EFFECTS OF ASPERITY SHAPE ON THE TRIBOLOGICAL BEHAVIOUR DURING STAMPING OF ZINC COATED STEEL SHEETS FOR CAR BODIES

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ABSTRACT

This work was initially focused to analyze the onset of systematic fractures of car body parts (Ford Focus model) during stamping. Fractures were attributed to unexpected high values of friction between the tools and the steel sheets. All the sheets that failed fulfilled the required standard mechanical properties and topographical surface requirements (Ra between 1.0 and 1.7 \( \mu \)m and peak count Pc >50 peaks/cm, according to the German SEP 1940 standard), and were processed with the same lubricant. A detailed study of the surface features showed that, having similar and correct values of the conventionally used parameters for surface texture requirements, such as Ra and peak count Pc, those sheets that failed had some different asperity features, related to the asperity peak shape. Experimental work (measurement of real values of surface contact Sc and friction behavior under boundary lubrication conditions) confirmed that these differences in the asperity shape have an important effect on the friction behavior, controlling the rate of surface roughness flattening and therefore determining the real values of surface contact area and the remaining valley areas able to carry lubricant. The differences in asperity shape were reproduced in single roughness models and the flattening process of the asperities was simulated by finite element analysis. The agreement between simulation and experimental observation was excellent. The influence of asperity shape was found to be very important, justifying the real differences found in the values of real surface in contact and hence in the friction behavior during stamping real car body parts.

INTRODUCTION

The experimental work in this paper was carried out on samples that failed causing fracture of the parts in actual press practice at one of the Spanish car manufacturing plants parts (Outer left and right side panels from Ford Focus). The fractures happened on critical areas under a combination of major and minor strains \( \varepsilon_1 \) and \( \varepsilon_2 \) near the marginal zone (safety factor inferior to 5%), in the forming limit diagram FLD.

One group of samples (group No OK) includes samples from nine zinc electro-coated steel coils, from different steel suppliers, that caused systematic fracture of the parts during stamping. The onset of fractures was associated to unexpected high friction values with the tools, detected by galling symptoms and by local modifications in the strain distribution with respect to the habitual values found in a FLD analysis [1]. This modification in the friction behavior was confirmed by plane sliding friction tests, designed to reproduce the boundary lubrication conditions found in real practice, with an Emmens factor of \( 10^{-4} \) [2]. Another group of samples (OK), was analyzed for comparison purposes, and includes samples from nine coils that allowed successful stamping of the same parts. The scope of the study was thus focused to identify the causes of the different friction behavior. Assuming that any other factor having some influence on the friction behavior had been found to be similar in both coil groups, attention was paid to analyze the effects of the surface texture of the sheets and its evolution during the stamping process.

FINITE ELEMENT ANALYSIS OF THE ASPERITIES FLATTENING PROCESS

Experimental Sc measurements suggested a relevant contribution from the shape of the asperities carrying load in the contact [3]. FEM simulation analysis (Ansys v 7.0) was performed to understand how the asperity shape influences the flattening process and thus the friction behavior, having also taken into account the effects of normal and transverse loads, with a surface friction coefficient 0.1, typical of well lubricated surfaces. The asperity shape was simulated defining asperities with the same total height in the surface texture profile (Rt = 10 microns), but with different number of high peaks and material ratio. The number of high peaks was Pc = 10 peaks/cm for the No OK group and Pc= 20 peaks/cm for the OK group. The shape of the asperity (asperity width) was defined by the real values of bearing material in the Abbot-Firestone curve corresponding to each group of samples. As a result, as shown in Figure 1, the asperity shape adopts a pseudo-Gaussian profile, similar to that used by Sutcliffe [4], but with well-
defined values of total height and short wavelength. Die tools were modeled as flat perfectly rigid bodies and steel sheet material as an elasto-plastic material with strain hardening index \( n=0.22 \) and \( Y = 160 \) MPa.

The evolution of the mean values of normal pressure on the top of the asperities as the vertical strain increases is shown in figure 2. The results reveal the existence of some “persistence effect”, that is, an increased resistance to deformation as the flattening process proceeds, and indicate that the persistence effect is clearly affected by the asperity shape. Normal stresses at 50% strain (\( U_y = 5 \, \mu \text{m} \)) have a value for the asperities around 1GPa, that gives a value for non-dimensional stress \( p/2k = 6.25 \). This value is very similar to the values found by Lee-Prudoe et al.[5] when analyzing the asperity persistence in the surface roughness of mild steel with Vickers hardness \( H_v = 141 \).

The real fraction of area in contact, measured by the width of the contact zone is clearly higher for the No OK group, as shown in figure 3. This is a very relevant result, because from a simple derivation of the different persistence between the two geometries, it could be expected that asperities more persistent would be consequently more resistant to flattening and hence more resistant to increase the values of surface contact area.

The results indicate that the different slope of the asperity, derived from a different value in the bearing material ratio curve, has a great influence on the evolution and growth of the real surface in contact, which being initially similar for the two geometries, grows faster for the asperities of the No OK group. Simultaneously, the values of free space to carry lubricant are consistently higher for the OK group of coils, thus confirming the experimental measurements and observations.

CONCLUSIONS

Samples that failed in real stamping due to unexpected higher values of friction with the tools had some texture features that were not appropriate and that are not detected by conventional specifications based on \( R_a \) and peak count \( P_c \) at a count level of 1 \( \mu \text{m} \). Simulation of asperities reproducing these differences in shape and the analysis of the flattening process by finite element confirmed the different tribological behavior observed in practice.

The asperities of the group No OK show higher persistence than the asperities of the OK group. However, as flattening proceeds during real stamping, the values of real contact area are higher for the group No OK. This kind of topography is prone to lose its ability to carry lubricant to the contact area under the typical boundary lubrication conditions found in practice, thus leading to early lubricant breakdown and galling between the sheet and the tools.

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REFERENCES