ANALYSIS OF SURFACE DEFORMATION UNDER STATIC AND ULTRASONIC COMPRESSION OF ALUMINIUM

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INTRODUCTION

The quantitative assessment of the topographic features of surfaces is important for interpreting a wide variety of problems in surface contact. The mechanism of friction depends on the nature of the real contact between die and specimen interface and also upon the distributions, sizes and shapes of the asperities. Measurement of these features provides an essential insight into the contact friction.

There have been a few studies that observed the profile and texture of a surface prior to and after undergoing a process of ultrasonic deformation. The early work to observe topographic texture of the deformed surface of an aluminium wire after ultrasonic drawing was carried out by Pohlman [1]. In this study, by using high magnification images, Pohlman observed that the oxide layer on the wire surface was torn open when ultrasonic excitation was applied. By applying a slow drawing speed, eruption effects of ultrasonic excitation were noticed on the drawn surface. This observation suggests that the texture of a deformed surface under applied ultrasonic load is substantially influenced by the operational speed. A similar study of ultrasonic strip drawing was carried out by Seigert [2], who also agreed with Polman's findings that the smoothing effect of microstructure of the deformed surface is affected by the velocity of the drawing process.

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EXPERIMENTAL PROCEDURES

In this present study, the ring aluminium specimens were initially compressed under static upsetting, longitudinal ultrasonic (LU) and radial ultrasonic (RU) vibration applied on the lower die. The ultrasonic vibration was generated using ultrasonic generator at 20 kHz giving the lower platen amplitude of 10 μm for LU and 4 μm for RU. The ultrasonic equipment and measurement system were previously calibrated in a previous work [4]. This ring test was purposely carried out to estimate the coefficient of friction between die and specimen [4].

Five different lubrication conditions were applied to investigate the effects of friction in the ring compression test: dry surface, chemically pure oleic acid (liquid), Lubrodal (liquid), Molyslip (semi-solid), and a thin soft solid film of PTFE (polytetrafluoroethylene). The working surfaces of the platens and specimens were machined to a smooth texture, and polished by fine abrasive paper (grit 1200) to obtain a uniform surface finish.

Subsequently the surface texture of the deformed aluminium ring specimens was assessed by a roughness measurement and topographic evaluation. To evaluate the surface, two common surface evaluation procedures were carried out; (1) Surface roughness measurement using a 2D-profilometer and, (2) surface topographic imaging using scanning electron microscopy (SEM). A correlation between coefficient of friction that previously estimated [4] and the observed surface texture of static, LU and RU compressions using five different lubrication conditions has been established.

RESULTS AND DISCUSSION

In general, the experimental data shows that the coefficient of friction and the roughness of the deformed surfaces depend on the compression method applied; static, LU, or RU, and also the types and properties of the lubricant used at the die-specimen interface.

However, there are some specific observations that may be suggested from the present investigation. Firstly, for a dry condition, the static, LU and RU compressions have effectively reduced the roughness of the surface. Without lubricant the coefficient of friction is slightly reduced using RU compression if compared to static and LU compressions.

Secondly, for the deformed surface with oleic acid and Lubrodal, a significant reduction has been achieved in both roughness and coefficient of friction for static compression. Under the same lubrication condition, longitudinal and radial ultrasonic have slightly reduced the surface roughness, however, the coefficient of fiction is slightly increased.

Third observation was carried out on the specimens that compressed using semi-solid lubricant, Molyslip, and soft film coating of PTFE. A slight low coefficient of friction has been estimated using these lubricants for static compression compared to LU and RU compressions. However the roughness has increased by applying semi-solid lubricant during LU and RU compressions but not for soft solid coating, PTFE.

It was observed that the roughness of each surface has been well correlated with its surface texture. Generally, for all compression methods, a smoother surface was achieved by using dry and liquid lubricants and a rougher surface was presented by using Molyslip and PTFE. The application of the ultrasonic excitation during a compression test was effectively to reduce the surface roughness for dry and liquid lubricants. However for the surfaces those were coated with Molyslip and soft solid film of PTFE, the LU and RU loadings created an uneven surface texture.

It is suggested that the reduced roughness value for some lubricants applied under static, LU and RU compressions could be explained by the asperities flattening. The uneven surface textures measured for static, LU and RU compressions were due to the physical and chemical actions of the lubricants and applied forces including hydrostatic pressure and partial preservation of asperities [5].

CONCLUSION

In conclusion, the present study would tend to suggest that the use of high viscosity lubricants in ultrasonic forming could not provide significant benefits over the use of low viscosity lubricants or no lubricant in terms of surface finish and reduction in the interface friction. In the absence of a lubricant or by using low viscosity lubricants, the surface finish of the deformed specimen can be improved for both static and ultrasonic compressions but there are no measurable improvements using high viscosity lubricants.

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