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An investigation into the mechanisms of wear of zinc from the surface of zinc-coated car-body sheets during friction

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ABSTRACT

This paper presents the results of an investigation into tribological wear of thin layers of zinc from the surface of car-body sheets during friction. The tribological tests were conducted with the use of an apparatus for drawing metal sheets. The influence of greases on the values of friction as well as on the diverse types of wear of top layers of zinc is analysed. The main emphasis is put on the mechanisms of wear affecting the top layers of zinc as well as on physical and chemical modification of the surfaces of mating elements. The author proposes a phenomenological model of tribological wear of zinc from the surface of car-body sheets.

1. Introduction

Due to mechanical and kinematic conditions, press forming of car-body sheets is not a very stable process. In the course of each cycle of press forming, the values of load, the speed of press forming and the temperature in the area of contact are all subject to change [1,2]. The complex shape of car-body drawpieces together with the requirements as to the quality of their surfaces makes it necessary to design complex tools and apply increasingly more effective lubricating substances [2,3,4].

Considering the above, the press forming process involves many factors which significantly influence the quality of the end product. Special attention is paid to the type of formed material, the tool geometry and the proprieties of lubricating substances [5,6,7].

At present, to manufacture elements of car bodies, particularly those that might be exposed to corrosive agents, steel-coated sheets are used. A very important issue, and simultaneously a technological challenge in the press forming process, is the choice of a suitable lubricating substance. Initially, for economic reasons, the same types of greases were applied to process both coated and uncoated (black) metal sheets. Predominantly they were oil compositions with metalorganic EP additives (S, P, O). These greases were effectively used in the process of press forming of black metal sheets. Scientific investigation has shown, however, the unsuitability of applying these greases to process zinc-coated metal sheets, a conclusion supported both by laboratory tests [8,9], and industry practice [10]. Paradoxically though, literature data indicate even better tribological characteristics during friction of zinc-coated metal sheets in an oil-based environment, compared to a composition with EP additives.

In this context, a detailed investigation into the questions concerning friction and lubrication of zinc-coated car body sheets under different lubricating conditions appears to have become a well-grounded necessity. Components of greases, apart from their key influence on the efficiency of the press forming process, can take part in physical and chemical modification of mating surfaces, thus affecting the quality of the top layers (TL) of drawpieces as well as the durability of tools.

The aim of the present paper is to explain the influence of technological lubricants, including those containing reactive (organosulphur) EP additives, on friction and wear of zinc-coated car-body sheets.

2. Materials and method of investigation

The investigations involved the use of strips of electrogalvanized car-body sheets, 0.8 × 35 × 1000 mm, from commercial 06JA material. The investigations were conducted under conditions of friction in the presence of pre-selected greases: SN150 base oil (OB), and a pre-prepared lubricant (on its base), i.e. a composition with an organosulphur additive $C_{12}H_{25}(S_5)C_{12}H_{25}$ (OB+S5). The content of additives in the mixture accounted

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for 1% of the total mass. A diagram of friction pairs in the apparatus and process parameters is presented below (Fig. 1).

Subsequent to tribological tests, an analysis of the chemical composition of samples collected from the top layers after friction was performed (scanning, XPS). Additionally, nanohardness testing of selected sections of samples was conducted.

The chemical analysis was performed using a Hitachi S-3000N scanning microscope with a “Vantage di” attachment for X-ray microanalysis.

Tests involving the XPS method were performed using an ESCALAB-210 photoelectron spectroscope designed by VG Scientific (England). The tests required the use of Al Kα X-ray radiation. The chemical composition was analysed on an area of approximately 6 mm^2 of sampled surface. Special attention was paid to the content of iron, oxygen, zinc and sulphur. Quantitative tests were carried out using the Multi-Line method [11].

Measurements of nanohardness were conducted using a Nanotest 600 Hardness Measurements device. The spots, predetermined by means of microscopic observations, were spaced each 5 mm, which amounted to 10 columns and 20 measurements per column.

In order to obtain more insight into the process of physical and chemical modification of the top layer (TL) of zinc-coated car-body sheets, a sample was prepared in the form of a 10 × 10 × 2 mm plate made of electrolytic zinc. After grinding, a droplet of S5 additive was placed onto the surface of the plate and then the plate was heated up on a stove, at a temperature of approximately 350 °C, over a period of 15 min. The sample was marked as Zn+S5. Thus prepared, the sample was then subjected to an analysis of its chemical composition.

3. Results of the investigations and discussion

Fig. 2 shows the results of the tribological tests. They indicate a negligible influence of the composition with S5 additive on the values of friction in comparison with base oil. The discovered correlations are confirmed in tribological tests performed using different tribological testing devices [10,12].

