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EXPERIMENTAL AND FEM STUDY OF OPEN DIE FORGING FOR BIMETALLIC CYLINDRICAL PARTS PRODUCED USING DIFFERENT MATERIALS

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Abstract: This study investigates character of bimetallic cylindrical component that contains has an outer ring and inner solid cylinder throughout open die forging process. AISI 1020 steel are used for the outer ring and Brass and Copper for the core. Process has been performed both experimentally and analytically by using FEM simulation software, DEFORM. Two different models have been considered to show material flow and the cavity took place over the interface during forming after %15, %30 and %40 reductions. Steel is outer ring material for each model. Brass is inner material for Model 1 and Pure Copper is inner material for Model 2. These produced models has been forged to %15, %30 and %40 reduction by the help of parallel smooth dies in 150 ton press machine. Forming load or final load was recorded. Results have shown that the models had very good interaction with interior block and outside ring and the contact between interior block and the outside ring had a different interface character with changing in assembly height. This gives an idea about producing bimetallic parts including brass and copper via this method.

Key words: Bimetal, Forging, Copper, Brass, Steel

1. INTRODUCTION

In metal forming world, open die forging is the most significant and basic technique. A lot of studies about open die forging of sole materials, like steel, copper, aluminum were worked both theoretically and experimentally over years. Vilotic et al., [1] have given special attention to process of upsetting of single cylindrical billets. K. Baskaran and R. Narayanasamy investigated the barreling effect of aluminium cylindrical parts (elliptic parts) that preformed irregularly shaped throughout the process of jumping up with the lubrication on both ends of elliptic cylindrical parts of pure aluminium under varied stress state situations such as plane, triaxial and uniaxial stress states, [2]. S. Malayappan et al. studied barreling effect of aluminium solid blocks experimentally by the use of a die for extrusion at one side, [3]. Aksakal et al. examined both theoretically and experimentally forging of polygonal specimens by means of developing couple stream functions, [4]. Barrelling effect of truncated cone billets of various metals has been investigated by researches Thaheer and Narayanasamy, [5]. Chang and Bramley [6] studied the determination and effect of the heat transfer coeffcient through workpiece-die interfaces during the forging process. Dyja et al., [7] analyzed the rolling process of Al-Copper and Steel-Copper bimetallic rods both theoretically and experimentally. Contact pressure distribution in upsetting of compound cylindrical and cubic metals has been examined Kocanda et al., [8]. Also Senthilkumar and Narayanasamy [9] evaluated the preforms of steel composite with the variety of TiC ingredients and showed some of the upsetting features of throughtout cold forging process under the state of tri-axial stress situations.

At the present time, especially in chemical industry, marine industry, and electrical components, bimetallic parts are mostly used in industry due to their some better properties comparing to single materials. For instance, bimetallic parts particularly offer better conductivity and corrosion resistance. Bimetallic parts differ from single materials because of each two materials consist of different chemical compositions. For instance, different grain size and impurities inside the using metals can be shown different plastic forming characteristics. However, bimetallic parts are not composites since reinforcing elements spread uniformly inside the matrix materials in composites.

During the recent years, plastic forming of bimetallic parts have studied by a lot of researchers. High temperature forging process of two or three metals cladded work parts with the usage of upsetting experiments has been investigated by Jingcai Wang et al., [10], Yang et al., [11] used upper bound method as a different approach for the same research. In order to produce bimetallic rods, Eivani and Tahiri [12] used equal channel angular extrusion process and they compared this to one produced by general extrusion process. Plancak et al., [13] studied using a closed die the experimental analysis of compound of two bimetallic axisymmetric parts from various materials by means of upsetting bimetallic parts. Then Plancak et al., [14] have been compared all the experimental data to one obtained by using finite element method in addition the older researches. Also the mechanical behaviour of bimetallic parts which has C45 steel outside ring and C15 steel interior block during the cold upsetting process by Plancak et al., [15].

Fig.1. Plancak Bi-metallic Model, [14]

Experimental and analytical approach of open die forging of bimetallic cylindrical parts producing using different materials designed as two models was examined in this work. This process may ensure many parameters such as formability and barreling for metal forming operations. This study aims to investigate and compare the flow of metal and requirement of load for these two materials when forging of bimetallic cylindrical parts.

2. EXPERIMENTAL WORK

Two bimetallic material models have been designed for this work for showing interaction between different materials. Chemical properties of these models have shown in Table 1. Fig. 2 shows technical drawing of Model 1 and Model 2.

