Substitution of Zinc Stearate in Cold Extrusion Processes

3F – Metalworking Fluids III

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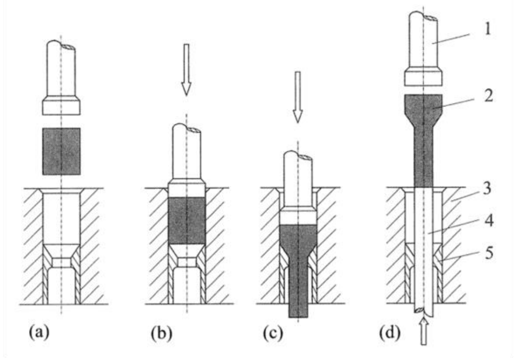
Introduction

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 e.g. in aerospace applications. Also the growing need for fuel economy and reduced greenhouse gas emissions in automotive engineering leads to a strongly increasing demand for parts made of aluminum alloys. Furthermore, its superior strength and light weight makes it an ideal material for sports, camping and outdoor equipment. Due to their excellent corrosion and weathering resistance aluminum parts are widely used in the construction, food and cosmetics industry as well as for household, container, marine and chemical plant applications.
Aluminum and its wrought alloys can be formed very economically in cold forming processes. The achievable variation of the diameter is very large, while the pressing force requirement is relatively low.

Cold impact extrusion

The term "cold impact extrusion" denotes a massive forming process that is used particularly for the extrusion of non-ferrous components under mass production conditions in high speed mechanical presses. The advantages of this process in comparison to metal removing operations, precision forging or casting processes are:

- Large material savings caused by optimal utilization of the material
- High production rates even when forming complex shapes
- Good dimensional accuracy and high surface quality
- Improvement of the material properties by taking advantage of the cold work hardening and favorable microstructure



a) Insertion of slug
b) Compressing (upsetting) of slug
c) Cold impact extrusion
d) Ejection of the finished workpiece

1 Punch
2 Workpiece
3 Extrusion container
4 Ejector

Figure 1: Solid forward impact extrusion process

Cold impact extrusion processes are classified depending on the direction of material flow in relation to the tool movement; e.g. forward, backward and lateral (figure 1). Additionally the processes are categorized according to the shape of the manufactured workpiece, i.e. solid or hollow.

Lubrication of cold impact extrusion processes

For all the different cold impact extrusion processes the correct application of a suitable lubricant is essential. An insufficient amount of lubricant causes an inadequate flow of the material; the desired shape of the workpiece will not be generated. Furthermore, the imperfect separation properties of the lubricant film can cause adhesion of workpiece material on the punch or die. This can lead to the sticking of the workpiece in the die. On the other hand, too much lubrication, e.g. by the application of an excessive amount of lubricant, or by the use of an improper lubricant, will cause a too rapid flow of material. This often results in an orange-skin like rough surface. Finally, an unevenly applied lubricant film also leads to an unevenly shaped workpiece.

Zinc stearate

For most 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 in cold extrusion processes because it works 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 a risk of dust explosion caused by electrostatic ignition. Additionally, toxic and irritating vapors are formed by thermal decomposition. To prevent the negative effects of zinc stearate, a research project was started to develop a lubricant with comparable lubricating properties but lower toxicity and without dust formation.

Testing of an alternative lubricant

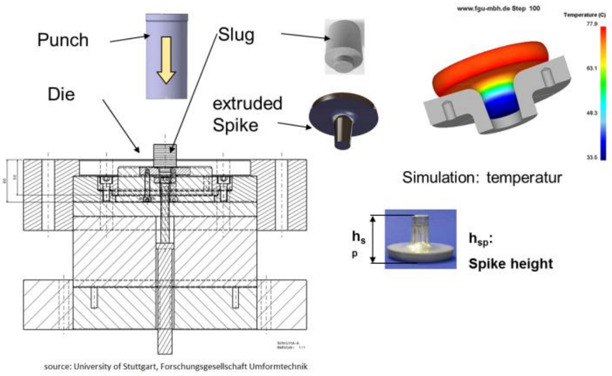


Figure 2: Design of slug, spike-test tool and cold extruded spike

The new lubricant consists of solid particles derived from renewable raw materials which are dispersed in water. It was tested by using a spike-test at the Institute for Metal Forming Technology of the University of Stuttgart, Germany (figure 2). This test combines an upsetting process with a forward extrusion process and is well known as a simulation test for cold extrusion processes. Before starting the spike-test, the lubricant was applied on the slugs by tumbling. After tumbling the water was completely evaporated and an extremely thin lubricant film covered the slugs.

