In the SPOTLIGHT

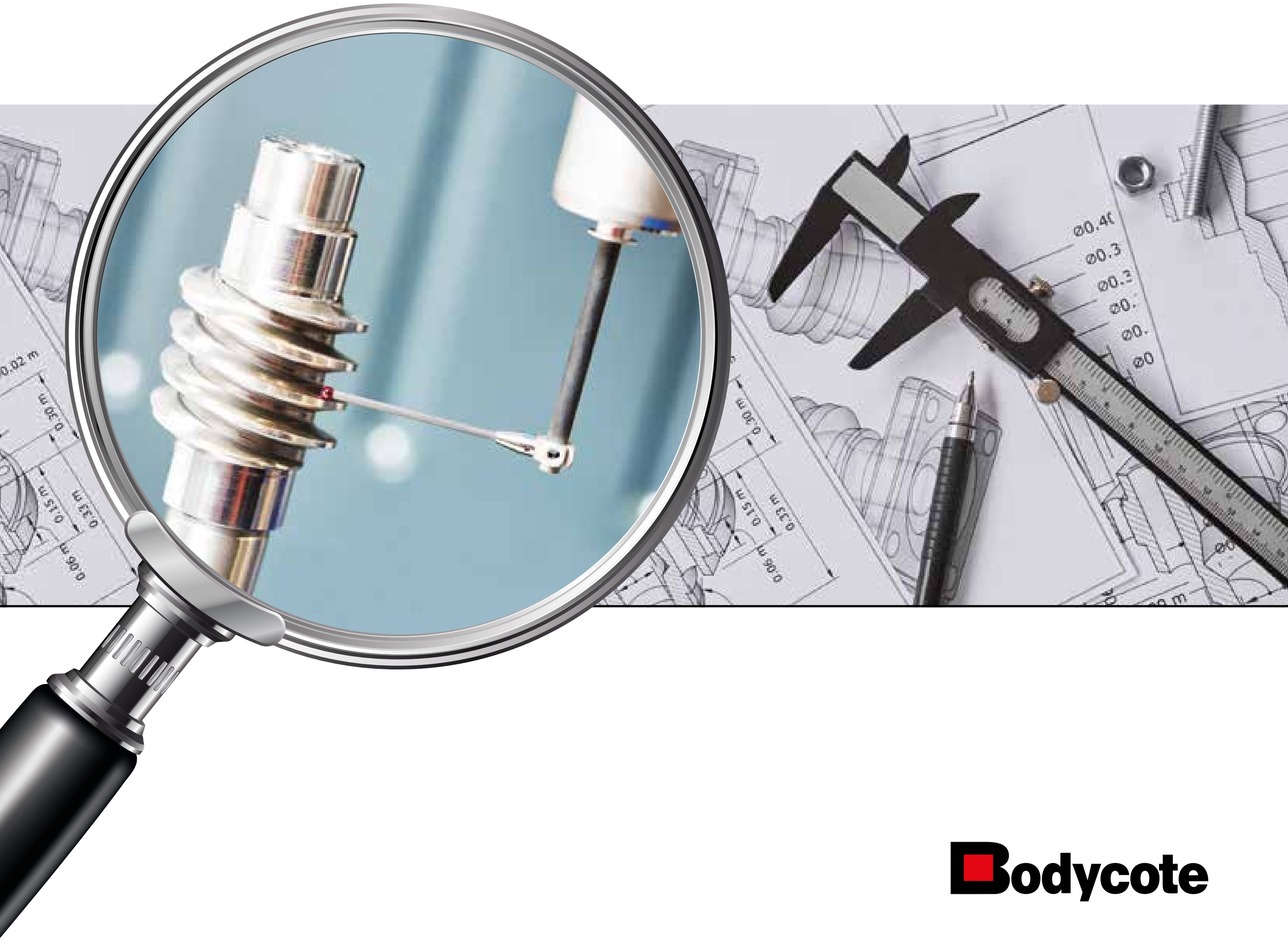
DIMENSIONAL STABILITY OF S³P-TREATED COMPONENTS

RETAINED PRECISE DIMENSIONS

MAINTAINED SURFACE ROUGHNESS

INCREASED WEAR RESISTANCE

UNCHANGED CORROSION RESISTANCE



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DIMENSIONAL STABILITY OF S^{3}P-TREATED COMPONENTS

Sophisticated, precisely machined components often have close dimensional tolerances and low surface roughness values in the smaller one micrometre range. These tolerances and surface morphology essentially determine the functionality of a system, which is why high demands are placed on the individual manufacturing processes.