Table 1. Chemical Properties of Model 1 and Model 2

Model 1: Ring AISI 1020 STEEL
Solid inner cylinder BRASS

Pb(%)	Al(%)	Sn(%)	Ni(%)	Fe(%)	Zn(%)	Cu(%)
1.6-2.5	0.05	0.3	0.3	0.3	Rest	57-59

Model 2: Ring AISI 1020 STEEL
Solid inner cylinder COPPER

O(%)	Cu(%)
0.04	99.9

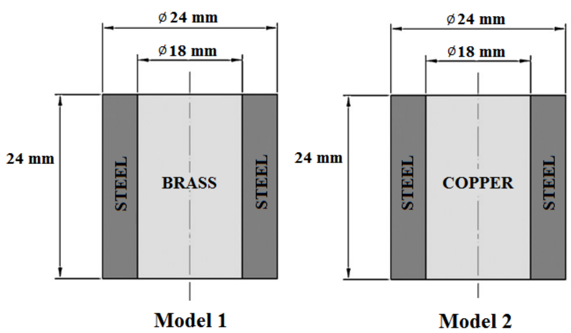


Fig.2. Design of Bimetallic Models

After preparation of all the materials in lathe machine with necessary dimensions, inner cylindrical block has been pressed by very low pressure into outer ring material in order to obtain designed bimetallic parts with suitable tolerances. Assembled two bimetallic parts are shown in Fig. 3.

Fig. 4 demonstrates the hydraulic press that has 150 ton capacity that the experiments were performed. The speed of this hydraulic press is 5 mm/s and constant. The hydraulic press has been equipped with a transducer with pressure current for measuring and recording the load change during the experimental procedure. The load or pressure value has been read by means of an I/O card of the any computer during the experimental procedure.

This I/O card value has been converted into a strength value, then this strength value, consequently the pressure value has been offered as an input value to the software.

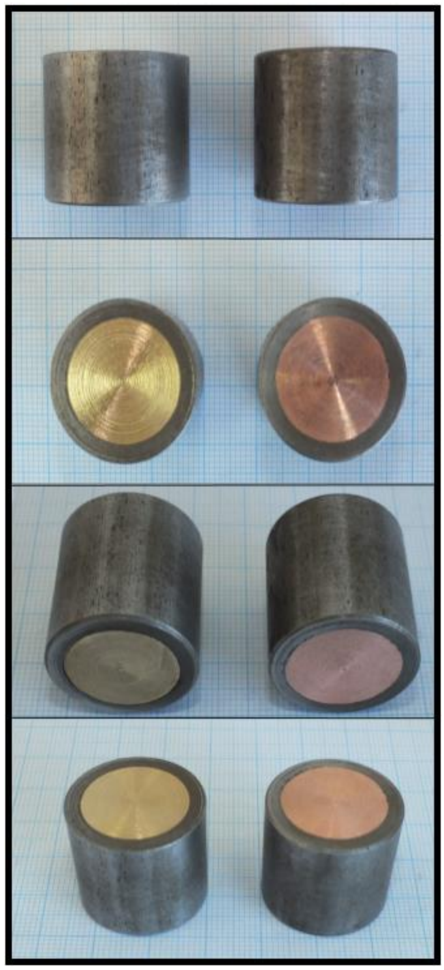


Fig.3. Obtained Bimetallic Parts

No special lubricants have been used though bimetallic specimens and flat swages have been sanded before the experimental procedure. The fixing of parts to hydraulic press is shown in Fig. 4. Then bimetallic parts have been forged with three different reduction ratios %15, %30 and %40.

