



TOOL STEEL

POLISHING IN MOLD MAKING

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THE SURFACE AS A MIRROR OF TIME

But what do they look like, the modern, future-oriented surfaces? Aesthetic, high-quality, robust, easy-care, with top-finish? The requirements to the perfect outer skin are varied. Likewise the fields of application.

The polishing ability of steel for certain application fields is of high importance. Especially in the plastics processing industry very high expectations are often placed on the surfaces of the tools.

The highest surface quality of the tools offers many advantages:

- » **Highest quality surfaces** of plastic parts
- » **Good release properties** (easy ejection) of plastic parts
- » **Improved optical properties** (e.g. for glasses, lenses, flat screens, headlights in the automotive industry)

Highly polished surfaces also offer technological advantages:

- » **Improved corrosion resistance**
Polished surfaces tend to have much smaller corrosive attack than ground surfaces
- » **Improved security against breaks or cracks**
A polished surface has a higher endurance strength and has lower notch effects than ground surfaces.
This results in an **increased tool life.**



REQUIREMENTS FOR STEELS REGARDING GOOD POLISHABILITY

Important parameters for the polishability of steels are the level of purity, the homogeneity of the microstructure and the size or respectively the distribution of carbides and other hard constituents in the steel matrix. Especially inhomogeneities can cause significant problems in polishing.

The homogeneity and purity of steel is significantly influenced by the manufacturing process. Primarily the melting technology as the first step of the production is crucial.

With open melting, oxide inclusions, with larger blocks, cannot be completely ruled out. But not only the size and quantity of inclusion are important for the polishing result, but above all the type of inclusion, which depends on the deoxidation process in steelmaking. Disadvantageous are larger, hard and brittle oxides, as they are „polished out“ during the polishing process and thus pores can be left behind.

A modern steelworks technology with corresponding secondary metallurgy reduces the oxygen content and thus the oxide content in the steel so far that critical inclusion sizes can be minimized. Block formats adapted to the final dimensions and a heat treatment appropriate to the material reduce segregations, and therefore compensate the differences in hardness, so that homogeneity differences hardly influence the polishing result.

In principle, the segregation state and thus the homogeneity of the steel can be improved by remelting processes such as vacuum arc remelting (VAR) or electroslag remelting (ESR/PESR). At the same time, non-metallic inclusions are minimized in these processes. The best level of purity is achieved by melting in the vacuum induction furnace (VIM) or remelting under vacuum (VAR).

INFLUENCING FACTORS ON POLISHABILITY

STEEL QUALITY

- » The melting process is decisive for the purity of steel
- » Inclusions in steel, mostly sulphidic, can be harder than the surrounding material and thus lead to elutriation
- » Often, inclusions are several microns in size and have elongated shapes