Dimensional stability after S^{3}P

Stainless steels are often used for high precision components, when they are exposed to corrosive media. However, the rather inferior tribological behaviour restrict the use of these materials in loaded applications. With S^{3}P, featuring Kolsterising® and S^{3}P ADM, the mechanical limitations can be overcome while simultaneously maintaining the outstanding corrosion properties. Close dimensional, shape and positional specifications are typically retained after S^{3}P, as examined for a precision turned part made of AISI 304 (1.4301) in Figure 1. The measured values summarised in Tab. 1 lay within the specified tolerances. Narrow tolerances of less than 10 µm resp. 395 µin should, however, be carefully evaluated.

Parameter		Target [mm]	Before S^{3}P [mm]	After S^{3}P [mm]	Deviation [mm]
∅	Diameter 1	$4.0000^{+0.040}_{-0.000}$	4.0259	4.0251	–0.0008
∅	Diameter 2	$5.0000^{+0.005}_{-0.150}$	4.9711	4.9706	–0.0005
◎	Coaxiality	$0.0000^{+0.060}_{-0.000}$	0.0127	0.0123	–0.0004
—	Straightness	$0.0000^{+0.025}_{-0.000}$	0.0006	0.0007	+0.0001
↗	Circular Runout	$0.0000^{+0.050}_{-0.000}$	0.0172	0.0187	–0.0015

Tab. 1 Selected measurement results of precision turned component made of AISI 304 before and after S^{3}P treatment. No dimensional changes after surface hardening. Specifications are still met.

Surface morphology retained with S^{3}P

When using surface hardening by S^{3}P, large amounts of carbon and/or nitrogen will be diffused into the microstructure of corrosion resistant Fe-, Ni- or Co-based materials at low temperatures (< 500 °C). A homogeneous, precipitation-free diffusion zone is formed. The atomic lattice expands and thus affects both, the base material and the surface of the component. The dimensional and topographical stability is typically not affected by S^{3}P, but can be influenced by several fundamental factors:

- **Material:** Sulphur-alloyed stainless steels contain compounds (e.g. manganese sulphide) that cause fundamentally poor surface topography.
  High-alloyed materials, such as AISI 904L (1.4539), show a larger degree of lattice expansion, which can lead to slight roughening effects after S^{3}P treatment.[1]
- **Machining:** Improperly adjusted, inappropriate, worn turning or milling tools can lead to indention, compression or smearing of material. Similar phenomena can occur within grinding or honing operations. In case of poorly machined or finished surfaces, roughness elevation could arise as a result of lattice expansion within the S-Phase. Therefore, all machining tools, surface preparing tools and processing parameters should be selected to suit the material and the subsequent application. A smooth and uniform surface condition is considered to be optimal for a uniform hardening process and maintain corrosion properties (Fig. 2).
- **Cleanliness:** Residues of adhesive substances (e.g. paints, glues, silicon, cooling lubricants, oil and grease) can decompose through a heat treatment process and can lead to visual or even functional impairments such as roughening or reduced hardening results. This is especially valid for bores, grooves and interior surfaces. Therefore, all components to be treated must be cleaned, metallic bright and free of any adhering residues.
- **Heat treatment condition:** Weld seams or other heat-affected zones can have different residual stress conditions. Further heat treatments, such as S^{3}P, may lead to geometrical or topographical changes due to certain relaxation effects. It is therefore advisable to perform a stress relief or solution annealing before S^{3}P treatment. Similar changes may occur on martensitic and precipitation hardening materials without a suitable heat treatment condition (aged or hardened) prior to S^{3}P treatment.

