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RESEARCH

Experimental Study of Adhesive Wear of a Holding Device Using a Cross Cylinders Tester

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A B S T R A C T

Adhesive wear was identified in a cylinder of a rotating holding device of a forming die system, which permits to hold and align a leaf spring to carry out a punching operation at the automotive industry. To investigate the causes of the wear observed, an experimental study using AISI 5160 H and AISI 9840 R steels was carried out in a cross cylinder tester. The steel materials simulated the leaf spring and the cylinder of the holding device respectively. Like a remedy to reduce the adhesive wear, thermal chemical diffusion nitriding hardening was applied on the AISI 9840 R material and tested against AISI 5160 H in dry and lubricated conditions. The results showed that applying nitriding, the wear rate reduced around 97 % in dry conditions compared to the untreated steel. In lubricated conditions the wear for treated and untreated reduced by 98 %.

1. INTRODUCTION

To manufacture leaf springs in a die process presents a problem to the cylindrical components of the holding system. The two cylinders are considerably wearing off, due to the repeated operations of pressing the leaf spring towards, punch it and make a hole. These operations are carried out up to 18 times per minute. In a day, this operation is carried out around 8500 times in 8 hours. Normally, three work journeys are carried out in 24 hours. Nevertheless, the worn cylinders are replaced around 5000 times, due to the wear damage occurred as a consequence.

When the manufactured leaf springs are jumbled pile for the drilling process, the precision of the located hole in the leaf spring is compromising by wear of the aligning equipment after some repeats.

So, it was suggested to carry out an experimental investigation on the components that are affected, in order to solve the wear problem. Primarily, we observed the wear scar in worn components to identify the wear mechanisms. Secondly, we selected a suitable rig to simulate the contact conditions and wear. Thirdly, we applied a diffusion thermal-chemical nitriding to the specimens as a potential solution. In addition, we carried out the experimental work looking at the wear performance of the treated and untreated material. And finally, we proposed to apply nitriding to the actual unworn components in the set.

2. PROCESS DESCRIPTION

The leaf springs is held and aligned by the two cylinders. They are punched pneumatically by the die system and simultaneously they falls leaving a hole with specific dimensions and tolerances. Finally, the leaf spring is released and removed to be taken to the next process. In Fig. 1 shows a schematic view of the main components of the holding system. Number 2 illustrates the cylinders holding the forming material.

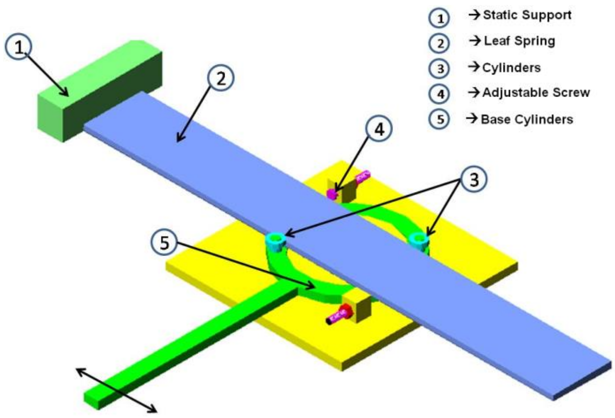

Fig. 1. Main components of the holding operation.

2.1 Wear scar analysis

In Fig. 2, the lateral contact for a single cylinder and the leaf spring can be seen. The Fig. 3 shows an elliptical worn area. The wear scar images taken by an optical microscope are shown in Fig. 4. The contact between the cylinder and the leaf spring has an elliptical shape at 90°.

Adhesive wear damage can be observed on the scars. The wear is initiated by the interfacial junctions formed by the cylinders and the leaf spring. When the load is applied, the contact pressure is turned extremely. It is believed that the yield stress is exceeding deforming plastically until it increases the contact area. The plastic deformation by impact was discarded because the tolerances between the cylinder and the leaf spring are extremely closed.

Fig. 3. Wear zone on a cylindrical component.

