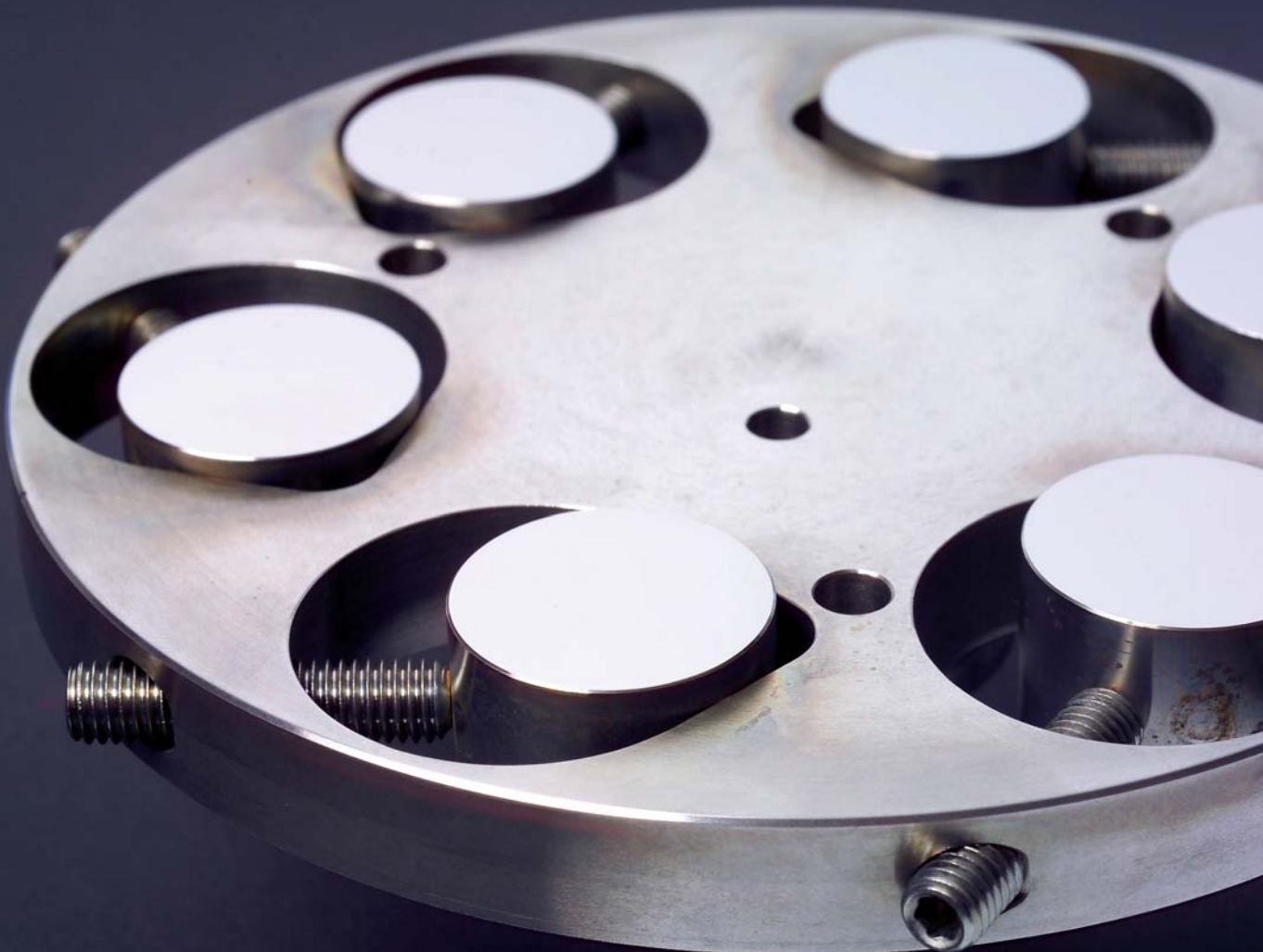




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FRAUNHOFER INSTITUTE FOR PRODUCTION TECHNOLOGY IPT

PROCESS STRATEGIES FOR DEFECT-FREE, POLISHED STEEL SURFACES



INVESTIGATIONS OF INFLUENCES PARAMETERS

As part of the T3 transfer project within the SFB/TR4 collaborative research center, the Fraunhofer IPT has scientifically analyzed the factors influencing the polishing process. The aim was to determine a conclusive explanation for the causes of polishing defects.

The relevant parameters investigated as part of the project are:

- composition and microstructure,
- manufacturing technique,
- polishing kinematics,
- cleaning strategies and
- polishing systems.

Robust process strategies were developed on the basis of many experiments in order to

- assist the manual polisher in his/her work,
- avoid mistakes,
- reduce polishing times,
- create a basis for an automated polishing process and to ultimately produce defect-free surfaces.

