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Analysis of the influence of loading and the plasticity index on variations in surface roughness between two flat surfaces

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ABSTRACT

Contact between two highly loaded flat surfaces is examined. In these experiments, a polished, hard metal surface was pressed against a rough aluminium alloy surface. The goal of the experiments was to flatten the peaks on the rough surface by plastic deformation. The experiments elucidated the relation between the normal load and the plasticity index, ψ, and the plastic deformation of the surface roughness peaks in the softer material. The results showed a significant reduction in surface roughness. Increasing the load caused a gradual reduction in the surface peaks. However, based on the values of the plasticity index ψ, it can be concluded that the peaks of the softer material underwent plastic deformation, regardless of the load.

1. Introduction

Finishing is a highly important segment of any manufacturing process. To increase the reliability and the service life of components, modern industry employs various technologies for modifying the surface of a workpiece such as surface treatments, thermochemical and chemical treatments, ion implantation and plastic forming. Cold plastic forming of material is a process in which the material yields under high compressive loads that exceed the elastic limit of the material. Plastic forming is also considered an efficient way to reduce the friction coefficient between tribological contact pairs. Plastic forming reduces the maximum heights of the surface roughness peaks [1,2].

Surface roughness is important for the proper functioning of mechanical assemblies, resistance to wear, the service life of assemblies and fatigue strength [3]. Measurements of the microscopic surface geometry can be used to describe the contact interface between surfaces and the contact interface surface roughness (form, distance and amplitude) [4]. Among the most common surface roughness parameters are R_a, R_q, R_{sk} and R_{ku}. The arithmetic average of the roughness profile, R_a, reflects the general differences between roughness heights. However, this parameter provides no information on the wavelength or the small differences in the peaks. The root mean square roughness, R_q, is more informative than R_a regarding the deviations of the peak heights from the mean profile line. The surface skewness, R_{sk}, defines the distribution of the valleys and the peaks, and kurtosis, R_{ku}, describes the sharpness of the probability density of the profile [5]. Surface roughness is also important for load transmission. Surfaces with very high R_q values are able to sustain small loads, whereas surfaces with medium or small R_q values can tolerate high loads without surface damage [6,7]. When a normal load is applied to contact surfaces, the contact occurs only between the peaks on the surfaces [8]. Depending on the magnitude of the normal force, the peaks may undergo elastic, elasto-plastic or plastic deformations. At the initial contact, the peaks elastically deform. As the load increases, the peaks are subject to plastic deformation. Consequently, when rough surfaces are in contact, some percentage of the peaks deform elastically and the remainder deform plastically [9,10]. The deformations in the contact area are opposite in direction to the applied load. If the deformation is proportional to the surface topography, then the effect of the normal load is strictly dependent on the magnitude of the roughness peak heights [11,12].

A review of the literature has established that finishing by indentation – which causes plastic deformation in the surface layer – is the most frequently used method besides conventional machining to reduce surface roughness [13–28]. Analytical and numerical modelling of elastic deformation and contact surfaces has been the subject of numerous investigations. Tadic et al. [15] analysed the influence of indentation performed with various tool geometries on the fixture load capacity. Many researchers have opted for spherical tool tips [16,21–23,27,28], and some have used

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