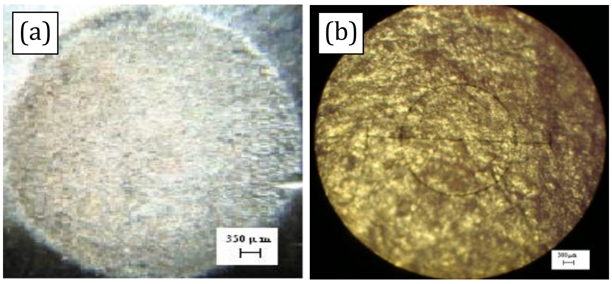

Fig. 4. Wear scar features of a worn cylinder of the holding system: (a) 18 × and (b) 100 ×.

3. EXPERIMENTAL PROCEDURE

3.1 Test approached

The cross cylinder tester was selected as it is suitable to simulate adhesive wear. It was thought, from some potential tests, that the cross cylinder test method was the most appropriate. It was also considered that this test approach would be better than the alternative pin-on-disk test (here a pin is held stationary and the disc rotates; the contact is a point or conformal), as it better replicate the elliptical shape contact.

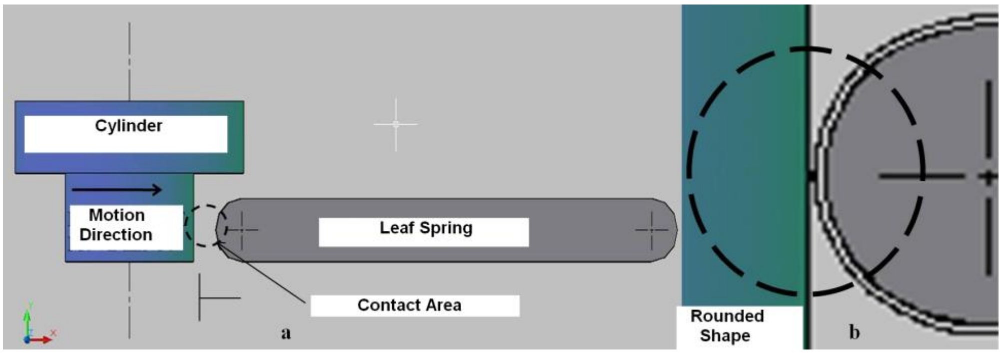

Fig. 2. Contact between the cylinder and the leaf spring.

3.2 Test apparatus

It consists of a solid cylinder as stationary wear element and the other solid cylinder as a rotating element that operate at 90°. The Figure 5 shows schematic representation of the two cylinders in contact, and Fig. 6 shows the cross cylinder test rig where basically the stationary cylinder is mounted on a holder with a ball bearing in an arm. A load cell assembled in the arm permits sensing the friction force and is connected to a PC. The rotating specimen is connected to the motor shaft [2].

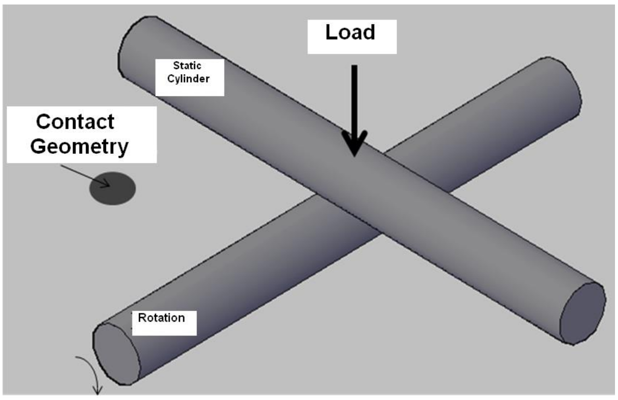

Fig. 5. Schematic representation of the two cylinders in contact.

Fig. 6. Cross cylinder test rig.