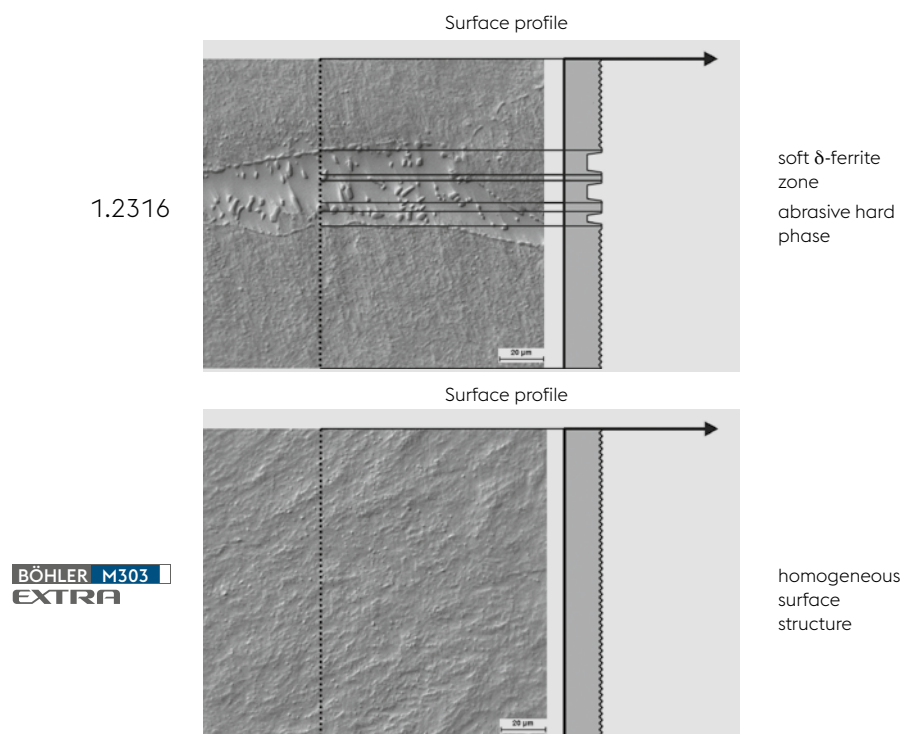
ALLOYING COMPONENTS

- » Form hardness differences in the structure
- » Lead to elutriation
- » in crystal form lead to breakouts of the surface

How the alloying design influences the polishability shows the following example:

In the case of steel 1.2316, the hard carbide phases embedded in the soft delta ferrite zone give a more irregular polishing result. In return, BÖHLER M303 EXTRA offers a uniform polishing pattern and thus a clear advantage compared to the standard.

Surface comparison





MANUFACTURING PROCESSES

Remelted steels

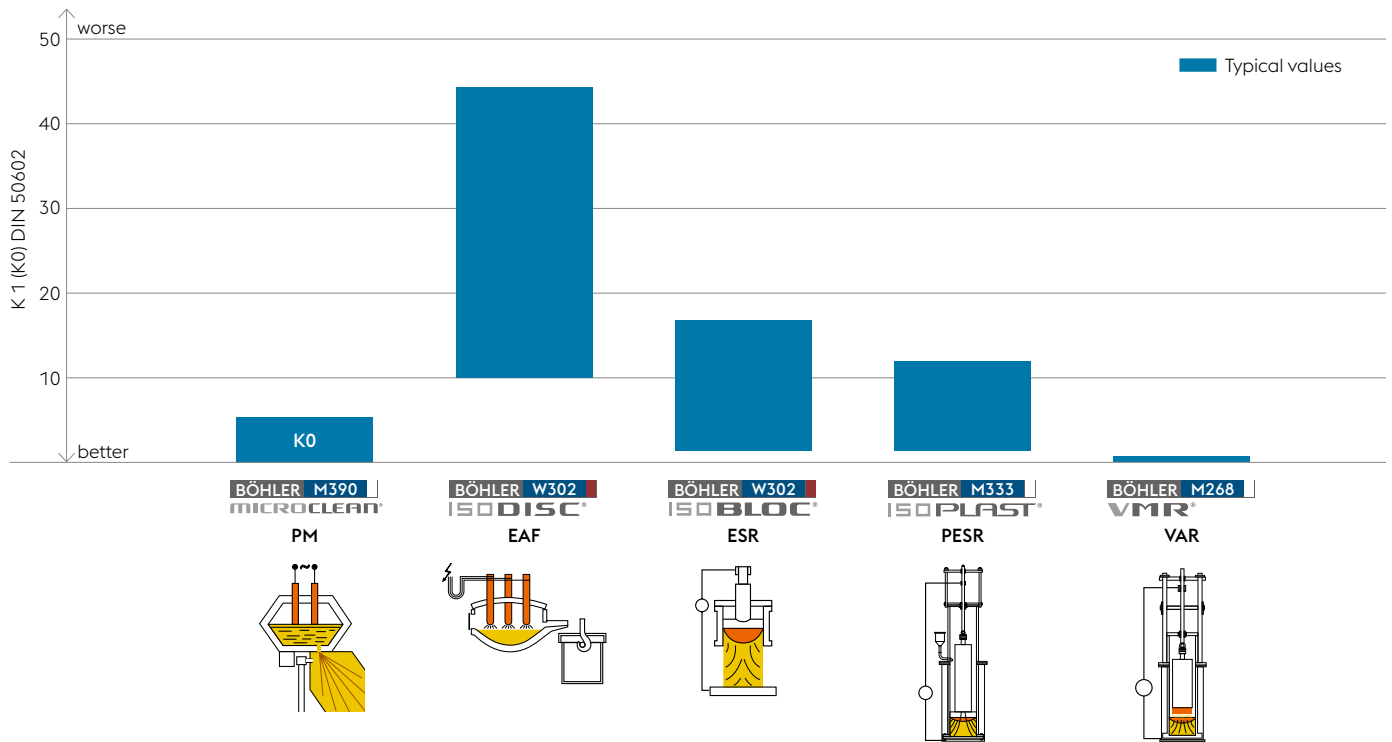
have the following advantages compared to conventionally produced steels:

