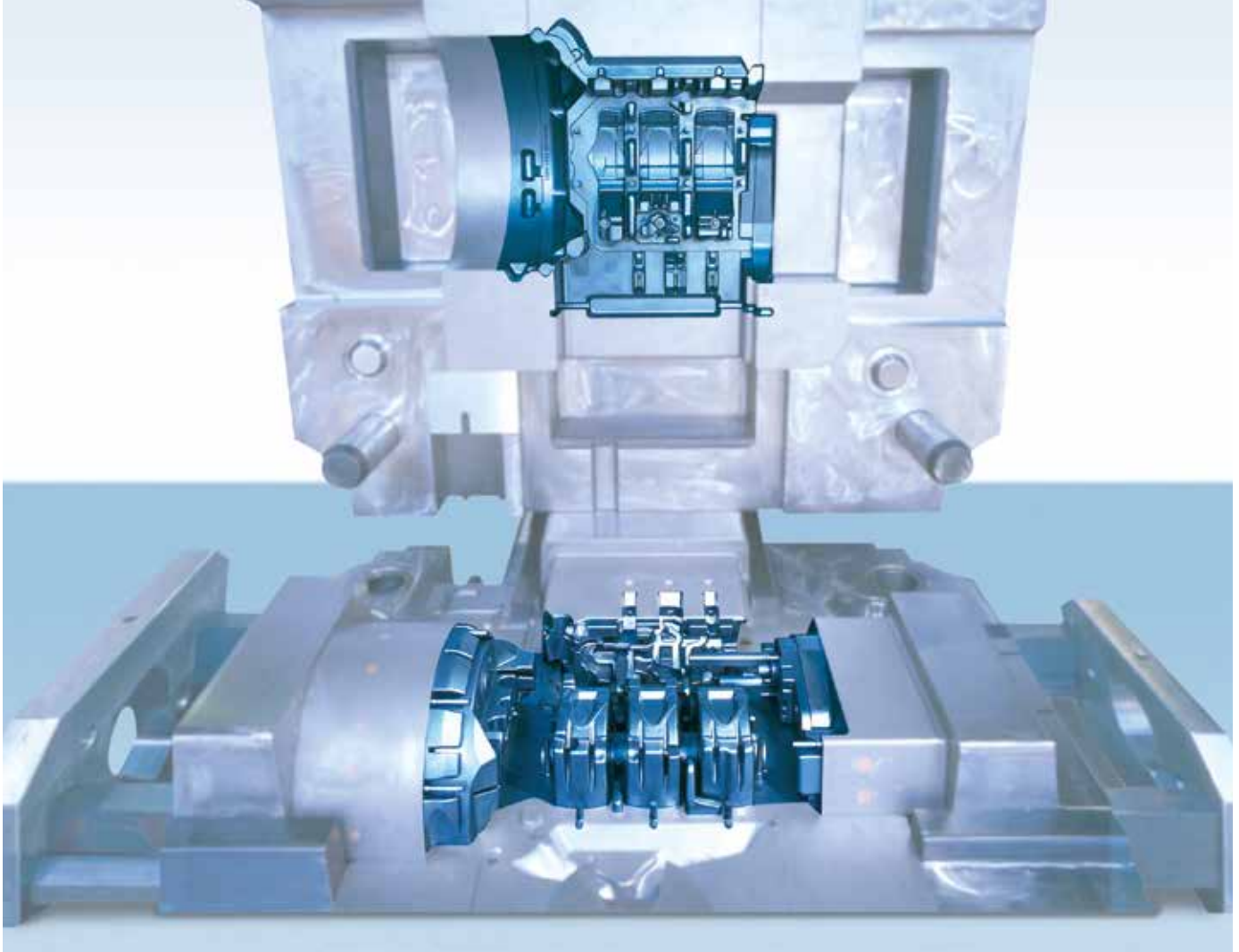
## DIE CASTING

In die casting liquid metal is injected into a die of the exact shape in which, under pressure, it solidifies. Meltings processed in this manner encompass materials with lower melting points such as tin, lead and zinc alloys, those with mid-range melting points such as aluminium or magnesium and their alloys, up to copper alloys with higher melting points.

