Comprehensive Wear Study on Powder Metallurgical Steels for the Plastics Industry, Especially Injection Moulding Machines

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Abstract

M390 microclean® of Böhler Edelstahl is a powder metallurgical plastic mould steel with a high level of corrosion and wear resistance and therefore often used in the plastics processing industry. But as a consequence of rapidly advancing developments in the plastics processing industry the required level of wear resistance of tool steels in this field is constantly rising. For that reason a new PM tool steel with higher hardness values and an increased amount of primary carbides has been developed to improve the resistance against abrasive and adhesive wear. The wear resistance of both steels against adhesive situations for components of the plastification unit of injection moulding machines has been tested with a novel method. In case of processing polyolefins with an injection moulding machine it was found that there is adhesive wear between the check-ring and the flights of the screw tip of the non-return valve under certain circumstances. The temperature in that region was measured with an infrared temperature sensor. The existence of significant peaks of that signal was used as an indicator for an adhesive wear situation.

Keywords : Adhesive Wear, Plastics Processing, PM Tool Steels

1. Introduction

The tribological loading on the components of a plastification unit of an injection moulding machine is quite complex. There is abrasive wear on the screw and barrel in case plastics with fillers, e.g. glass fibre reinforced plastics, are processed. Some plastics, e.g. polyvinyl chloride (PVC), can cause corrosion on the components which get in contact with the melt. Investigations in abrasive and corrosive wear of PM-steels used for components of the plastification unit are presented in [1,2,3]. In some cases adhesive wear on the flights of the screw was observed [1]. Recently it was found that severe adhesive wear can also appear on non-return valves [4]. The ring-type non-return valve consists of the screw tip, the sealing ring and the stop ring (fig. 1).

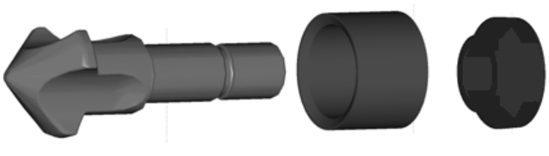

Fig. 1. Components of the non-return valve.

During injection the screw works like a piston so the sealing ring prevents the back-flow of melt into the screw channels. During metering the screw rotates and the melt flows in front of the screw through the gap between the sealing ring and the stop ring. The screw tip rotates at the same circumference speed as the screw and the sealing ring rotates with a very slow speed or even stands still. It depends on the lubrication behaviour of the melt whether both components get in direct contact or whether there is a lubricating film in between. For polyolefins processed at screw circumference speeds higher than approximately 300 mm/s it was found that solid friction occurs because of the lack of a proper lubricating film [5].

2. Experimental and Results

Usually adhesive wear leads to an increase in temperature on the friction surface. If the temperature rises above the annealing temperature of the steel there is a tremendous reduction in hardness which leads to increased wear. It was found that the results of dry sliding tests performed with a pin-on-disc tribometer, described e.g. in [6], did not match the practical findings under real injection moulding conditions. So the plastic melt as surrounding medium can not be neglected for the tribo tests. In order to detect the occurrence of adhesive wear under production-like conditions the test stand has been designed. The screw diameter was 40 mm which gives a circumference speed of 690 mm/s at maximum screw speed of 330 1/min. An infrared temperature sensor (IR-sensor) was installed close to the friction area. Pressure transducers were located in front and behind the sealing ring respectively. Because of the pressure difference and the volume flow through the non-return valve the resulting force on the sealing ring can be calculated. When processing a low density polyethylene

(PE-LD) the pressure drop with a proper geometry of the non-return valve was 20 bar, equivalent to a contact force of 600 N. The influence of the geometry on the pressure drop has been studied in [7]. The IR-sensor measures the melt temperature close to the friction area. It was found that massive adhesive wear always occurs in combination with significant temperature peaks. A model simulation gave a temperature rise up to 800 °C directly on the friction surface. A SEM examination of the worn components leads to similar conclusions.

M390 microclean® (X190 CrVMo 20 4 1), trademark of Böhler Edelstahl, is a plastic mould steel produced by powder metallurgical methods. This highly alloyed martensitic tool steel is corrosion resistant because of a dissolved matrix chromium content above 13 mass-% and highly wear resistant because of a primary carbide volume content of about 20 vol.-%, consisting of 2.5 vol.-% vanadium-rich MC- and 17.5 vol.-% chromium-rich M7C3-carbides. But nevertheless the M390 microclean® used for the screw tip and for the sealing ring showed severe wear under certain processing conditions described above. After a tribo-testing time of 2 h, equivalent to only 50 kg of PE-LD, processed at maximum screw speed the wear on the flights of the screw tip has been 5 mm. So this material combination is not suitable for this industrial application.

For that reason an experimental alloy with increased primary carbide content and hardness has been produced in laboratory scale. This alloy is a modification of M390 microclean® with marginally lower chromium-content but significantly higher vanadium- and carbon content to raise the fraction of vanadium-rich MC-carbides. Vanadium carbide is one of the hardest carbides present in tool steels and for this reason it has been used with great advantage to improve the wear resistance of these materials [8]. But the added vanadium is also dissolved in chromium carbide and increases the hardness of the M_7C_3 carbides [9]. Figure 2 shows SEM images of the primary carbide volumes that are found in M390 microclean® and the experimental alloy.

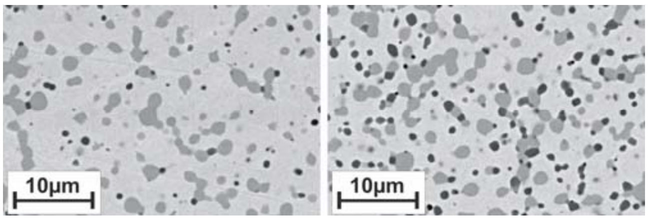

Fig. 2. Primary carbides of M390 microclean® (left) and the experimental alloy (right).

The vanadium-rich MC-carbides appear dark, M_7C_3-carbides appear grey. The experimental alloy obtains a primary carbide volume content of about 28 vol.-%, consisting of 8.3 vol.-% MC- and 19.7 vol.-% M7C3-carbides.

The experimental alloy showed no adhesive wear during the 2h-test procedure which can be seen in the absence of temperature spikes. The improved adhesive wear resistance of the experimental alloy is primarily caused by the increased macro hardness [10] and the reduction of the mean free path between the carbides [6].

3. Summary

When polyolefins are processed the adhesive wear on the flights of the screw tip and on the sealing ring is the main reason for the stoppage of the production. The occurrence of adhesive wear on non-return valves of injection moulding machines has been studied on an instrumented test stand. Different steel grades have been tested and it was found that a novel PM tool steel leads to a tremendous reduction of wear.

4. References

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