- » Uniform primary structure and extensive absence from block segregation and internal defects due to solidification
- » Low crystal segregations and thus more uniform microscopic microstructure
- » Reduced quantity and size as well as better distribution of non-metallic inclusions (better level of purity)

Powder metallurgically produced steels

are mostly high-alloy tool steels and have isotropic properties as well as a fine structure. The carbides are homogeneously distributed in the size of a few microns in the matrix, which has a positive effect on the polishability.

Purity depending on the melting process



HEAT TREATMENT

For best polishing properties the heat treatment should be performed very carefully and preferably in vacuum or protected gas furnaces. Due to carburization or decarburization effects in course of the heat treatment uneven hardness at the tool surface and so worse polishing behavior can arise. Either precipitations at the grain boundaries or grain growth due to unfavorable austenitizing temperatures, holding times as well as slow cooling rates can influence the polishability negatively.

ERODE

Eroded surfaces should be given special attention during polishing. The erosion process causes a structural change on the surface. It can lead to an enrichment of the steel surface with carbon, which in turn leads to the formation of carbides. Furthermore, the rapid local solidification leads to a very brittle martensite. This so generated carbides increase the risk of pinholing, breakouts and orange peel. For a good mirror finish polish, the material must be removed to below the eroding skin.

3 QUALITY LEVELS 3 TECHNOLOGIES

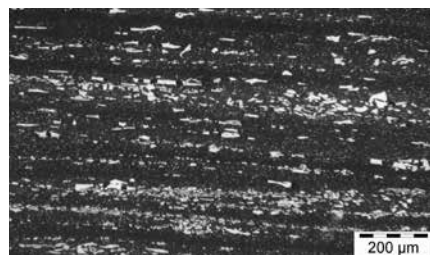
BASIC



Conventional production

Products made using the electric arc process are designated as conventionally melted materials and are the “basic materials” for ordinary loading, with the following primary properties:

- » Banded carbide distribution
- » Sufficient cleanliness



Micro structure of conventional 12% chromium steel

PREMIUM



ESR / PESR or VAR Manufacture

Products with improved properties can be produced using the ESR / PESR or VAR method. Using remelted materials leads to longer tool life due to:

- » High level of cleanliness
- » Low segregation
- » Larger bar dimensions can be produced with the same carbide distribution
- » Uniform dimensional changes
- » Improved toughness



Microstructure of 8% chromium steel in ESR grade

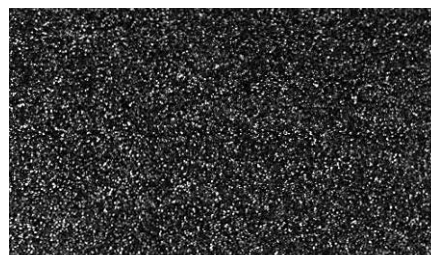
SUPERIOR



Powder metallurgical production

Materials produced using powder metallurgy are increasingly being used to meet the most stringent requirements with various processing methods. These materials offer properties that meet demanding requirements:

- » No segregation
- » Extremely fine carbide distribution
- » Homogeneous properties
- » High wear resistance
- » Very good dimensional stability
- » High compressive strength
- » High toughness with high hardness



Microstructure of PM materials

THE RIGHT POLISHING TECHNOLOGY IS DECISIVE



TYPES OF POLISHING

The requirements for the surface of a workpiece arise from the intended application areas. It is roughly divided into 4 qualities:

Stroke polish

- » Simple surfaces - finishing mostly with abrasive cloths, polishing bench stones or files
- » Used to facilitate demoulding of molded or die cast parts
- » Applying with non-visible surfaces, e.g. inside of a housing
- » As a preparation for nitrating and graining
- » Tools used have a grain size between 320 – 400

Gloss polish

- » Smaller processing marks are often still visible
- » Surfaces and recesses are shiny
- » Especially for visible parts, which should be visually appealing (household items, transparent parts...)
- » Clean shiny surface, controllable with the eye
- » Final polish with felt and diamond pastes between 3 – 6 µm achievable

Mirror finish

- » No visible scratches or cords (crack-free mirror finish)
- » Especially used when products are chrome-plated

Dimensionally accurate and form-true mirror finish

- » Highest demands on the surface
- » In addition to the crack-free high gloss also the adherence with the macrostructure is required, i.e. flatness, sharp edges and angularity

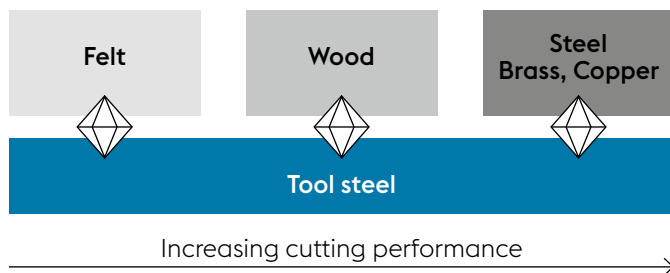


INFLUENCE OF CARRIER MATERIAL / POLISHING TOOL

The hardness of the carrier material and the size of the polishing grain can be decisive for the roughness depth of the surface to be processed. The greater the penetration depth into the polishing tool at same grain size, the lower the penetration depth into the workpiece surface or the cutting performance of the polishing agent. The adhesion of the grains in the polish carrier is crucial for the polishing result. If the grains adhere firmly to the polishing agent carrier, the cutting process is favored and rolling of the polishing agent on the workpiece surface is avoided. The stickiness of the grains can in turn be influenced by the processing pressure or the liquid used.

Requirements for a successful polishing are:

- » Proper rough grinding and finishing
- » Selection of suitable polishing tools and polishing pastes
- » Avoidance of overpolishing
- » Avoidance of high contact pressures
- » Careful care and cleaning of the polishing tools
- » Cleanliness (best cleanroom-like conditions)



LISTEN TO YOUR EYES

POLISHING PROCEDURE

Due to the mutual influence of the many influencing factors, it is not possible to draw up general guidelines for the creation of a polished surface. The selection of the individual work steps and the respective polishing agents and tools is primarily determined by experiments and experiences. The following polishing guide represents a common sequence of operations from machining to polishing.

Depending on the quality and processing of the starting surface (eroded, milled or ground), an abrasive wheel with a grain size of 320, 400 or 600 is chosen to completely remove the traces of prefabrication. An optimized polishing result is achieved by sandblasting after the finishing, whereby the surface is compacted.