Roughness measurement

The surface roughness is commonly indicated by R_a, a measuring method based on the averaging of measured values to a reference line, which minimizes the influence of extreme profile peaks and valleys and therefore does not fully describe the surface condition. Comparative measurements of untreated and surfaces treated with Kolsterising® may vary due to this value levelling (see Tab. 2, machined condition). For highly polished surfaces (R_a < 0.1 µm resp. 4 µin) a valid measurement result is to be expected, which can indicate a certain increase in surfaces roughness after S³P (see Tab. 2, lapped condition). Typically, R_a values in the range of 0.8 µm resp. 31.5 µin are required for technical surfaces [2], which are not affected by S³P. A roughness specification with R_z is recommended, since also extreme values are included and thus represent the real surface condition.

If the roughness is no longer in the specified range after surface hardening, the following measures can be taken:

- Optimization of machining quality before Kolsterising®, as described above
- Reworking by suitable processes such as vibratory grinding, polishing or electropolishing and adapted parameters
- However, ablative finishing slightly reduces the surface hardness, which is why this finishing should be limited to a few micrometers after S³P treatment

Surface condition	R_a before S³P [µm]	R_a after S³P [µm]
Machined surface	0.22 – 0.25	0.21 – 0.26
Lapped surface	0.04 – 0.05	0.06 – 0.08

Tab. 2 Comparative measurements of technical surfaces of AISI 904L (1.4539) before and after S³P treatment. Dependent on the surface quality, roughness measurements may vary slightly due to measurement uncertainty. However, on highly polished surfaces (here: lapping) a slight increase in R_a can be observed.

Advantages of S³P

- Increases wear resistance without affecting dimensions
- Retains surface conditions
- Precise function secured in a long-term perspective
- Maintains corrosion resistance

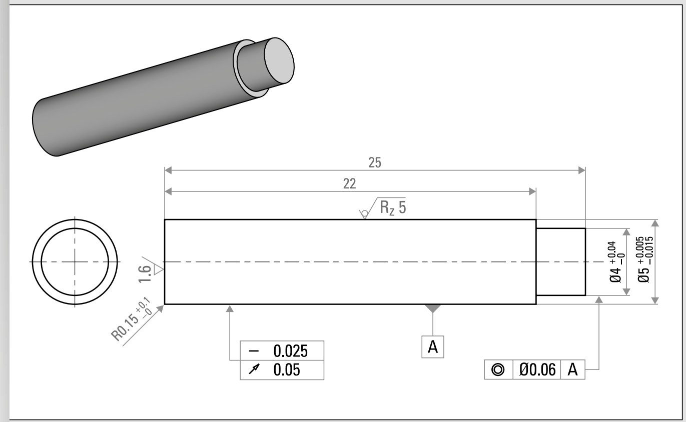

Fig. 1 Technical drawing of precision tuwrned component made of AISI 304 (1.4301) with dimensional, shape and position specifications including tolerances in mm.

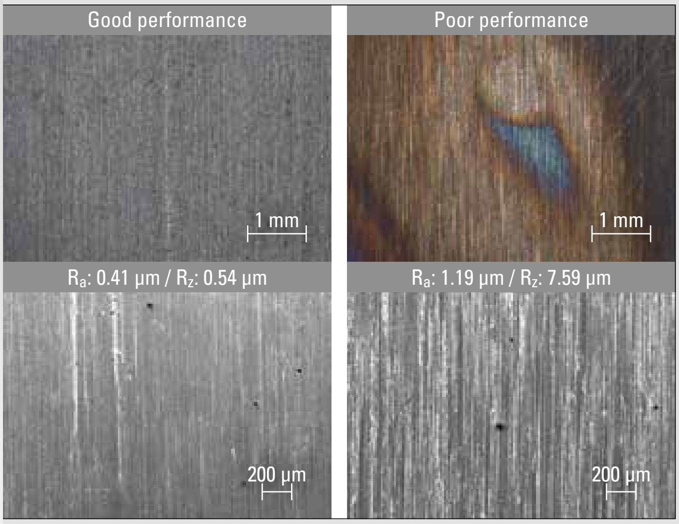

Fig. 2 The corrosion resistance of stainless steels is significantly determined by the machining condition. The finer the surface finish, the higher the corrosion resistance. Example: Two SiC deep grinded surfaces (Material AISI 316L, 1.4404) before surface hardening with good (left, fine grinding mesh) and poor (right, coarse grinding mesh) performance after corrosion testing in 0.5 m NaCl solution.