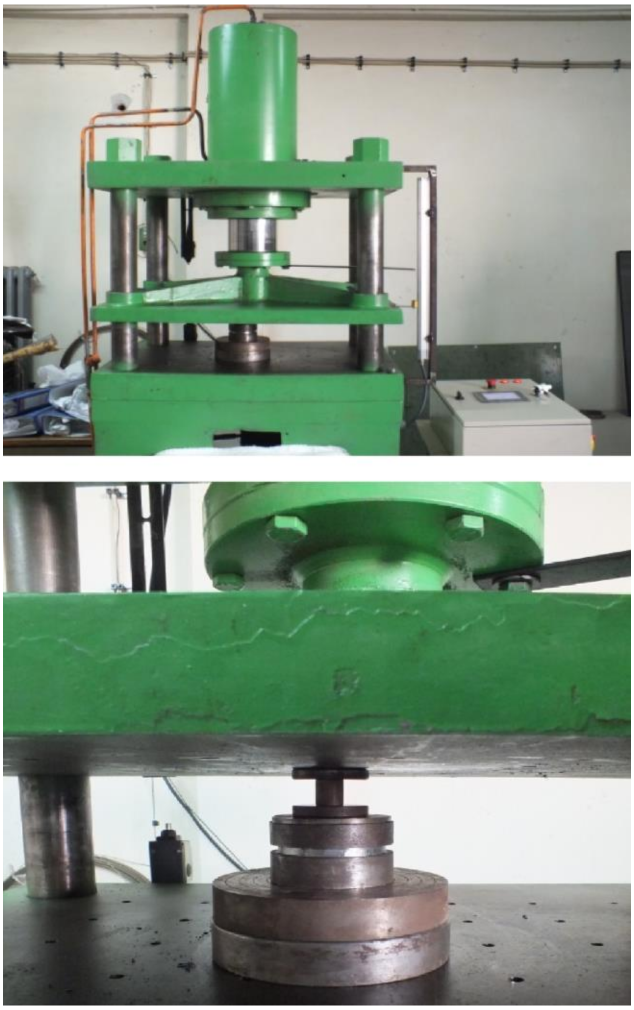


Fig.4. Hydraulic Press and Fixing of Parts

3. FEM SIMULATION

On the purpose of validation of experimental procedure, a theoretical model has been developed with the help of the finite element software-DEFORM. Finite element approach offers more insight and it helps to compare to experimental data of open die forging of bimetallic parts, also it provides varying out more analyses about this research.

First of all, bimetallic parts has been designed in DEFORM software. Models have been considered as 2D model and due to the symmetry only one half of the parts have been performed. Mechanical properties of all the metals used were selected from Deform software library and they were assigned to the designed parts. For meshing, 8 node axisymmetric elements were used. For all the FE models, at the part-die interfaces a friction coefficient 0.1 is considered, but between the interface of interior solid block and the outside ring zero friction was assumed. Surface-to-surface contact was applied to all the friction locations. Fig. 5 shows meshed component and interactions between all the contact surfaces.

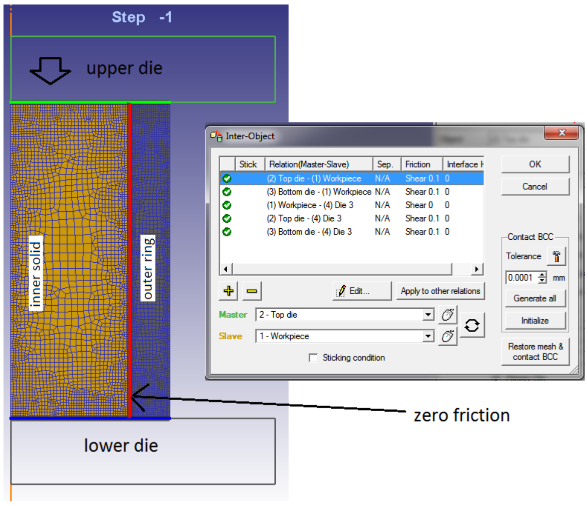


Fig.5. Meshed component and interactions

4. RESULT AND DISCUSSION

Open die forging of bimetallic cylindrical parts producing using different metals was studied experimentally and analytically for two different models. Three different metals have been used in order to produce bimetallic part models that have a ring and a solid cylinder. Model 1 has a ring material brass, and Model 2 has copper, each of these has steel solid cylinder. These parts were forged in an open die with reduction ratios %15, %30 and %40 experimentally and FE simulation model has run for the same conditions.