The polishing process follows in several steps. Starting with a harder carrier such as hardwood, brass or plastic with a paste of about 15 microns (roughly corresponds to an abrasive grain of 1000 – 1200). All traces from the previous step should be removed. Subsequently, the hardness of the carrier / tool is maintained but the grain of the paste is reduced e.g. 9 µm. After this step, the carrier can be changed to a softer medium such as e.g. felt or softwood. This scheme is repeated until finally the grain size 1 – 3 microns with felt or a flocced cloth is used.

Starting surface	Polishing bench stone or linen				Emery cloth or hardwood with paste	Softwood or polishing felt	Polishing felt or cloth
Eroded	K320	K400	K600	K800	K1000 15 µm	6 µm 9 µm	3 µm
Finely milled							
Fine ground							
R_o (µm)	0.4	0.3	0.2	0.1	0.06	0.03	0.02
R_z (µm)	3.2	2.3	1.2	0.7	0.4	0.2	0.15

CLASSIFICATION OF POLISH DEFECTS



The content „Classification of polishing defects“ has been provided by courtesy of the Fraunhofer Institute for Production Technology IPT.

Source: PROCESSTRATEGIES FOR DEFECTFREE POLISHED STEEL SURFACES, pages 9 – 15, Fraunhofer Institute for Production Technology IPT

LAMINARY DEFECTS

Scratches

Non-directional flat recesses, mostly caused by the cutting edges of the polishing particles or foreign particles (depth ~ roughness Rt).

Tips

- » Depending on the requirements of the surface fine scratches can persist
- » Pay attention to the cleanliness of the environment, that no foreign particles cause scratches
- » Final polishing with small abrasive particles

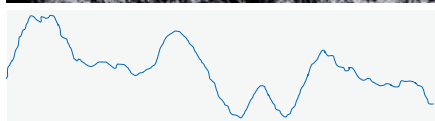
Orange peel

Fine valleys and hills give the appearance of an orange peel. Excessive pressure or too long polishing time can cause such a defect.

Tips

- » Work with low pressures
- » Do not polish too long (» overpolish «)

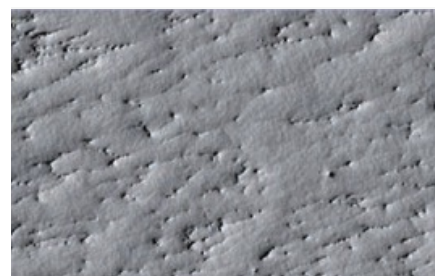
Orange Peel



Pitting



Relief



Mist

Less shiny surfaces. Mist may result from deposits of the polish.

Tips

- » Use pH-neutral polishes that do not cause a chemical reaction
- » Work with low pressures to prevent the polishing grains from being pushed in

Pitting

Surface pitting means many small holes that are spread over the entire surface.

Tips

- » Keep pressure constant
- » Short polishing steps, cleaning in between and good dry to avoid corrosion

Relief

Differences in the removal of individual phases due to different material phases (hard / soft).

Tips

- » Before polishing, make sure that the material structure is as homogeneous as possible in order to keep the different material phases low
- » When polishing, choose a tool that is as hard as possible, so that the material phases are removed evenly despite different hardnesses

FORM DEVIATIONS

Edge radiusing

Undesired material removal on workpiece edges.

Tips

- » Use suitable polishing tool: hard polishing cloth with low impact resilience
- » Reduce pressure

Ripple

According to DIN EN ISO 8785, the ripple is a deviation of the actual geometry in the millimeter to centimeter range. It mainly occurs during manual polishing.

Tip

- » Homogeneous pressure distribution during the polishing process to achieve a uniform removal

CLASSIFICATION OF POLISH DEFECTS



LOCAL DEFECTS

Cracks

Very deep scratches, sharp edges, mostly due to high material stress.

Tip

» Avoidance during the polishing process is not possible, because it is more a material error. For this reason, the workpiece should be examined in advance for invisible cracks / material defects.