In the **cold chamber die casting process** the melting of the metal to be processed is drawn in portions from a dosing furnace and filled into a casting chamber by means of a ladling device. Afterwards the metal that was poured in is pressed into the die with a hydraulically driven plunger. Due to the fact that the casting chamber does not come into contact with the liquid melting during the entire casting process, thus is cold in contrast to the melting, the term cold chamber process is used. In the **hot chamber die casting process** the casting chamber is in constant contact with the melting. This chamber is at casting temperature.

Since aluminium alloys and copper alloys react with the steel of the casting chamber, a longer contact of this melt with the tool components leads to erosion and corrosion. For this reason these metals are processed using the cold chamber procedure. In order to be able to guarantee even casting of the dies without premature solidification on thin gage parts as well, the melt is moulded under pressure of 200 – 300 bar. Due to these high pressure conditions the casting processes take place correspondingly quickly. Even the dies of aluminium castings weighing several kilograms are filled within seconds.

Nowadays approximately 80% of the aluminium castings are produced using the cold chamber die casting procedure.



Requirement profile	Casting chamber	Piston	Die	Core
Wear resistance	★★★★	★★	★★★	★★★
Retention of hardness	★★★	★★	★★★	★★★★★
High temperature strength	★★	★	★★★	★★★
Heat checking resistance	★★	★	★★★★	★★★★★
High temperature toughness	★★	★★	★★★★★	★★★

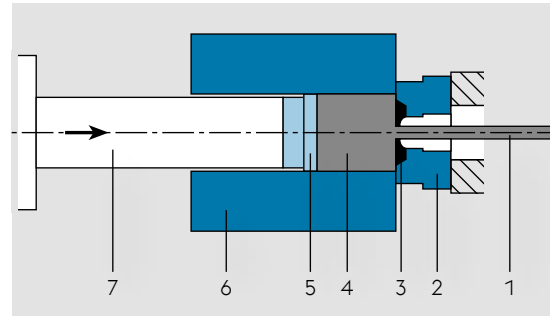


# ROD EXTRUSION

## DIRECT EXTRUSION

Direct extrusion is the process used most often. Here the billet to be extruded is pressed towards and through the die by the stem. The friction arising between billet and liner limits the length of the container. Because the material to be extruded is always deformed at the die end of the container, not only does a higher thermal loading occur here but wear is also more extensive at this point, leading to a very one-sided loading situation.

Since this is the oldest extrusion process, some containers without controllable heating systems are still in operation. Modern direct extrusion presses are usually equipped with a zone-controlled resistance heating system and sometimes also with a cooling system, despite the comparatively short length of the container.

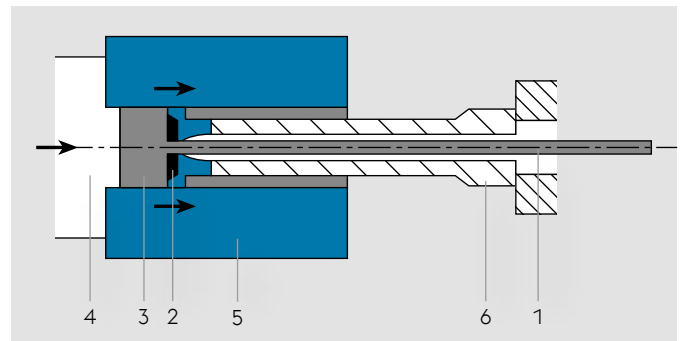


- |              |               |        |
|--------------|---------------|--------|
| 1 Extrusion  | 4 Billet      | 7 Stem |
| 2 Die holder | 5 Dummy block |        |
| 3 Die        | 6 Container   |        |

## INDIRECT EXTRUSION

The indirect extrusion process has gained significant importance in the last few years. In this process the container, with the billet, is pressed directly against the hollow stem, with the result that the friction between billet and liner becomes negligible thus lowering the necessary force. This enables the use of very long containers. The resulting long press times lead to higher thermal stresses in the container components.

Since the extruded material must pass through the bore in the stem, the diameter of this bore limits the dimension of the extrusion which can be produced. In order to be able to produce a wide range of products despite this, the hollow stem is usually designed with a large bore which in turn leads to a high compressive stress on the stem and so necessitates careful selection of materials. Most indirect presses are equipped with containers over 1200 mm in length, meaning that multi-zone heating systems and cooling systems are standard.



