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Substitution of zinc stearate in aluminum cold extrusion

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ABSTRACT – Zinc stearate is widely used for the lubrication of aluminum cold extrusion processes to prevent adhesion and to reduce tool wear. It is a powder that has to be applied on the slugs by a tumbling process and leads to strong dust formation. Furthermore, it can cause respiratory irritation. This paper presents the development of a new lubricant for the cold extrusion of aluminum parts based on renewable raw materials. The new lubricant is free of zinc or other metals. Because it is a water-based suspension, it can be applied easily and without any dust formation.

1. INTRODUCTION

One of the fastest growing segments of the metalworking industry is the machining of aluminum alloys. Because of the very favorable ratio of strength to density it is widely-used in aerospace applications. The superior strength and light weight makes it also an ideal material for camping and outdoor equipment. The growing need for fuel economy and reduced greenhouse-gas emissions in automotive engineering furthermore leads to a strongly increasing demand for parts made of aluminum alloys.

Aluminum and its wrought alloys can be formed very economically in cold forming processes [1]. Cold extrusion is a forming operation where the work-piece, also called billet or slug, is pressed with high force and without preheating into the deforming die. The term “cold impact extrusion” is used specifically for the extrusion of non-ferrous components under mass production conditions in high speed mechanical presses.

For most of the aluminum cold extrusion processes zinc stearate is used as lubricant. Zinc stearate is a white powder with a very low density of approximately 1.1 g/cm³. It is widely used because it works very well as a solid lubricant and mold release agent. It is applied on the slugs before extrusion by a tumbling process. Because of the low density of the powder there is a strong dust formation when using zinc stearate although there are usually exhaust systems installed. The dust however can cause irritation of the skin, eyes and the respiratory tract. There is also the risk of a dust explosion caused by electrostatic ignition. At thermal decomposition toxic and irritating vapors are formed.

To prevent the negative effects of zinc stearate a research project was started to develop a new lubricant with comparable lubricating properties but lower toxicity and possibly without the problem of dust formation.

2. METHODOLOGY

Several tests in the laboratory were carried out with liquid lubricants, based on vegetable oils and containing different kind of extreme pressure or antiwear additives (Figure 1). For the first tests a backward cup extrusion process was used on a Müller-Weingarten hydraulic press with a maximum pressing force of 2000 kN. A punch with a hemispherical shaped end was used to form the cup from the slug, increasing the overall surface area by the factor 7.9.

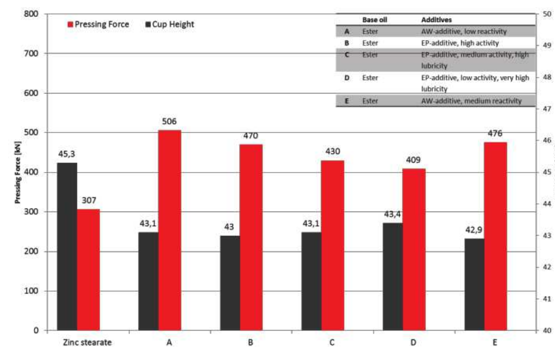

Figure 1 Test results of liquid lubricants

All these tests failed because of insufficient material flow and material adhesion on the cold impact extrusion tool. The test results lead to the assumption that liquid lubricants are not suitable for the process because the lubricant film will be squeezed out under high pressure. Thus, the further tests were done using a new kind of lubricant formulation. This new lubricant is a suspension of solid lubricant particles in water and can be applied in the same manner than when using zinc stearate. The solid lubricant particles are based on raw materials from renewable resources.

For the evaluation of the new lubricant in the laboratory, the spike test has been used because of its high validity as a simulation test for cold extrusion processes and its good repeatability. This test combines an upsetting process with a forward extrusion process. A cylinder-shaped slug with a conical extension on one side was pressed into a die, forming a spike (Figure 2). The polished tool surface causes very low friction and reduces adhesion of the workpiece material.

Additionally, to the spike test, to evaluate the properties of the lubricant under real production conditions, a field test was done in an aluminum processing company which is focused on the production of cold impact extrusion parts. The part that was used for the field test is manufactured from a slug in one step in a combination of a forward solid and forward cup extrusion process and a backward cup extrusion process with variation of pressing speed and pressing force (Figure 3).

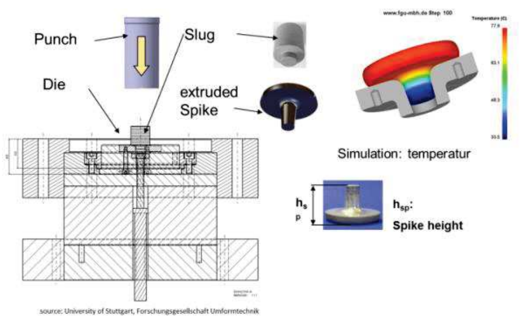

Figure 2 Design of the spike test tool.

