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Force-displacement motions of a lubricated and dry tapering process of an AlMgSi1 alloy

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Abstract

Lubricants are commonly used in metal forming to reduce friction between work piece and forming tool, to protect semi-finished products and goods against corrosion and to reduce tool load. According to the aim of environment friendly production technologies it is strived to realize dry forming by the absence of lubricants. In this study tapering of aluminium rods of an AlMgSi1 alloy with a tungsten carbide forming die is investigated. The diameter is tapered from 9.25 mm to 9.00 mm. The tapering investigations were performed lubricated as well as dry. The lubricated forming investigations showed a mean maximum press force of 5.4 kN ± 1.5 kN. The dry tapering investigations of aluminium alloys were stopped after two samples, due to aluminium adhesion in the forming zone, which prohibited tapering of more samples. Dry tapering processes lead to adhesion of aluminium in the deformation zone very quickly by the use of a tungsten carbide forming die, which prevents the tapering of a high quantity of aluminium rods.

Keywords: dry forming, tapering, aluminium

1 Introduction

Dry massive forming [1] of aluminium components is of high interest in construction and automotive industry as well as in aircraft construction. Anodic oxidation is a common method to protect aluminium components against corrosion and increase the hardness at the same time. This process is based on the conversion of the upper metal layer where an oxide layer is formed. Anodic oxidation requires a clean surface which is free of grease. Another field of application, where especially dry tapering of aluminium is of interest, is the production of transoceanic cables. Therefore an aluminium tube is positioned around a cable bundle and tapered afterwards to archive a compaction. Thereupon the aluminium tube is coated by synthetic material. Located lubricants between aluminium tube and synthetic material coating can lead to an electrical short circuit. Due to this reason the tapering needs to be executed under dry conditions. Currently the tapering in this case is already realized under dry conditions, with the use of polished tungsten carbide forming dies. But big problems occur due to cold welding by the absence of lubricants, which lead to a life time reduction of the forming die and thus to a frequent exchange of the forming die. [2]

Tapering can be realized at different process temperatures, whereas cold extrusion (press method at room temperature) is economically the most important one [3]. The methods of cold massive forming are of high interest due to the high material utilization with simultaneously low need of energy.

The difference between impact extrusion and tapering is the construction of the extrusion container. Whereas the blank is totally enclosed in impact extrusion processes, the blank is not supported in tapering processes. This leads to a lower possible cross section decrease than it can be realized in impact extrusion. Tapering is in contrast to wire drawing a process, where single parts are produced. Tapering is used in production of screws, rivets, bolts, axes, shafts, spindles, etc. [3]

The tapering investigations in this publication show the difference of dry and lubricated forming and serve as reference for planned coatings to improve the dry tapering of aluminium.

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2 Methods

To execute the tapering processes a Zwick Roell Z250 test machine with a maximum press force of 250 kN is used. The manufactured device for the tapering process is shown in Figure 1. The tapering die is manufactured as a shrink joint to enable for researches, regarding the coating of the forming die, just to buy tungsten carbide cores as coating substrates. The successful coated core can be afterwards be shrink joint in a steel casing. The tapering die has an opening angle of 20°, a diameter of 9 mm at the narrowest position and exit angle of 60°.The workpiece has a backlash of 0.15 mm in diameter inside the guidance, as it is typical for tapering processes. [4] As workpiece material the aluminium alloy AlMgSi1 (EN AW 6082) is used. The diameter will be tapered from 9.25 mm to 9.00 mm on a shaft length of 17 mm. This leads to a forming degree of 0.05, which has to be smaller than 0.3 regarding to [3]. The forming process is executed with a punch velocity of 1 mm/s and the machine is programmed to move the punch 17 mm downwards. After the tapering process the samples are removed out of the forming die into the backward direction.