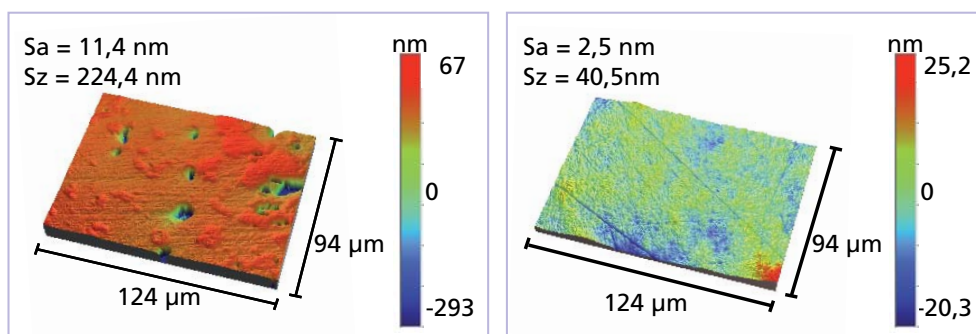
The Fraunhofer IPT therefore examined different types of steel: the work on standard tool steels ensured that the research was relevant to industrial practice. Investigates were also

carried out on an additional steel (1.2379) that is normally not polished in tool-making applications. This was done in order to clarify the effect of the steel composition.

Examined tool steels

- 1.2083 (X40Cr14)
- 1.2311 (40CrMnMo7)
- 1.2316 (X36CrMo17)
- 1.2343 (X38CrMoV5-1)
- 1.2343mod. (X35CrMoV5-1)
- 1.2367 (X38CrMoV5-3)
- 1.2379 (X153CrMoV12)
- 1.2738 (40CrMnNiMo 8.6.4)
- 1.2738mod. (26MnCrNiMo 6.5.4)
- 1.2767 (X45NiCrMo4)

Experiments on different steel compositions have shown that slight differences in the alloy components manganese, molybdenum and vanadium do not have an effect on the polishing result. Analyses of the different microstructures and steel manufacturing processes clearly prove that the amount of carbides and non-metallic inclusions have a decisive effect on the quality of the polished surface.



Results of measurements taken of polished steel samples using white light interferometry: 1.2379 (left), 1.2083 (right)

CLASSIFICATION OF POLISHING DEFECTS

Defects which affect wide areas

Scratches

Non-directional flat indentations, normally caused by the sharp edges of the polishing particles or foreign particles (depth ~ roughness R_t).

Tip:

- Fine scratches can be left untreated if the surface requirements are less rigorous.
- Ensure that the working environment is clean in order to prevent foreign particles causing scratches.
- Use smaller abrasive particles for the final polishing step.

Orange peel

Fine peaks and valleys that give the impression of an orange peel. Polishing for too long or the use of excessive pressure can lead to this type of defect.

Tip:

- Work at lower pressure.
- Avoid over-polishing.

Haze

Less shiny surface areas. Haze arises where abrasives are deposited.

Tip:

- Use a neutral pH abrasive that does not cause chemical reactions.
- Work at low pressure to avoid grains being forced into the material.

Pitting

Also "dimples". Numerous small holes distributed across the entire surface.

Tip:

- Maintain constant pressure.
- Polish for short periods, clean the material in between and dry thoroughly in order to prevent corrosion.

Relief

Differences in the removal of each material phase due to differences in hardness between the phases.

Tip:

- Before polishing, check for material homogeneity in the microstructure in order to reduce the differences between material phases.
- Use the hardest possible tool for polishing in order to remove the material phases evenly despite the different hardness.

Form deviations

Edge effects

Undesired material removal at the workpiece edges.

Tip:

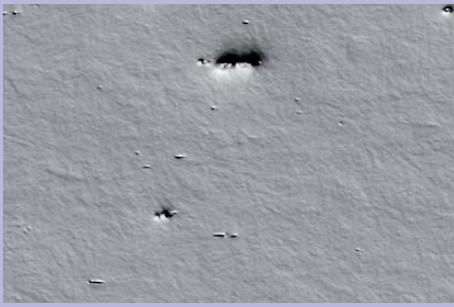
- Use the appropriate polishing tool: a hard polishing cloth with low impact resilience.
- Reduce pressure.

Waviness

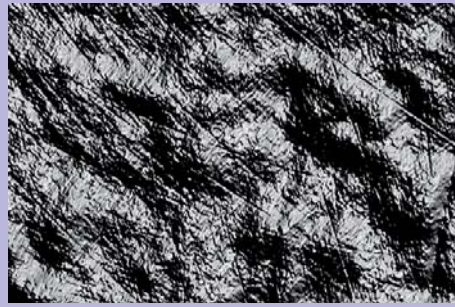
According to DIN EN ISO 8785, waviness is a deviation from the desired geometry in the millimeter to μm range. It occurs mainly during the manual polishing process.

Tip:

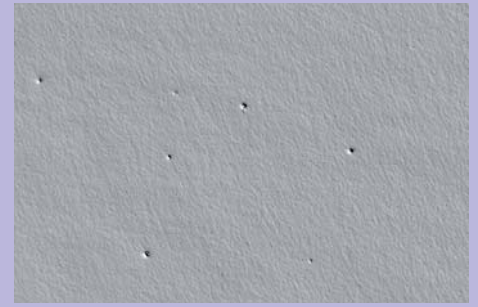
- Distribute pressure homogeneously during the polishing process to ensure that material is removed evenly.



