MATHEMATICAL MODELING AND EXPERIMENTAL PROCESSING OF STEEL PLATE BY ACCUMULATIVE SURFACE FORMING

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Introduction

Severe plastic deformation (SPD) is an important technique for fabrication of bulk materials with ultrafine grain sizes. SPD has attracted a great deal of attention over the past two decades because of the materials' enhanced properties [1, 2].
In the past decade, a number of the various severe plastic deformation (SPD) techniques have been used to refine the structure of metals and alloys. To introduce large plastic strain into bulk material, different techniques have been used, such as ECAP [1], high pressure torsion (HTP) [3], accumulative roll bonding (ARB) [4, 5], constrained groove pressing (CGP) [6], and others. All the above mentioned techniques are designed to produce submicron- and nano-grained materials in the entire volume of bulk material.
Accumulative Surface Forming (ASF) of metallic materials uses a deformation force acting on the surface of metal. This deformation force produces a load that is many times higher than the flow stress of the material. The deformation process introduces very high strain into the material within a certain depth (depending on the dimension of the projection on the tool). The microstructure of the processed layer then exhibits considerably refined grain. This technique also preserves the original dimensions and shape of the workpiece. Its principle is presented in the following example:
A tightly-fitting workpiece is placed into a die. The top face of the workpiece is then processed by the action of a plate with a projection (Fig. 1). The plate with the projection makes linear movement between two limit positions. The linear movement of the projection causes forming of the material. The cycle can be repeated to obtain multiple deformation cycles. The forming ends when the plate with a projection returns to its initial position. The workpiece therefore retains its original shape and dimensions.

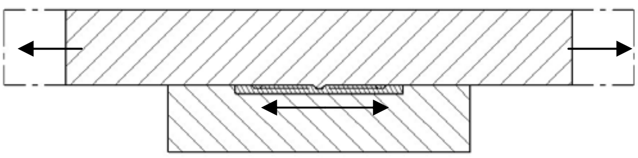

Fig. 1 The principle of the ASF technique

Experimental Procedure

<u>Forming tool for sheets 100 × 100 mm with 5 mm thickness</u>
The tool for cyclic forming of a surface of a sheet with dimensions of 100 × 100 mm and 5 mm thickness has a prism-shaped moving die with a rectangular projection. The sheet is placed in a multi-part die (figure 2). The multi-part die concept was developed in order to eliminate potential notch effects. The die consists of several blocks which are joined with high-strength M20 thread rods. The assembly is shown in the following figure 2.

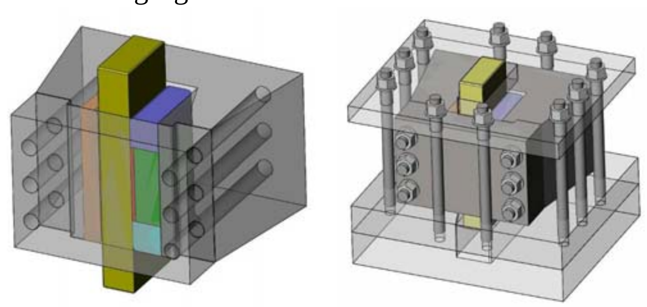

Fig. 2 CAD 3D model of the tool assembly

<u>Forming of the 100 × 100 × 5 mm sheet</u>
A groove matching the shape of the moving die with a projection must be made in the specimens in order to allow the die to be assembled. Prior to inserting the specimens into the die, the surfaces to be formed (the contact surface of the moving die and the specimen) were treated with graphite lubricant GRASIMETH BAZ 15 (producer: Fuchs Lubritech GmbH). One specimen was made from AlMg3 alloy and processed with one forming cycle. By this, the operating ability of the tool was verified. The subsequent work and numerous tests were performed with 1.0314 steel. The tool proved usable and suitable for further forming experiments. It would be practical for further application to reduce the friction between the moving die and the specimen by applying a PVD coating on the moving die (TiN).

Results and Discussion

The specimen was processed with ten passes, then removed, turned 90° and processed with additional five passes. Its initial dimensions were 100 × 100 × 5 mm with h6 tolerance. After ten passes, the workpiece length (in the forming direction) was 100.6 mm and the width (perpendicular to the forming direction) was 100.09 mm. The thickness is shown in fig. 3.