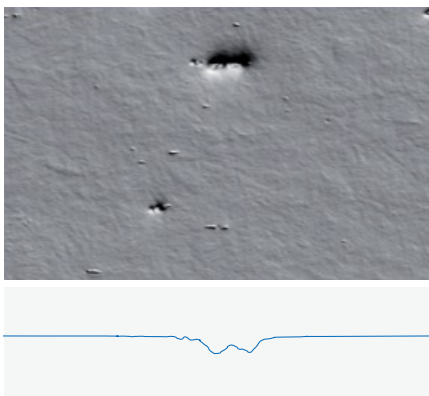
Holes / Breakouts

Unevenly shaped holes. They are formed where non-metallic inclusions and carbides are present in the microstructure.

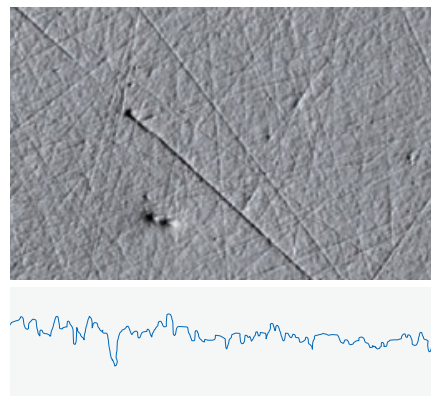
Tips

- » Work with low pressures to avoid tearing
- » Use the most homogeneous steel structure as possible in advance, if the surface quality requirements are very high (purity level)
- » Use a napless polishing cloth, as this promotes tearing out of carbides and inclusions
- » Low pressures already during pre-grinding and fine grinding

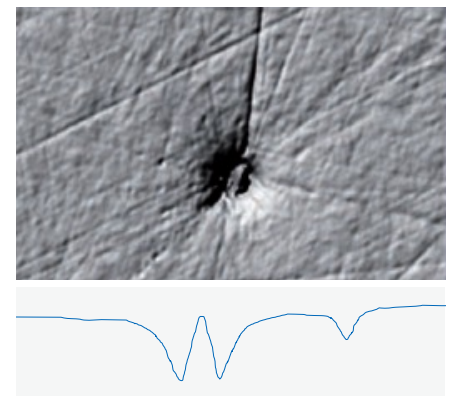
Holes / Breakouts



Scoring



Impurities



Scoring

Deep, directional tracks (depth >> roughness Rt). They arise when the processing traces of the previous step (usually the pre-processing) were not completely eliminated.

Tip

- » Always remove pre-processing marks thoroughly

Peak

Uneven elevations. These are either workpiece material that has been unevenly removed during the polishing process, or polishing particles that have pressed into the surface during the polishing process.

Tips

- » Homogeneous pressure distribution
- » Use high viscosity polish

Comet tails

Inclusions that have a „tail“ and therefore the appearance of a comet.

Tips

- » In the metallographic sample preparation, it should not be possible to polish in synchronism when comets appear
- » When polishing manually, a higher speed can prevent comet formation

Impurities

A hole filled with foreign material (dirt particles or material removal products).

Tips

- » Working clean
- » Use low pressures to prevent the particles from getting into the hole

FURTHER DEFECTS

Corrosion

Reaction of machined workpieces with substances from the environment. Corrosion often results from poor drying after cleaning.

Tips

- » Clean and dry samples immediately after processing
- » Store samples dry

Burn mark

Fire pattern on the workpiece surface. Caused by too much heat during the polishing process and often causes damage to the surface structure (microcracks).

Tip

- » Use sufficient coolant / lubricant during the process

Discoloration

Area that appears differently (in most cases dull) to the actual surface. Topographically, there is usually no difference.

Tips

- » Use neutral polishes to avoid damage to the surface
- » For soft material, work with low pressures to prevent polishing grains from settling in the surface

For post-processing of BÖHLER tool steels joke recommends:

ENESKAmicro from joke – the new generation of grinding, polishing, milling and deburring.