Holes/Pull-out



Orange peel



Pitting



Local imperfections on the surface

Peak

Groove

Deep, aligned marks (depth $\gg$ roughness R_t). These arise when the traces of previous machining operations (generally pre-processing operations) have not been fully eliminated.

Tip:

- Always thoroughly remove traces of pre-processing.

Uneven elevations. This is due to either the workpiece material being removed unevenly during the polishing process or to polishing particles being forced into the workpiece surface during the polishing process.

Tip:

- Homogeneous pressure distribution.
- Use an abrasive with a higher viscosity.

Cracks

Very deep scratches, sharp edges, generally due to strong loads on the material.

Tip:

- Cannot be avoided during the polishing process as it is more a problem of the material itself. The workpiece should therefore be checked for hidden cracks/material defects beforehand.

Comet tails

Inclusions that leave a trail behind them and giving the impression of a comet.

Tip:

- During metallographic sample preparation, avoid polishing with parallel feed if comets appear.
- During manual polishing, use higher rotational speed to prevent comet tails from emerging.

Hole/pull-out

Irregularly formed holes. They arise where non-metallic inclusions and carbides exist in the steel's microstructure.

Tip:

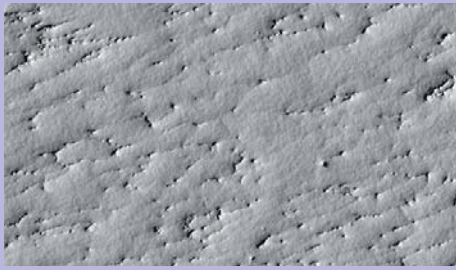
- Work at low pressure in order to prevent the material from being torn out.
- Use the most homogeneous steel possible if the surface quality standards are set very high (degree of purity).
- Use a fluoride-free polishing cloth as this helps to prevent carbides and inclusions being torn out.
- Use low pressures for pre-grinding and fine grinding.

Foreign material

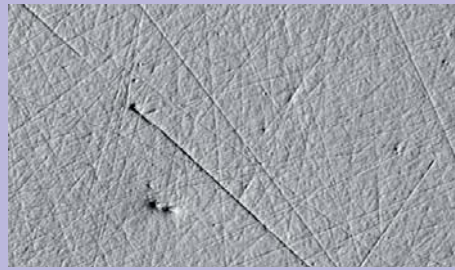
Hole filled with foreign material (particles of dirt or removed material).

Tip:

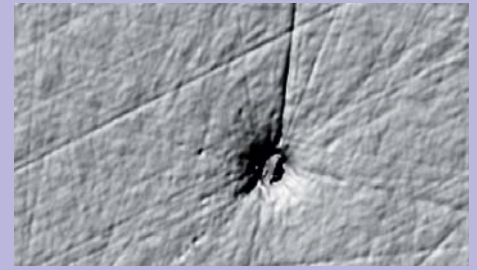
- Clean up work space.
- Work at low pressure to prevent particles being forced into holes.



Relief



Groove



Contamination

Other defects

Corrosion

Reaction of the workpiece to materials in the environment. Corrosion is often the result of insufficient drying after the cleaning process.

Tip:

- Thoroughly clean and dry samples immediately after machining.
- Store samples in dry conditions.

Burn marks

Branding on the workpiece surface. If too much heat builds up during the polishing process, this will often damage the surface structure (micro-cracks).

Tip:

- Use sufficient coolant/lubricant during the process.

Discoloration

Areas that look different to the rest of the surface (generally matt). There is usually no topographical difference.

Tip:

- Use a neutral abrasive to avoid damage to the surface.
- Work at low pressures when polishing soft materials in order to prevent polishing grains accumulating in the workpiece surface.

Defect chart: systematic identification of polishing defects

According to DIN 8589, polishing is not a manufacturing technique in its own right and is only used in combination with other manufacturing processes such as polish grinding, honing and lapping.

In the tool and mold making industry, the different "polishing levels" such as brush finish, gloss or high-gloss are considered the subjective opinion of the polisher. The divergence in quality standards often leads to disputes or even legal proceedings between steel manufacturers, polishing specialists and the plastics processing companies.

In cooperation with Halmstad University in Sweden, the Fraunhofer IPT has taken the first step towards standardizing the vocabulary involved in polishing through the creation of its defect chart, based on the European Standard EN ISO 8785. This table is the result of a number of systematic polishing tests.

The aim of further research work at the Fraunhofer IPT is to automate polishing systems, both machine integrated and robot-based, to compensate the disadvantages of manual operations and to make the work of the manual polisher easier. Up to 80 percent of the manual polishing process could be automated, leaving 20 percent of the work to be carried out by hand.

Other research projects deal with the understanding the process of manual polishing, with the automation of fine machining processes and with the qualification of the finished surface.

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