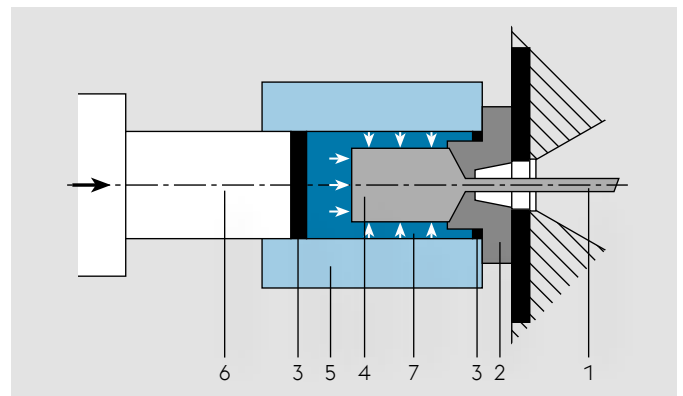
- |                        |                         |        |
|------------------------|-------------------------|--------|
| 1 Extrusion            | 3 Billet                | 6 Stem |
| 2 Dummy block with die | 4 Sealing plug with die |        |
|                        | 5 Container             |        |





## HYDROSTATIC EXTRUSION

Hydrostatic extrusion is a relatively rare process and is primarily used only for products which are otherwise difficult to manufacture. This process is usually operated at very high pressures so that the container components are subject to a high degree of material fatigue. These tools are a particular challenge for tooling suppliers. Our VMR qualities with the best material properties have proven to be a good solution here.



- 1 Extrusion
- 2 Die
- 3 Seal
- 4 Billet
- 5 Container
- 6 Stem
- 7 Hydrostatic medium

Requirement profile	Mantle	Liner holder	Liner	Stem
Wear resistance	★	★	★★★★	★★
Hot hardness	★★★	★★★	★★★★	★★★★
High temperature strength	★★★	★★★★	★★★★	★★★
Creep resistance	★★★★★	★★★★★	★★★	★
Heat checking resistance	★	★	★★★★	★
Compressive strength	★	★★★	★★	★★★★★
High temperature toughness	★★★	★	★★★	★★

# FORGING PROCESS

Forging is the non-cutting shaping of metals between two tools. The choice of tool steel is primarily determined by the respective forging process.

## DROP FORGING

Drop forging is carried out by impacting material with a hammer or by applying a great amount of pressure with a forging press or forging machine.

When forging with a **hammer** the forging piece is only in contact with the die for a short period of time. Due to this, the die has to withstand lower temperatures. However, the **mechanical stress is high**. Thus, it is quite important for the hot work tool steel used to have very good toughness properties.

Compared with that, the contact during **forging pressing** occurs over a longer period of time, which then causes a **higher temperature strain on the tool**. Thus, in such a case hot work tool steels with a chromium-molybdenum base are used, which are singled out as having good tempering resistance, high temperature strength, hot wear resistance, and hot toughness.





## RAPID FORGING

A fully automatic multi-stage press is forging equipment that produces even the **most difficult shapes from materials hard to deform in several stages of deformation**. This equipment mostly produces **rotation symmetric parts**. Heating the slugs, feeding, shearing and deforming take place completely automatically.

## SEMI HOT FORGING

The term semi hot forging refers to a deformation process in which **the workpiece is preheated to such a point that permanent strain hardening** occurs under the given deformation conditions. This definition means that the material is deformed below the recrystallization temperature, yet the term is also used for temperatures occurring above this. In practice this is understood to be the deformation of steel in the temperature range of 650 to approx. 950 °C. These temperatures lie significantly below the conventional forging temperatures of 1100 – 1250 °C.

Requirement profile	Drop forging with hammer	Drop forging with press	Semi hot forging
Wear resistance	★★★★★	★★★★★	★★★★★
Retention of hardness	★★	★★★★	★★★
High temperature strength	★★★	★★★	★★★★
Heat checking resistance	★	★★	★
High temperature toughness	★★★★	★★★	★★



## ERODING

In the eroding process material on the surface is melted and is withdrawn drop by drop by means of a local electrical discharge. By melting the surface a quickly solidified, untempered martensitic layer, the so-called white layer, is formed. This layer is very brittle and cracks may easily form in this region, disseminating in the base material. In order to minimize the formation of cracks to a great extent the rough pre-machining should always be followed by fine eroding. Low levels of current strength and a high rate of pulse frequency reduce the thickness of the area influenced.

