INFLUENCE OF LUBRICANTS ON THE WEAR RESISTANCE OF ALUMINIZED STEEL STRIP

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Abstract
The article presents a properly planned and designed tests of the abrasive wear resistance of aluminized (Al-10%Si) steel under friction conditions involving various lubricants. Research is focused on the effects and relationships, enabling selection of the best lubricant for the use in industrial environments. Three lubricants of the Orlen Oil Company were selected for tests. Tests made without the use of lubricants were performed for a comparison. The tester T-05 was used for tests. The counter samples used for tests were made of tool steel NC06. The results presented in the graphs show the friction force, depth of wearing out, friction coefficient, loss of mass of samples as a function of test time and load, in dependence on lubricants used for tests.

Keywords: aluminized steel strip, abrasive wear, lubricants

1. INTRODUCTION
Aluminized steel strips [1] due to their properties, strength and plasticity [2-6], warranted by the base material as well as due to the corrosion resistance guaranteed by the coating, found applications in many industrial sectors, among others, in motorization, heat engineering, building and household appliances production. An essential feature, still limiting the application of such strips and their products, is a low abrasion resistance of the Al-Si coatings in contact with forming tools as well as with external factors influencing the coating during its exploitation. Thus, the application of the proper lubricating-cooling medium during plastic treatment of such strips seems obvious. Investigations concerning aluminised steel strips were, up to the present, realized as a selection of lubricants at forming open-joint tubes [7] as well as an influence of various factors on abrasion resistance, structure, properties and deformability of this material [8-13]. The results of the properly planned and designed wearing quality tests of aluminized steel strips are presented in the hereby paper. Tests carried out under various friction conditions and with using various lubricants of the Orlen Oil Company were aimed at looking for effects and dependencies allowing the selection of the best lubricant to be used for press-forming under industrial conditions.

2. EXPERIMENTAL SETUP
Tests were carried out on samples of aluminized steel strips of DX53D+AS120 grade 1.5mm thick and of a coating thickness app. 25μm on each side (Fig. 1a). Tool steel of NC06 grade was applied as the counter sample material (Fig. 1b). A fresh counter sample was used for each test. Three lubricants of the Orlen Oil Company were chosen for tests: oil for press-forming L, PRESSOL B and PRESSOL PT, marked in the further part of the paper as A, B, C. Investigations without applying lubricants were performed for the comparative purposes.

The abrasion resistance tests were performed by using the T-05 tester (Fig. 2). This tester enabled performing tests in accordance with the methods determined in Standards ASTM D 2714, D 3704, D 2981 and G 77.
The sample (1) was mounted in a sample holder (4) equipped with a hemispherical insert (3) ensuring the proper contact between the sample and the rotating ring (2). The wearing surface of the sample was perpendicular to the pressing direction. Double lever system input the load \( L \), pressing the sample to the ring with the accuracy of ±1%. The ring rotated with a constant rotational speed.

The wear tests conditions chosen for the current investigations were:
- tested samples - rectangular as-infiltrated specimens 20 x 4 x 1,2 mm,
- counterpart (rotating ring) - \( \varphi \) 49.5 x 8 mm, steel NC06, 55 HRC,
- rotational speed – 136 rev./min.,
- load – 60, 160, 310 N,
- test time – 1000s.

Investigations were performed at a temperature of app. 23°C. The obtained results are presented in diagrams as the dependence of the friction force, depth of wearing out, friction coefficient and the sample mass loss - on the sample load and the applied lubricant. After finished investigations the microscopic observations of sample surfaces and macroscopic observations of counter samples surfaces (after the wear test) were performed. Observations were performed by means of the optical microscope MULTIZOOM AZ 100 and the digital photo apparatus of the Nikon Company.

3. RESULTS AND DISCUSSION

3.1 Investigation results of the friction force and the depth of wearing out after the abrasive wear

The obtained results of the average friction force and the maximum depth of wearing out after the abrasive wear, at sample loads being: 60, 160 and 310N, in dependence of the lubricants are presented in Fig. 3-5.
The highest friction force values (50, 160, 250N) and depths of wearing out (170, 210, 280μm) respectively for loads of: 60, 160, 310N occur for samples tested without any lubricants. However, in case of tests performed with the application of lubricants, the situation is completely different. The most stable pathways of the friction force and depth of wearing out curves occur in case of applying lubricants A and B. With a sample load increase the measured values increase, in addition to which the application of lubricant B – in a majority of cases – causes obtaining the smallest friction force and depth of wearing out values in relation to lubricants A and C.
3.2 Investigation results of the mass loss and friction coefficient after the abrasive wear

The obtained results of the mass loss and friction coefficient of rubbing couples in dependence on the sample load and applied lubricant – after the abrasive wear - are presented in Fig 6.