3.3 Specimens

The specimens: top and bottom cylinder were manufactured from AISI 9840 R and AISI 5160 H steels representing the cylinder in the die system and the leaf spring, respectively. The characteristics of a specimen made of AISI 9840 R steel are shown in Figs. 7(a) and 7(b).

In Fig. 8 shows the diffusions of the thermal chemical nitriding diffusion into the base material. It is approximately 100 μm depth in AISI 9840R steel.

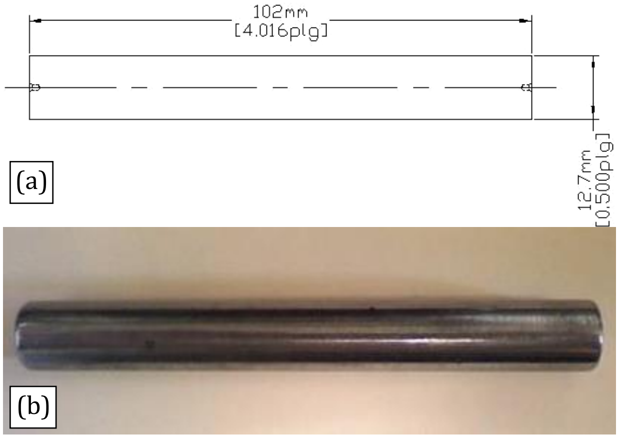

Fig. 7. (a) schematic view of a specimen and (b) cylinder sample made of AISI 9840 R Steel.

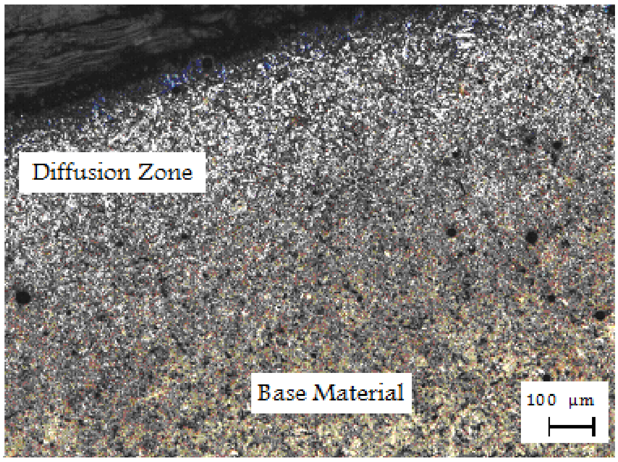

Fig. 8. Thermal-chemical diffusion in nitriding.

3.4 Test Parameters

The tests were carried out at 300 rpm and 71 N load applied. The two cylinders form an elliptical contact shape with a contact pressure of 2.5 GPa. This value was deliberately selected as extreme Hertz contact condition for the tests, in order to accelerate the wear process. For the lubricated tests, SAE 25W-60 oil was used. The duration time for each test was 110 minutes. All the specimens were perfectly ultrasonically cleaned and weighted [3].

4. RESULTS

4.1 Wear rate *Q* and wear coefficient *k*

In Fig. 9 displays the wear rate Q, and Fig. 10 indicates the wear coefficient k, calculated from the wear tests. The highest values were for the untreated AISI 9840 R material. As can be observed for steel with nitriding in dry condition, a low wear rate was observed, which is similar to the values for untreated and treated AISI 9840 R steel in lubricated condition.

4.2 Wear features

Images of the wear scar of the tested AISI 9840 R steel specimens are shown in Fig. 11 (a) big wear scar was obtained for the untreated dry test following by a treated dry test (see Fig. 11b). The smallest wear scars were obtained in lubricated conditions for untreated and treated materials (see Figs. 11c and 11d, respectively).

The wear features shown in Fig. 12a, displayed that some material has been transferred from the counterface and some wear were debris produced; some sort of cracking is also observed. By other hand, Fig. 12b shows small amount of the transferred material and some ploughing action. In lubricated conditions for treated and untreated steel specimens, ploughing, material transfer and cracks were observed, as illustrated in Fig. 12(c), [4].

