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Ageing of roughness artefacts - impact on the measurement results

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Abstract
Ageing effects can influence the properties of engineering surfaces, especially when highly precise surface structures like roughness artefacts are considered. In order to describe the behaviour of roughness artefacts after a given period of use and storage, the impact of ageing on their use and recommendations for their handling are investigated. In the experimental studies the roughness artefacts were exposed to constant temperatures in a climatic chamber and extracted after individually defined time spans before their surface topography was characterised with a large number of stylus instrument measurements. As a quality indicator the ISO 13565-2 roughness parameters were evaluated to characterise the ageing process at different temperatures.

roughness artefacts, ageing, metrology

1. Introduction

The general ageing procedures for many metals, especially steel, have been extensively investigated. However, the specific consequences for high-precision structured surfaces like roughness artefacts have not yet been systematically examined. The contamination of roughness artefacts was analysed in previous work [1]. This new study investigates ageing effects and gives recommendations for storage.

2. State of the art - ageing and internal stress

Ageing includes all irreversible chemical and physical processes which arise in the course of time [2]. The resulting changes in material properties are often undesired. There are reasons for ageing which result from effects within the workpiece and reasons based on the environment of the workpiece. The mechanical ageing of steel is described in literature: Solute carbon and nitrogen atoms diffuse into dislocation troughs [3]. Ageing which is caused by natural climate usually takes months to years, at high temperatures ageing effects occur within minutes [3].

Due to the different composition, the ageing effects of steel cannot simply be transferred to brass. Brass is an alloy of copper and zinc which has a high corrosion resistance and machinability [4]. After fast cooling processes brass shows structural transformations. Thus, modifications of mechanical characteristics are generally caused by high or low temperatures [5]. In addition, brass is known for pitting corrosion [6]. Internal stresses in workpieces are caused by a change of volume or shape resulting from irregular deformation. Changes of volume often appear because of dilation, chemical reaction or constitutional change. In the field of plastics testing there is a wide range of methods for artificial ageing [7]. However, there is no standardisation for environmental simulations for metallic roughness artefacts. Thus, it was examined whether the existing standards for plastics testing can be assigned.

3. Experimental setup

The experimental setup is illustrated in figure 1 and can be divided into sample manufacturing, separation, storage, measurement and evaluation.

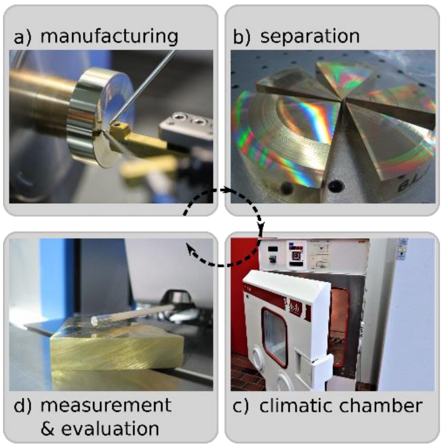

Figure 1. Experimental setup

3.1 Sample preparation

The experimental studies were carried out with a brass measurement artefact that features defined R_k-parameters. The design approach is described elsewhere [8]. The sample features a stratified functional surface whose distinct valleys might be plugged in a notably way when corrosion or deposits result from ageing. Another benefit of the surface is the high sensitivity of its calibrated roughness parameters. The roughness artefacts were manufactured as shown in figure 1 a. An ultra-precision lathe with high stiffness was used. The workpiece was screwed on the spindle and a preceding face turning process was realized. After its fabrication each artefact was measured with a stylus instrument and separated into six pieces with a precision cutting machine (figure 1 b). Immediately after that one of the pieces was measured a second time to determine R_k-parameters as reference values and to examine the effects of the separation process.

3.2 Measurement and evaluation

Design of experiments was applied. It was supposed that time would affect the measurement results in a non-linear way. Due to that it is essential to allocate the factor more than two steps. Therefore five different time spans were chosen. To investigate the influence of the factor temperature, the two different values 80 °C and -10 °C were selected. For realizing the mentioned influences of time and temperature the samples were stored in a climatic chamber on an acrylic glass slice to prevent interactions with their underlayment. The climatic chamber was steam-tight and its walls could not absorb any water. Drying agent was stored in the chamber to realize dry air conditions. Figure 1 c shows the climatic chamber which was used to store the samples at a defined temperature during their ageing process. After each time span, one of the artefact's pieces was taken out of the chamber and measured with a stylus instrument after the sample had cooled down to room temperature. The measurement is shown in figure 1 d. For each piece, the entire 12.8 mm long profile was measured three times at seven different measuring positions.