[1] G. Maistro, L. Nyborg, S. Vezù, Y. Cao: Microstructural characterization and layer stability of low-temperature carburized AISI 304L and AISI 904L, in: La Metallurgia Italiana, 2015

[2] DIN EN 1672-2: Food processing machinery - Basic concepts - Part 2: Hygiene requirements, 2009

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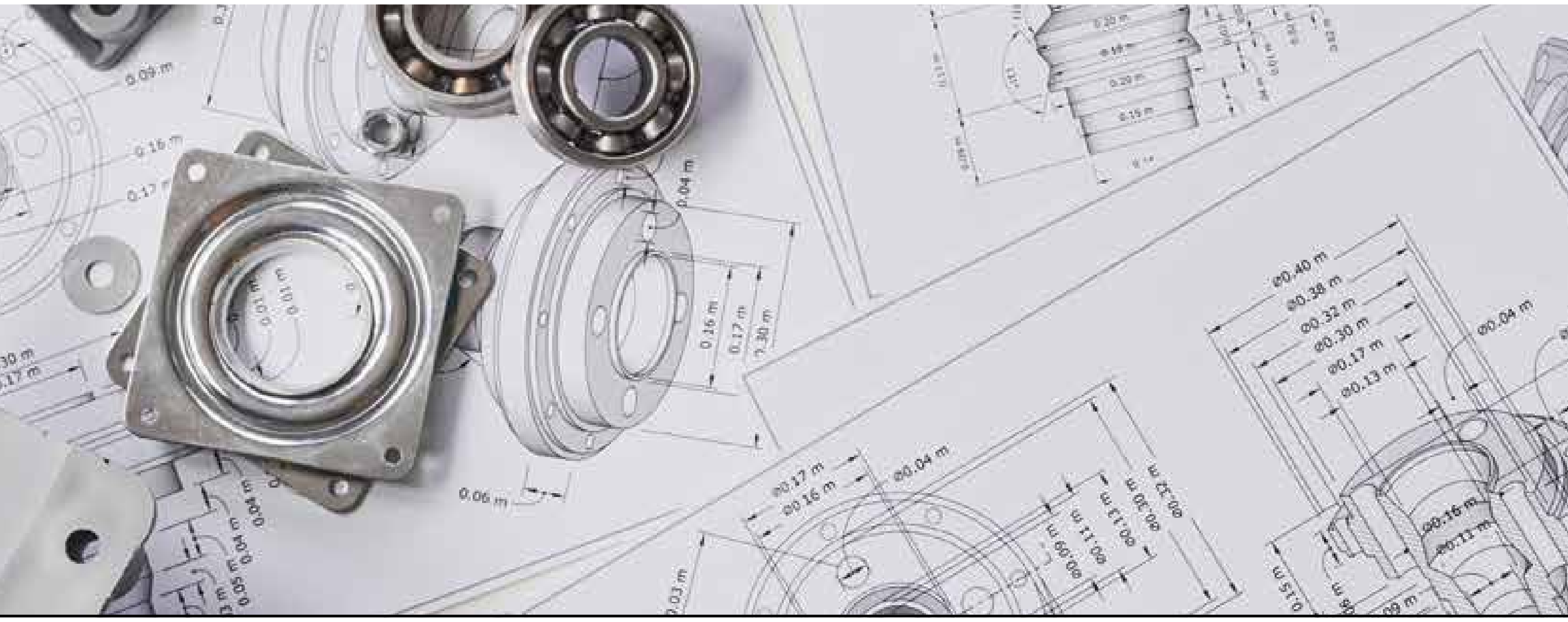

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