**On-off-switch directly
at the motor**

**tool holder & motor
producer overall
compatible**

**highest
clamping
force
worldwide**

**refined
tool holder**

**30 % more
power**

**highest
concentricity**

**20 % higher
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to IP 54**

**extremely
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ASSESSMENT OF POLISHABILITY

The surface quality of forming parts of compression or injection molds is often defined by indications such as „polished“ or „mirror polished“, without these terms being defined in standards by measurable variables. Although a good reproducibility can be achieved by specifying the processing steps required for a certain surface quality, however, no guarantee of the predefined polishing quality can be given by the before mentioned influences.

The visual impression of a smooth, shiny surface is composed of a variety of optical and physiological effects. As a result, the correlation of the visual impression with quantitatively measurable variables is difficult. Therefore, the subjective assessment of the surface finish by experts is widespread.

POLISHING OF BÖHLER GRADES



The following assessment of polishability was conducted with experienced polish specialists at **joke-Technologies**. The assessment is based on the basic suitability of the material for **mirror polishing** and the **time** required for polishing.

The assessment refers to small round dimensions (50-80 mm) and polishing transverse to the grain direction and represents a principal comparison of the polishability of the grades. In actual workpieces, deviations from the polishability due to the dimension, the removal position and the structural coherency between the fiber direction and surface of the workpiece to be polished may occur. In addition, the polishability depends on the type of polishing process and the sequence of polishing steps.

Wear-resistant, non-corrosion resistant steels

BÖHLER K110	★
BÖHLER K340 ISODUR®	★★
BÖHLER K360 ISODUR®	★★
BÖHLER K390 MICROCLEAN®	★★★★
BÖHLER K490 MICROCLEAN®	★★★★★
BÖHLER K600	★★★★★
BÖHLER K890 MICROCLEAN®	★★★★★
BÖHLER S390 MICROCLEAN®	★★★★

Hot work tool steels

BÖHLER W300 ISOBLOC®	★★★
BÖHLER W302 ISOBLOC®	★★
BÖHLER W350 ISOBLOC®	★★★★
BÖHLER W360 ISOBLOC®	★★★★
BÖHLER W400 VMR®	★★★★★
BÖHLER W403 VMR®	★★★★★

Hardenable, corrosion resistant steels

BÖHLER M310 ISOPLAST®	★★★
BÖHLER M333 ISOPLAST®	★★★★★
BÖHLER M340 ISOPLAST®	★★
BÖHLER M368 MICROCLEAN®	★★★★
BÖHLER M390 MICROCLEAN®	★★★
BÖHLER N685	★