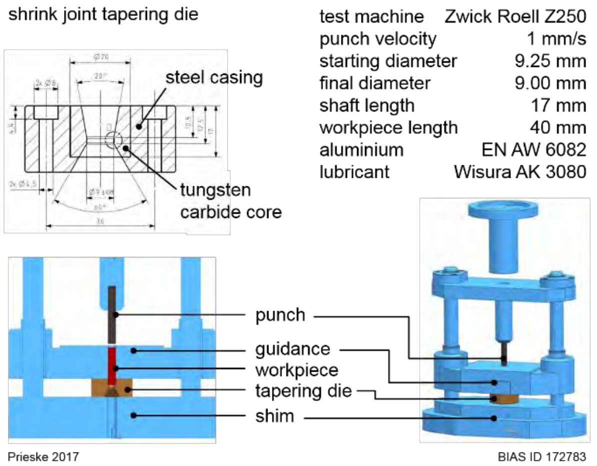

Figure 1: Device to execute tapering processes in a Zwick Roell Z250 test machine.

To proof if the chosen dimensions and material of the workpiece can be successfully tapered with the forming degree of 0.05 two requirements have to be fulfilled. First of all the condition to avoid upsetting has to be met which prohibits the forming of a bulge. This condition would even be fulfilled for a coefficient of friction of 1.0. The other condition restricts the workpiece length to avoid a buckling of the workpiece. This is given for a maximum workpiece length of 132 mm. This can be calculated with the formulas given in [4] and the material properties of the used workpiece material.

The lubricated tapering processes were executed with the usage of the lubricant Wisura AK 3080. Prior to the dry tapering processes the tapering die is cleaned by a Tickopur solution (10% Tickopur R33) in deionized water to remove residual lubricants [5].

Scanning electron microscopy (SEM) (Carl Zeiss Microscopy EVO MA-10) using the secondary electron (SE) signal was used to observe the surface structure of the forming die. An integrated energy dispersive X-ray spectroscope (EDX) (Bruker Nano GmbH XFlash Detector 610M) was used for element analyses and mappings of the forming die to detect aluminium adhesions.

3 Results

The results of ten lubricated tapering processes are shown in Figure 2. The photo shows that all ten lubricated tapering processes where successful. The mean maximal punch force is 5.4 kN with a standard deviation of 1.5 kN. All samples have a shaft length of 17 mm. The total sample length elongated from 40.0 mm to 41.2 mm.

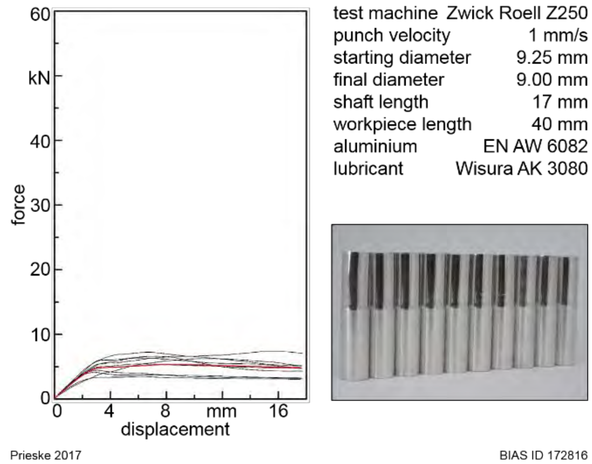

Figure 2: Force-displacement motions of lubricated tapering of aluminium rods. The red line in the diagram shows the mean force displacement motion.

The force-displacement motions of the dry tapering processes are shown in Figure 3. The first sample needed a maximum punch force of 26.8 kN, whereas the second one needed a punch force of 59.5 kN.

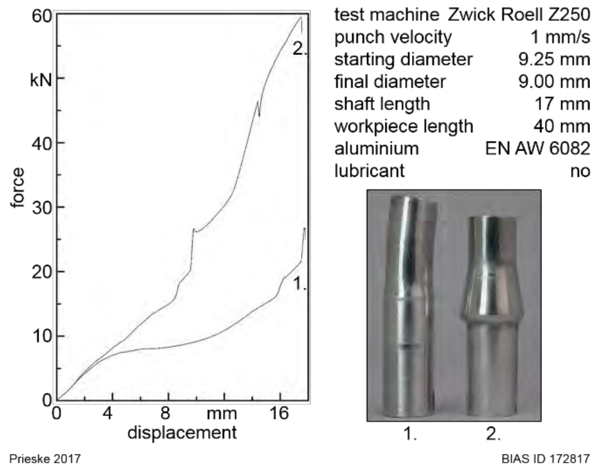

Figure 3: Force-displacement motions of dry tapering of aluminium rods.