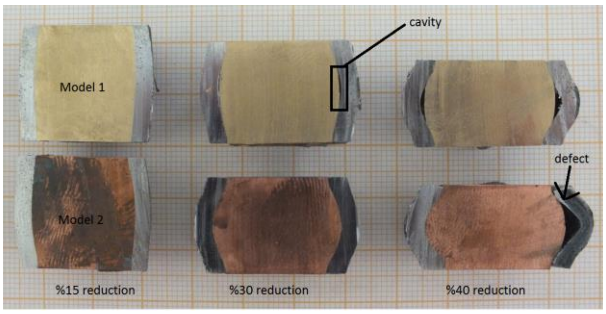


Fig.6. Meridional cut after %15, %30 and %40 reductions

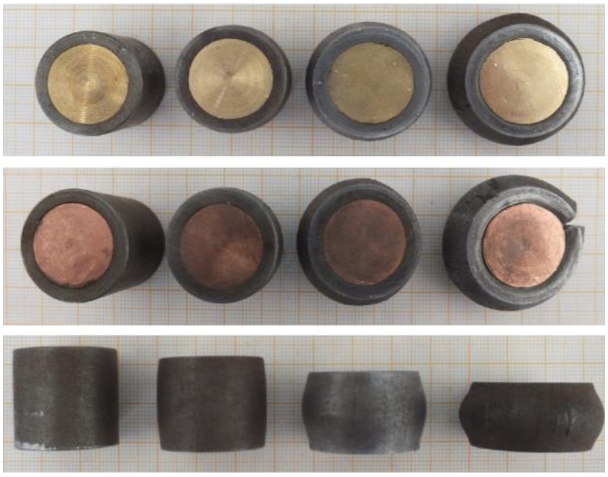
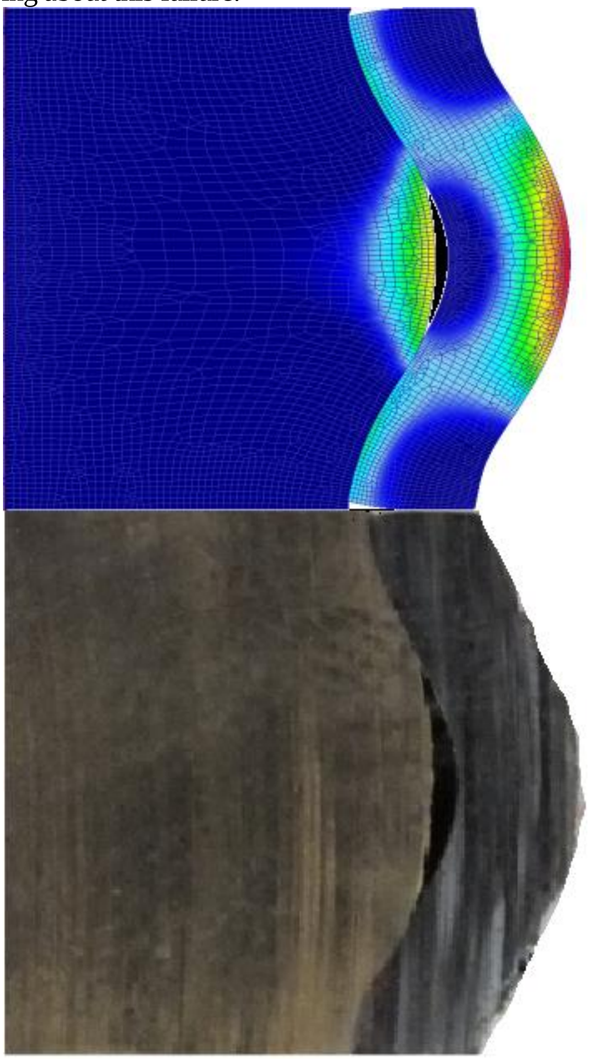
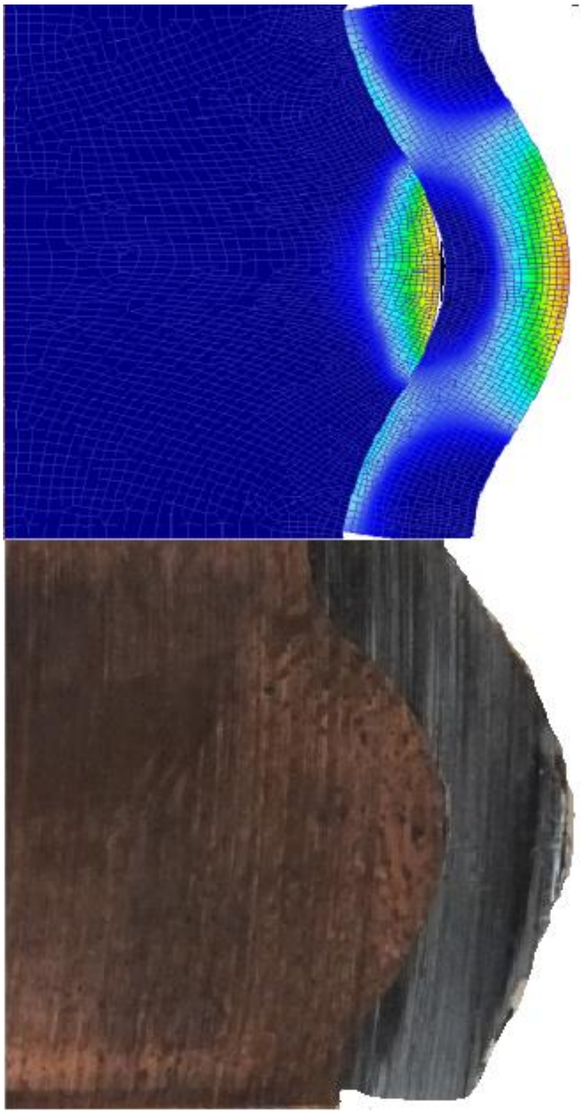