A mass loss being 8-13%, is the highest for samples tested without lubricants. In the remaining cases this loss is below 2%. The smallest mass loss value (0.8%) at the maximum load was found when lubricant C was used and not much higher (1.2%) for lubricant B (Fig. 7a). With a sample load increase a mass loss increases in all cases. The highest values of the friction coefficient, in a range: 0.5-0.9, were noticed for samples tested without any lubricant. When lubricants were applied the lowest value of the friction coefficient - being 0.05 at a load of 310N – was found for lubricant B. The coefficient of friction for lubricant A is within a range: 0.08-0.1, while for lubricant B: 0.18-0.21 (Fig. 7b). It should be noticed that in each case the friction coefficient decreases when the sample load increases.

3.3 Observation results of the sample surfaces after the abrasive wear

The results of the microscopic observations of the sample surfaces after the abrasive wear are presented in Fig. 7-10.

Fig. 7. Surface of the Al-Si coating after the abrasive wear, without any lubricant and at a load of:

a) 60N, b) 160N, c) 310 N
Complex wearing out mechanisms occurred during friction without any lubricant. Traces of wearing out in forms of scratches and grooves were observed on not deformed grains. While the part of the tribological contact surface, under a load of 60N, underwent plastic deformation and cracks - both transverse and longitudinal versus the friction direction - occurred (Fig. 8a). A load increase to 160N caused the enlarged areas of a plastic deformation, adhesive wear traces and sample surface spalling were also observed (Fig. 8b). At a load of 310N the oxidation wear was found as well as cracks and material spalling was observed (Fig. 8c).

When lubricant A was applied the abrasive wear traces were found on the strips surfaces – mainly micro-ploughing and scratching, and additionally grooving. In this case the abrasive material constitute carbide particles occurring in the counter sample, which either protrude from the surface or were crushed in a tribological contact (Fig. 9). An intensity of these processes grows with the load increase, especially the micro-ploughing fraction increases causing an essential mass loss.

When lubricant B was applied small abrasive wear traces could be seen on the sample surfaces – mainly micro-ploughing and scratching (Fig. 10a, b). The load increased to 310N caused a small crumbling occurrence (Fig. 10c). A minimum wear of the coating surface during the tribological contact is reflected in a minimum mass loss of samples.
Traces of abrasive wear – mainly micro-ploughing and scratching – can be seen on the strips surface when lubricant C was applied. In addition the presence of a few grooves can be found (Fig. 11a). The intensity of these processes visibly grows when a load is increasing (Fig. 11b), especially for samples subjected to the highest load. On surfaces of such samples visible crumbling occur (Fig. 11c). The observed surface effects cause the largest mass loss and the highest values of the friction coefficient for the applied lubricants.

3.4 Observation results of the counter samples surfaces, after an abrasive wear

Some examples of the macroscopic observations of the counter samples surfaces, after an abrasive wear, at a load of 310N are presented in Fig. 11.

![Counter samples surfaces](image)

**Fig. 11. Observation results of the counter samples surfaces, after an abrasive wear**

a) without any lubricant, b) with lubricant A, c) with lubricant B, d) with lubricant C

An occurrence of traces on the counter samples during an abrasive wear performed without lubricants is characteristic (Fig. 11a). An application of lubricants A and C decreases wearing out of counter samples (Fig. 11b, d), while the smallest wearing out occurs when lubricant B was applied (Fig. 11c).

4. CONCLUSION

The results of the suitability assessments of lubricants for forming coatings in an aspect of wearing out of rubbing couples simulating influencing the frictional couple: material-tool are presented in the paper. On the bases of the obtained results of friction forces, depths of wearing out, sample mass losses and coefficients of friction as well as observations of surfaces of samples and counter samples it was found that the best lubricant for press-forming of aluminized steel strips is PRESSOL B.

LITERATURE


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