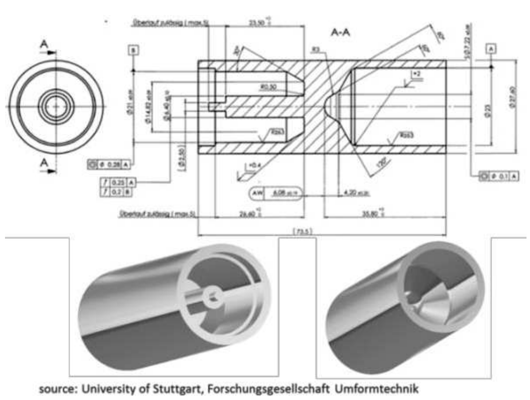

Figure 3 Drawing of the field test part.

3. RESULTS AND DISCUSSION

By using the spike test, the material flow properties of the new lubricant were found to be similar to zinc stearate (Figure 4). There was no significant difference measured in the height of the produced spikes or the temperature of the parts measured directly after the extrusion process.

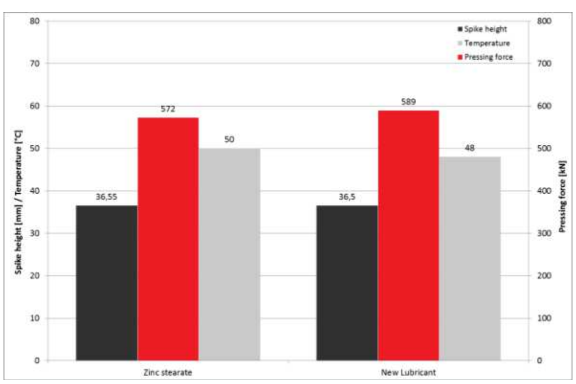

Figure 4 Results of the spike test.

In the field test, the new lubricant was applied to the slugs by tumbling which is the same process that is used for applying zinc stearate. Contrary to zinc stearate there was no formation of dust observed during the tumbling process and when the tumbler was discharged. This is a significant improvement of the occupational safety of aluminum cold extrusion processes.

During the field test, the shell temperature of the pistons was measured directly after the extrusion process. The temperature of the extruded parts which were manufactured with the new lubricant was slightly lower than for those which were produced with zinc stearate (Figure 5). The pressing force with the new lubricant was only approx. 1.6% higher than with zinc stearate. Material flow and surface quality were very good. These results clearly indicate that there is no change of the process or tool design necessary when the new lubricant is used.

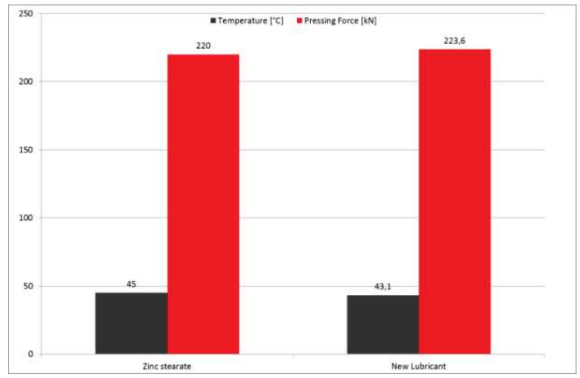

Figure 5 Temperatures and pressing forces at the field test.

Also, there was no adhesion of aluminum at the tool. In comparison to zinc stearate there was less lubricant residue at the punch and the die which was easily removable by wiping. The remaining lubricant film on the manufactured parts could be removed by washing with water-based cleaners which can reduce the ecological impact of the washing process.

4. CONCLUSION

The test results show that it is possible to substitute zinc stearate as lubricant in aluminum cold impact extrusion processes by a suspension of a solid lubricant in water. This new lubricant formulation has the following advantages:

(a) Based on organic solid lubricants from renewable raw materials,
(b) Metal free,
(c) No dust formation improved occupational safety,
(d) Forms a very thin homogeneous lubricant film,
(e) Material flow is similar to zinc stearate, no changes in the process necessary,
(f) Suitable to form complex shapes, e.g. pin bloc coolers or aerosol spray cans,
(g) Less residue on die and punch,
(h) Easy handling, precise dosage,
(i) Easily removable by washing processes or heat treatment.

REFERENCE

[1] Sivaraj, M., Muthuraman, S., & Selvakumar, N. (2018). Effect of Processing and Nano scale Reinforcement on the cold forming of Al-TiC Composites. *International Journal of ChemTech Research*, *11*(02), 283-295.