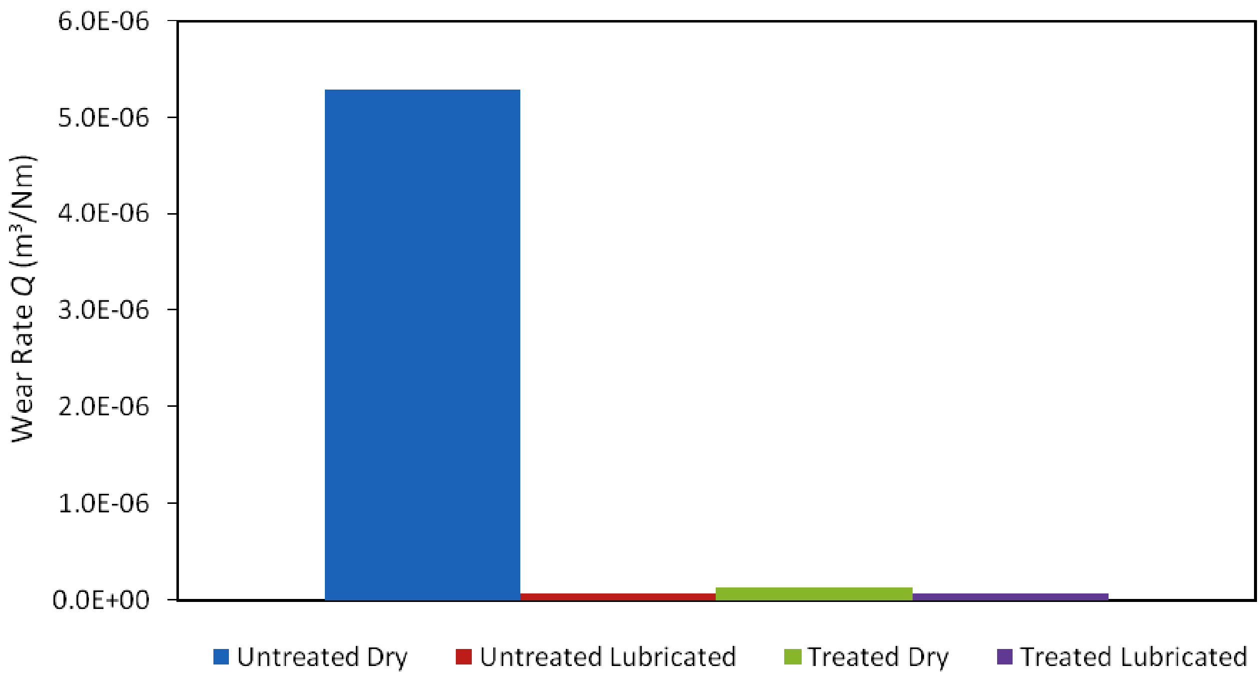

Fig. 9. Wear rate Q.