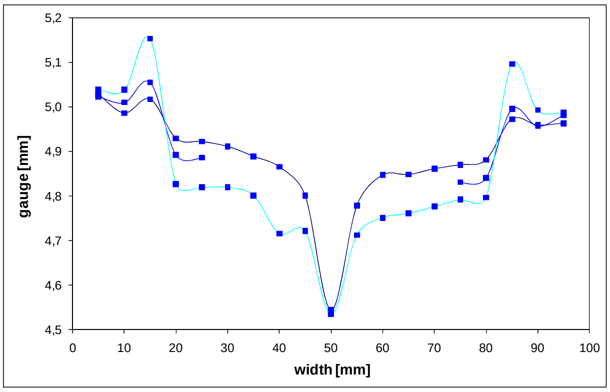

Fig. 3 Thickness of the specimen after 10 passes

After measuring, the workpiece was rotated 90° and placed back in the tool. Then it was formed in five passes. After forming, its length (in the forming direction) was 100.56 mm and the width (perpendicular to the forming direction) was 101.07 mm. The thickness is shown in fig. 4.

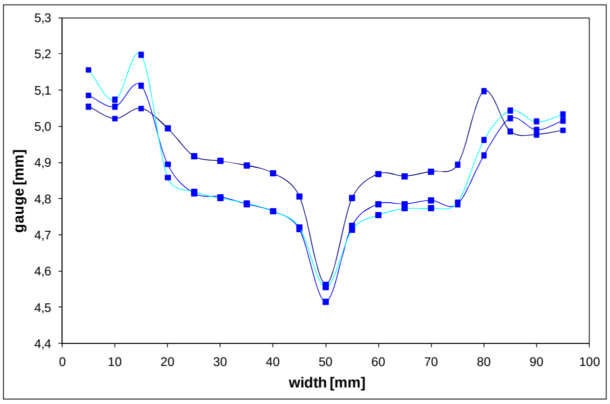

Fig. 4 Thickness of the specimen after 15 passes

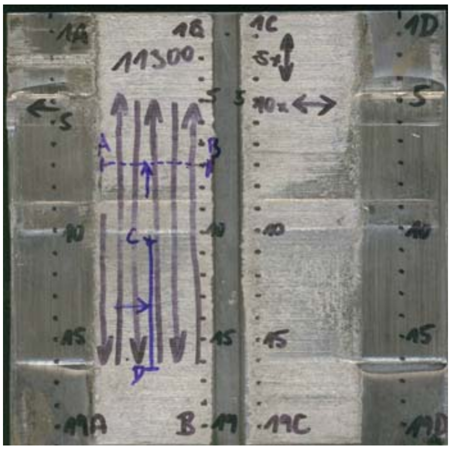
Fig. 5 Macro photograph of the plate

Microstructure on the cross-section marked as A-B in fig.5 is shown in the following figures. The thickness of the formed layer on the cross section varies from 100 μm on the A side (fig. 5) to over 500 μm on the B side.

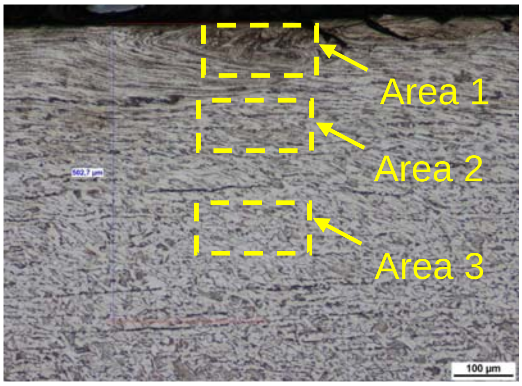

Fig. 6 Deformed surface of the plate 100×

Fig.6 indicates the approximate thickness of the deformed layer where near the B side it reached the depth of about 0.5 mm. Detailed micrographs of the regions marked in fig.6 are shown in the following fig.7.

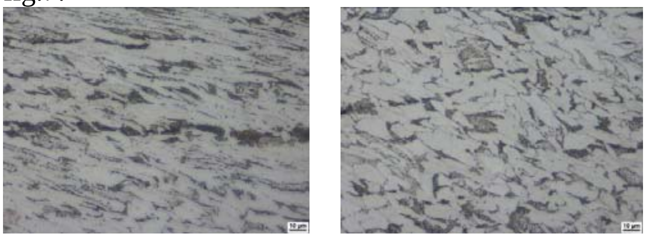
Area 2, mag. 500× Area 3, mag. 500×

Fig. 7 The microstructure of areas 2 and 3

Conclusions

A tool for Accumulative surface forming of metals has been designed in this study. It is a multi-part die with a moving die for cyclic forming of the surface of sheet metal with the dimensions of 100 × 100 × 5 mm. The operating ability of the tool was first verified by a finite element method calculation. The design was used for manufacturing a die for a trial.

Experiments with 1.0314 steel sheets have proven the effect of microstructure refinement in about 10 passes. Observation in a light microscope revealed significant deformation of the structure spanning the entire length of the formed zone. The thickness of the deformed layer along the whole longitudinal section was about 300 μm. The grain size and dislocation density will be determined using other methods.

References

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