Fig. 3 illustrates the results described in paper [10], obtained using a pin-on-disc apparatus. The pin-on-disc tester is a classic tribotester and this is why its description was omitted. The node of the STS apparatus is shown in Fig. 1. In both cases (pin-on-disc and STS apparatus) we deal with a conformal contact. In both cases we have the same parametres of external excitations. In both cases the same lubricant is used, i.e. OB base oil and a composition with sulphur content, OB+S5. The values of initial viscosity of the liquids are obviously the same. Ultimately, in both cases we have the same conditions of friction.

The aim of the pin-on-disc test was only to predetermine the tribological properties of the lubricants (it is obvious that it does not reflect the conditions of friction in a plastic sheet metal forming process). In this case (also in other papers, [12,13]),

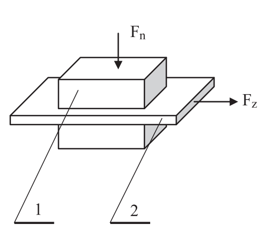

Fig. 1. Friction pairs in the STS apparatus: Fz—pulling force, Fn—pressure force, 1, 2—mating element pair (pressure elements, metal sheet); parameters in the test: 1. Elementary pressure: p=0–16 MPa, and 2. Speed of pulling: v=0.15 m/s.

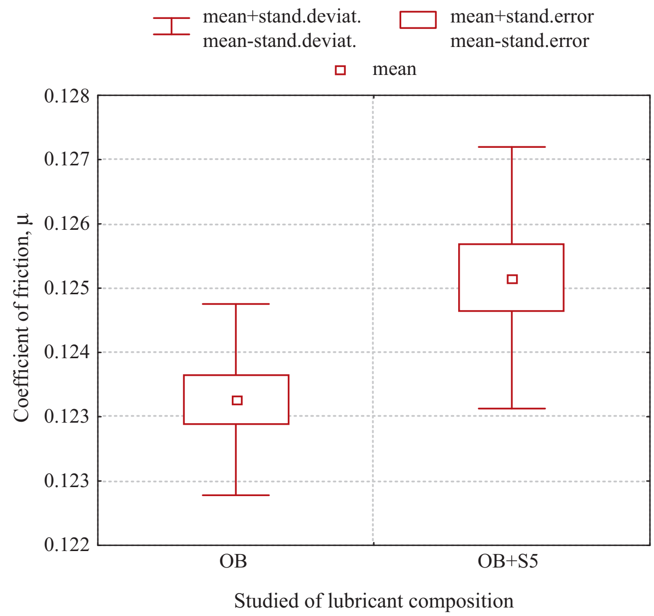

Fig. 2. Coefficient of friction in the presence of the investigated greases (P=8 MPa, STS apparatus).

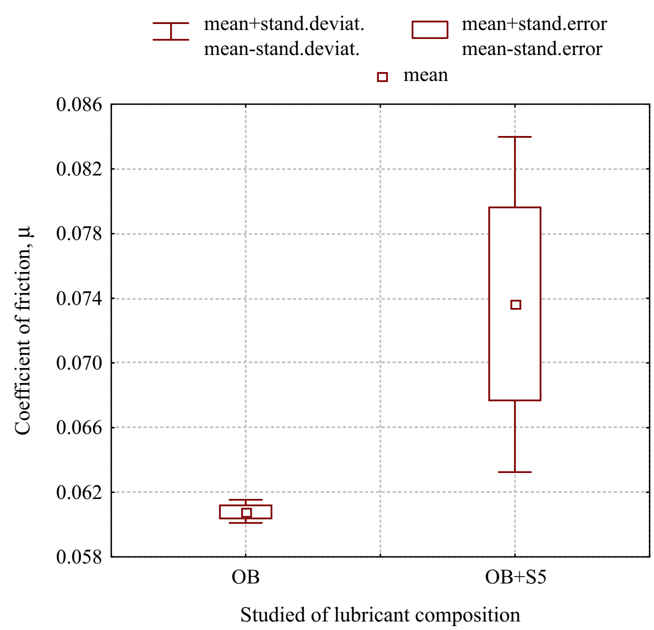

Fig. 3. Coefficients of friction in the presence of the investigated lubricants (pin-on-disc apparatus, P=8 MPa, t=3 h, and v=0.15 m/s).

increased resistances of movement were confirmed under conditions of friction in an environment involving a composition with organosulphur additives.

It should be noted that lubricating oils containing sulphur compounds are commonly used as effective greasy compositions in press forming processes of car-body sheets without zinc coating. Lack of tribological efficiency of such greases in relation to zinc-coated car-body sheets requires explanation, for the purposes of both understanding and implementation.

The author's own observations, supported by analyses in literature data, indicate that in the case of friction involving base oil, there occurs a deformation followed by a cutting of zinc layers, which is a result of its low resistance to cutting tensions. This causes, in addition to a transfer of zinc into other areas of samples,