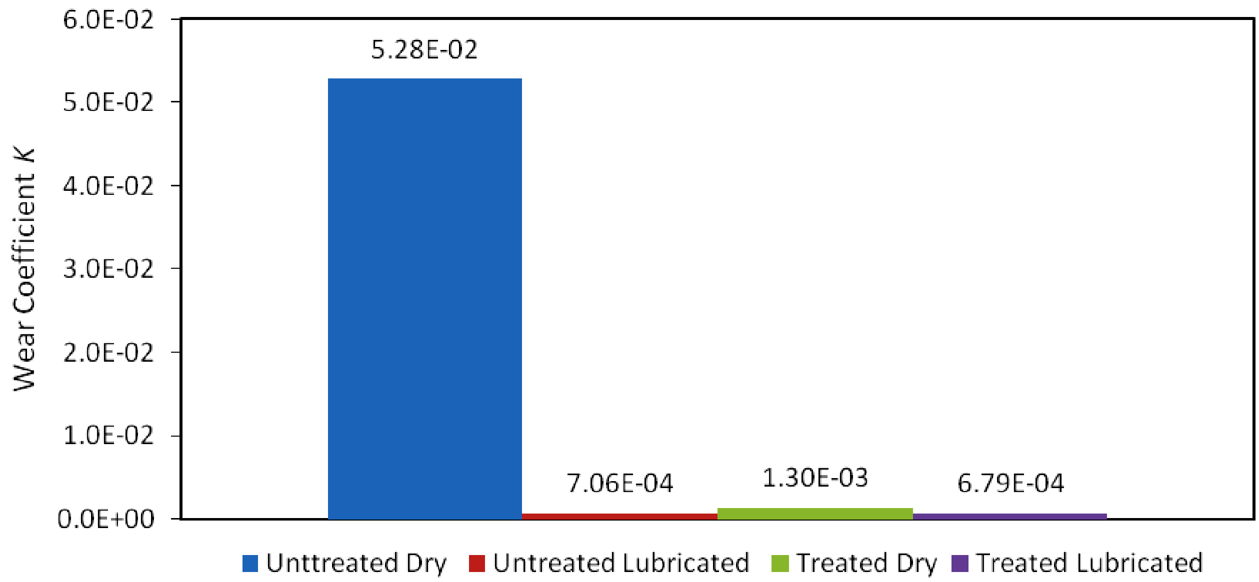

Fig. 10. Wear coefficient k.

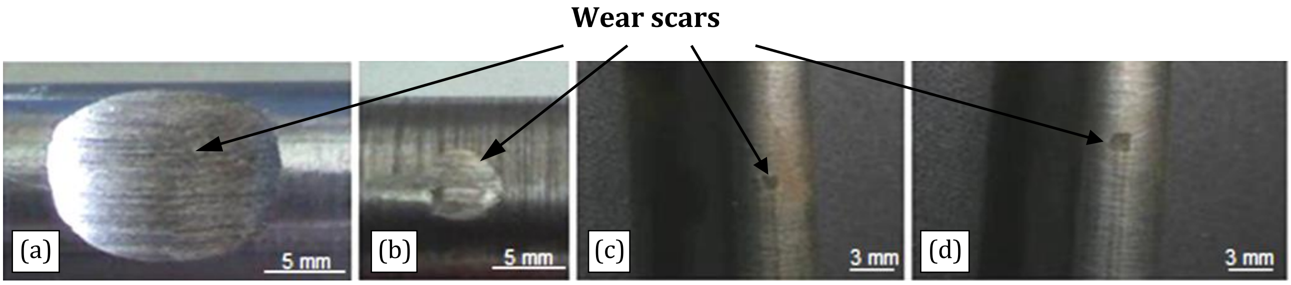

Fig. 11. Wear scars for AISI 9840 R steel: (a) dry conditions; untreated steel specimen, (b) dry conditions; treated steel specimen, (c) lubricated conditions; untreated steel specimen and (d) lubricated conditions; treated steel specimen.