Prehardened steels, non-corrosion resistant

BÖHLER M200	★★
BÖHLER M261 EXTRA	★★★
BÖHLER M238	★★★
BÖHLER M238 EXTRA HIGH HARD	★★★★
BÖHLER M268 VMR®	★★★★★

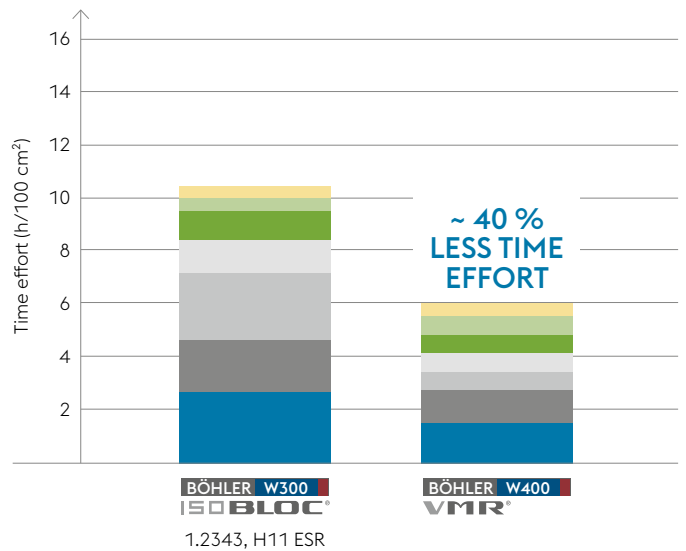
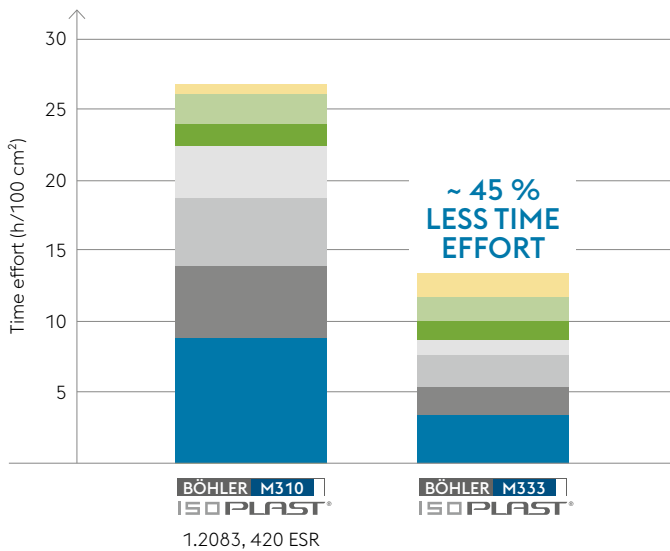
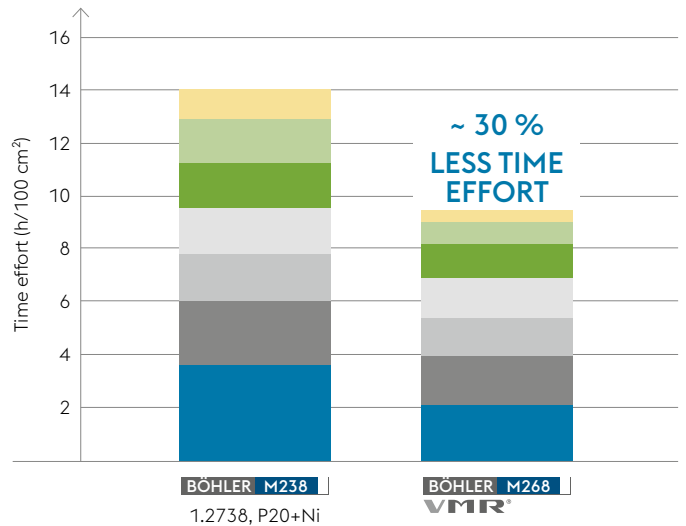
Prehardened steels, corrosion resistant

BÖHLER M303 EXTRA	★★★★
BÖHLER M303 EXTRA HIGH HARD	★★★★★
BÖHLER M314 EXTRA	★★
BÖHLER M315 EXTRA	★
BÖHLER N700	★★★

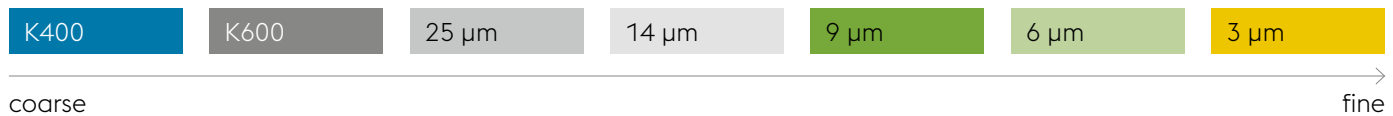
The comparative assessment of polishability takes place within material groups. A comparison of the evaluation of grades of different groups does not make sense.

CASE STUDIES

The following comparison illustrates exemplarily the **time effort reaching a mirror-polished surface** starting from a pre-ground surface.



Polishing steps



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