Afterwards the layer should be removed by grinding or polishing or the tool should be tempered 30 °C below the last tempering temperature. Should none of these options be possible, the crack propagation can be reduced by raising the toughness of the tool steel.

Impurities in the dielectric can lead to stray field electrolysis, whereby material is removed in an uncontrolled manner by unwanted discharges. For this reason the quality of the fresh water should be checked on a regular basis. Further information can be found in our pamphlet „EDM Machining of Tool Steels“.

## HEAT TREATMENT

Nowadays heat treatment is not primarily used to regulate the targeted hardness, but rather it influences numerous mechanical properties such as toughness or thermal shock resistance. For this reason it is necessary to treat the BÖHLER high performance steels according to exactly prescribed instructions found in the respective product pamphlets.

Particularly in the hot work tool steel segment the tools are often of enormous dimensions. These dimensions often pose a challenge for the heat treatment process. Hardening should be done in a salt bath or in a vacuum. In order to avoid gross cracking during the heating up, this phase should take place slowly particularly in the lower range, in order to allow for a temperature equalization between the core and the surface.

For this reason at least three pre-heating phases should be planned. In order to obtain optimal structural conditions quick quenching of the hardening temperature is necessary. A warm bath simulation is recommended. In order to avoid cold cracks here.



# TOOLMAKING

## NITRIDING

The term nitriding is used to refer to the enriching of the surface layer of a tool with nitrogen by means of a thermochemical treatment at temperatures of approx. 500 – 580 °C. A layer consisting primarily of nitrogen compounds and thus referred to as a compound layer is formed on the surface due to the high amount of nitrogen available. Metallographically isolated from the layer, the so called diffusion layer, below it, the nitrogen remains in the mixed crystals upon quick cooling. With slower cooling acicular nitrides are precipitated.

The hard compound layer is responsible for the high degree of wear resistance of the workpiece treated and reduces the adhesive gradient and the gradient of cold welding. For this reason, tools exposed to heavy-duty wear are commonly nitrided. Nonetheless it must be considered that by nitriding the potential toughness of a material is substantially reduced. Since the compound layer is quite brittle cracks can easily be formed on nitrided surfaces which then disseminated into the base material.



Before nitriding is performed a perfectly clean, metallically polished surface must be ensured, by means of pickling for instance. In general it should be observed that complicatedly shaped parts with different cross-sections or larger dimensions are to be heated and cooled slowly. In order for the workpiece to be nitrided to remain thermally stable at the nitriding temperature, it should first be tempered at temperatures above the nitriding temperature. Any internal stress is to be eliminated before the nitriding treatment begins by means of stress relieving.



# MAINTENANCE IN APPLICATION



## PREHEATING

Maximum efficiency of the tool can only be obtained with correct treatment both prior to installation and during operation. In order to reduce the jolting thermal stresses from the hot metal which is being processed, and thereby reduce heat checking, the dies must be carefully preheated according to the temperatures of the material to be processed.

Preheating of the dies has to be carried out slowly and thoroughly.



## STRESS RELIEVING

Stresses which arise from the continual changes in temperature and the mechanical load need to be relieved from time to time by means of an appropriate tempering treatment. Experience has shown that an intermediary stress relief improves tool life. This stress relieving treatment should take place over a period of several hours and should occur at a temperature 30 – 50 °C below the highest tempering temperature, followed by cooling in the furnace (cf. the tempering chart in the BÖHLER data sheets).

After disassembly of tools to be kept in stock, cleaning and stress relieving is recommended.

## WELDING

Welding is often necessary with hot work tools. In general both hot work tool steels that have been annealed and those that have already been hardened and tempered are weldable. Preheating to at least 325 °C is absolutely necessary. During the welding procedure the temperature may not drop below this level and should not rise above 475 °C.

After having completed the welding procedure, a slow cooling phase is recommended. Previously annealed material should be annealed once again after the welding treatment. A tool which has already been hardened and tempered should also be brought to 30 °C below the last tempering temperature.

Further information can be found in our pamphlet „Welding in Toolmaking“.



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