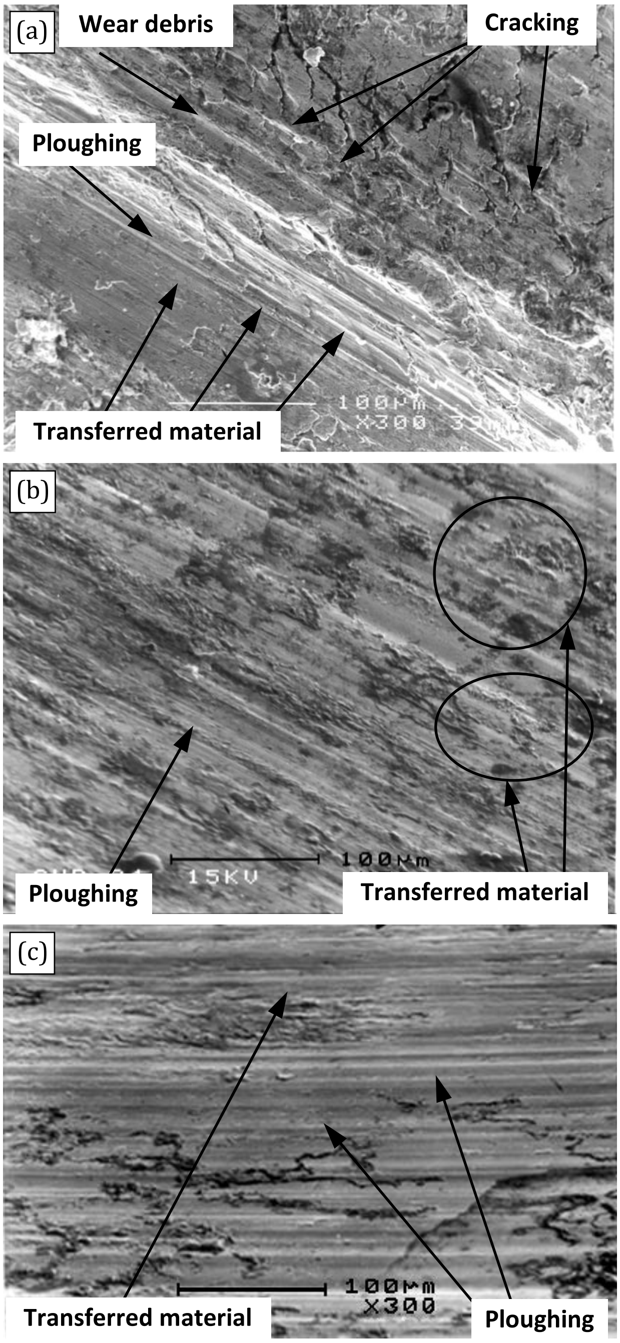

Fig. 12. Micrographics of AISI 9840 R steel: (a) dry conditions; untreated steel specimen (b) lubricated conditions; untreated steel specimens and (c) lubricated conditions; treated steel specimens.

5. DISCUSSION

The wear scar examination showed that mild adhesive wear is generated through the operation life of the cylinder. However, the wear is related to the number of times the holing operation is carried out. Thus, it is thought that the contact pressure has not had a significant relation to the wear process.

In the other hand, the aim of choosing a high load in the experimentation was to accelerate the wear process and compare the wear results with the tested manufactured specimens.

The wear rate was high for the untreated AISI 9840 R steel. During the test the AISI 5150 H steel is continuously in contact, producing a grooving action and transferring the material onto the AISI 9840 R steel. For the treated AISI 9840 R, the wear rate was low compared to the untreated specimen in dry test. The lowest wear rate was in lubricated conditions, compared to the dry conditions tests, for treated and untreated material. Though the results are very promising, the option of applying lubricant instead of nitriding in the actual components was discarded by the company. They preferred to continue carrying out the holing operation with no lubricant at all. It was believed that a lubricated system may increase the maintenance costs, since the nitriding of the actual components is more convenient, as well as changing of the cylinders in case of failure. They did not consider the cost of the thermal-chemical diffusion process whatsoever.

The overall work has shown that applying of the nitrinding to the AISI 9840 R steel specimens and the cylinders of the holding device system was possible. It increased the wear life of the components. The wear rate was reduced down by 97 % compare to the untreated steel in dry conditions [5].

6. CONCLUSION

The wear scars examination for the actual worn cylindrical components has shown mainly mild adhesive wear.

The used rig has shown that it is a suitable rig for the simulation of the adhesive wear. It was suggested only to treat the AISI 9840 R steel and carry out the process in dry conditions, since this represents a low cost maintenance and the treated material in dry conditions has shown its efficacy in terms of wear and friction.

Tribology contributes in the initial stage of design of machine elements, and it also has a key contribution when any mechanical component of any machine is working in real conditions and significant wear is observed, by looking into a very local area of some components in a holding device die system where wear has been occurring.

Acknowledgement

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