The measured profiles were interpolated to equidistant distances in the lateral direction and the starting point for the evaluation was detected. The dataset was divided into 5.6 mm long sections. The filter of ISO 13565-1 with lc = 0.8 mm was applied. Considering the filter running-in and -out-lengths, a 4 mm extract of each evaluation position was used for the ISO 13565-2 parameter calculation. The evaluation section of 5.6 mm was shifted laterally in 100 µm steps along the entire profile, leading to 73 evaluations for each profile and a total number of 1533 evaluations per measurement.

4. Results and discussion

In figure 2 the time-dependant plot of the roughness parameters after a storage at 80 °C in the climatic chamber is shown. Figure 3 provides the same information for -10 °C. Each point represents the mean value of 1533 evaluations.

The experimental results show an increase of the material ratio at low height values when the roughness artefact is stored in dry air at 80 °C but in return the core roughness values decrease. When the sample is stored in dry air at -10 °C the material ratio increases in the area of profile peaks but decreases in the area of profile valleys. Some of the mentioned deviations, especially at the profile peaks, occurred after a very short time of storage. They are probably caused by the environment. Other modifications appeared after a long storage time and are therefore classified as time-dependant factors.

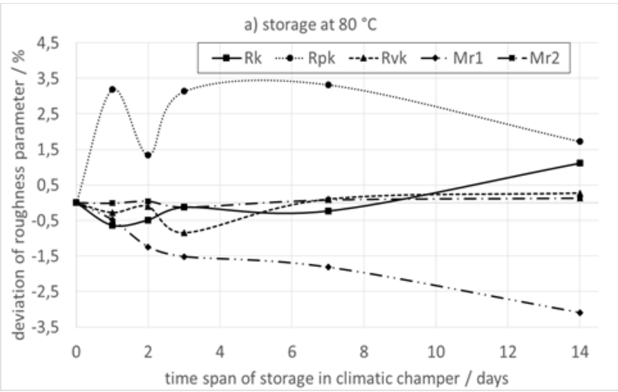

Figure 2. Roughness parameters after ageing: storage at 80°C.

Deviations which occur at a very early stage might be caused by internal stresses. The temperature of the samples outside changed much faster than in its inside, leading to the mentioned processes. Changes which were caused by time could be evoked by corrosion or accumulation of dust or dirt particles.

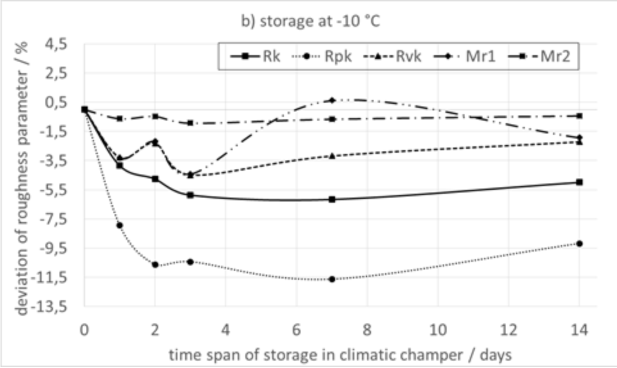

Figure 3. Roughness parameters after ageing: storage at -10°C.

5. Conclusion

It was proven that the procedures and requirements of plastics testing are transmittable for brass' ageing testing. Storage in a climatic chamber with a defined temperature can cause considerable deviations of roughness parameters. The observed deviations were dependant on the temperature. Some deviations appeared after a short time of storage and some of them needed a certain time to become observable.

This shows that temperature and time have different influences on the ageing process. It is assumed that internal stress, corrosion und dust particles have a significant influence on the samples. Thus, ideally roughness artefacts should be stored in vacuum.

In future work, multiple materials and coatings will be examined as well as the effects on ageing of temperature cycles and atmospheric humidity.

Acknowledgement

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