The first sample has a tapered shaft of 16 mm length, but also a bulge of 9.7 mm thickness with a length of 9 mm. The total length of sample one is 40 mm. The second sample shows a shaft length of 9 mm where the diameter is tapered to 9.0 mm, which is accompanied by a punch force increase in the force-displacement motion. A big bulge is formed with a maximum diameter of 12.1 mm and even the area with the initial diameter of 9.25 mm is thickened to 9.54 mm. This leads to a cracking of the guidance (made out of hardened steel) which had a diameter of 9.4 mm. Due to this circumstances the dry tapering processes where stopped after two samples.

Due to preliminary lubricated forming investigations, the forming die showed already little wear before the lubricated tests of this study were executed as shown in Figure 4 a). After the lubricated tests the forming die shows just a little increase in wear as can be seen in Figure 4 b). Especially the inner area is still very clean. Figure 4 c) shows that after the dry tapering processes heavy aluminium adhesions can be detected, which becomes even clearer in Figure 5.

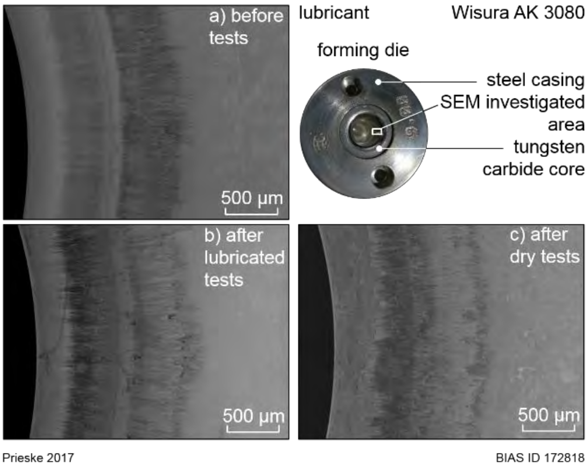

Figure 4: Secondary electron images of the wear of the forming die a) before the tests, b) after lubricated and c) after dry tests.

The photography of the tungsten carbide core in Figure 5 a) shows aluminium adhesion at the inner diameter. The EDX mapping (Figure 5 b) just received signal at the outer area due to the sharp incident angle of the electron beam. But it can still verify that the foreign substance, which can be seen in the images is aluminium. The close up images in Figure 5 c) and d) show the surface structure of the adhesive aluminium.

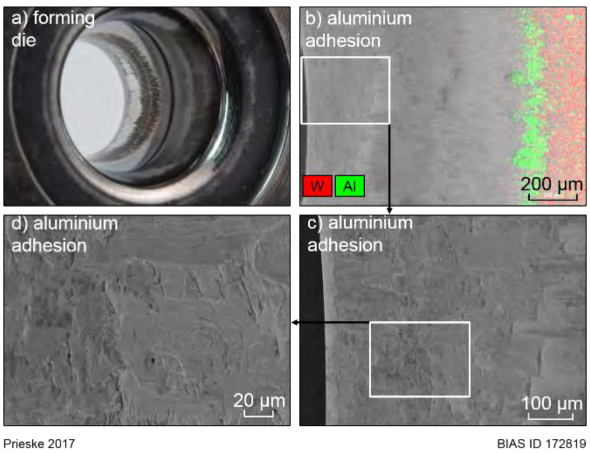

Figure 5: Wear of the forming die after dry tapering a) shows a photo of the forming die, b) an EDX measurement and c) and d) close up images of the adhesion.

4 Discussion

Some of the tapered samples with lubricants are bend into one direction. The strength of the incline varies between the samples. This circumstances could come from irregular friction in the circumference of the forming zone, which leads to different exit velocities of the workpiece and therefore to a bending.

It seems that the impact on dry tapered samples is even bigger, which is shown by the first dry tapered sample. The second sample got stuck in the deformation zone which led to a deformation of the aluminium into the free space in the forming die and the guidance.

5 Conclusion

The investigations showed, that dry tapering of aluminium rods with a tungsten carbide forming die was not possible without formation of a bulge. Adhesion of aluminium in the deformation zone occurs very quickly, which prevents the tapering of a high quantity of aluminium rods.

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