The evaluation of the lubricant was done by using the following parameters:

- The spike height gives an indication of the material flow
- The pressing force which is needed for the cold impact extrusion process
- The temperature of the spikes after the extrusion process
- The adhesion of workpiece material and the formation of lubricant residues in the die

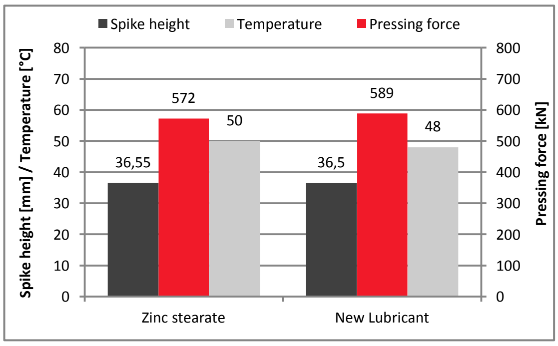


Figure 3: Results of the spike-test

In particular the material flow properties of the new lubricant have to be similar to those of the zinc stearate to avoid the expensive reconstruction of the cold extrusion tools.

Compared with zinc stearate, the spikes that were produced with the new lubricant showed nearly the same height. The temperature of the spikes after the cold extrusion process was slightly reduced however the pressing force was slightly increased (figure 3).

Testing under production conditions

To check the properties of the lubricant under real production conditions a field test was done in a company that is focused on the production of aluminum cold impact extrusion parts. A quite challenging part in this company is the DK-piston (figure 4) which 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. The tests were done on a Dunkes hydraulic press using a pressing force of maximum 270 kN, the maximum pressing speed was 60 mm/sec. Again the maximum pressing force and the shell temperature of the manufactured parts were used for the evaluation of the lubricant. The test results (figure 5) show that 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. The pressing force was up to 2.2% higher than with zinc stearate. When using the new lubricant, material flow and surface quality were very good. The inner surfaces of the pistons looked even shiny. Also there was no adhesion of aluminum on the tool. In comparison to zinc stearate, there was less lubricant residue at the punch and in the die which was easily removable by wiping. The best results were realized with a lubricant film of approximately 0.0016 mg per mm². When using zinc stearate an amount of approximately 0.0023 mg per mm² was needed for an optimal material flow.

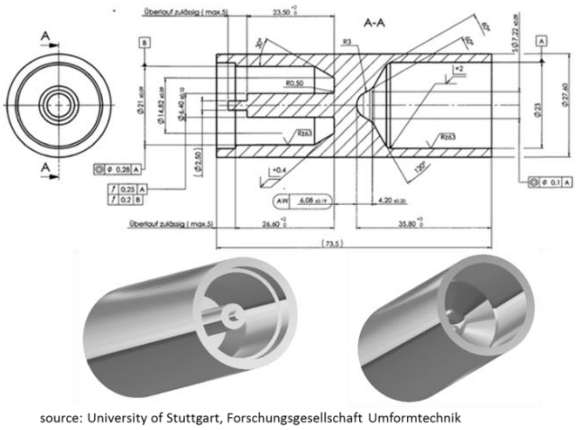


Figure 4: Drawing and image of the DK-piston

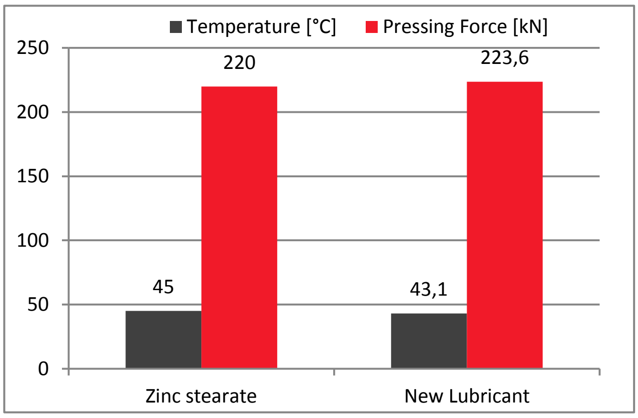


Figure 5: Average temperatures and pressing forces of the DK-piston test

Additional tests showed that the new lubricant can be easily and completely removed by washing the parts with solvents (perchloroethylene and alcohols) or water based cleaners.

Conclusion

The test results demonstrate 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. The new lubricant formulation has the following advantages:

- Based on organic substances from renewable resources
- Forms a very thin, homogeneous lubricant film
- Material flow is similar to zinc stearate
- Less residue in the tool
- Suspension in water, no dust formation, easy and precise application
- Easily removable by washing