Fig.7. Deformations and barreling after %15, %30 and %40 reductions

After reduction, samples were cut and barrel profiles of the inner solid cylinder and outer ring were observed. Fig.6 and Fig. 7 shows that deformations and barreling of bimetallic parts after %15, %30 and %40 reductions. Clearly it is shown that Model 2 has much better material flow and zero cavities between the inner and outer interface. It is well observed that the middle vertical cross section of inner block material flows very quick and take place a barrel profile differ from a normal barreling behaviour. Inner block material barreling behaviour is not identical with the outer ring material barreling behaviour. Also it can be observed that in Model 1 no contact occurred between inner block and outer ring material and a cavity take place in the inner meridian part of inner material. Occurred cavity can be described that inhomogeneous plastic deformation takes place in the centerline of part and this cavity explained with a state of hydrostatic stress. After %40 reduction Model 2 has a failure on the right side. It is considered that speed of hydraulic press is very high and the familiar flow curves of copper and steel may bring about this failure.



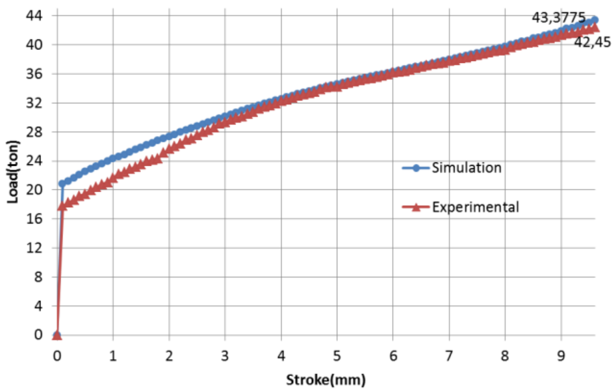
(a)



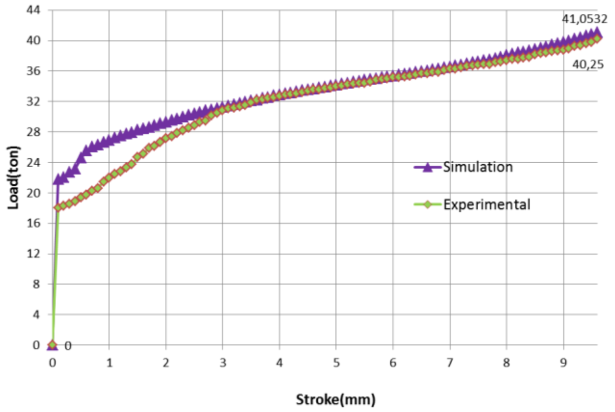
(b)

Fig.8. Comparison of FE simulation and experimental work after %40 reduction, (a) Model 1 (b) Model 2

Fig.8 shows that comparison of FE simulation and experimental work after %40 reduction. FE simulation has really similar agreement with the experimental results.



(a)



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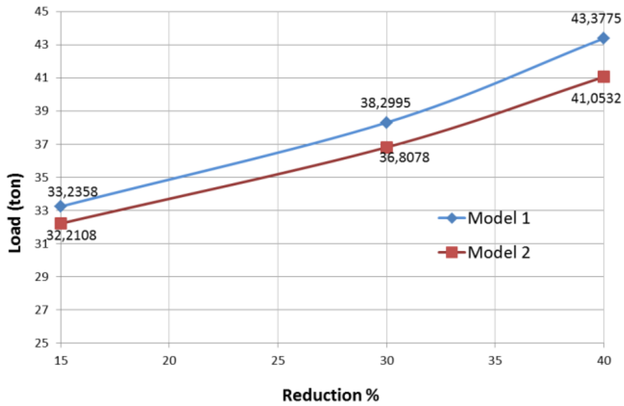

(c)

Fig.9. Load graphs of experimental work and simulation
(a) Model 1
(b) Model 2
(c) Comparison of Model 1 and Model 2

Fig. 9 shows the forming load changes during the forging process. It can be clearly seen that Model 1 needs more forming load than Model 2 as done in same conditions. Also the FE simulation values have very good agreement with the experimental values. The character of the load–stroke graphic is same for whole conditions despite the FE values demonstrate a little underestimation of the load from the experimental procedure.

5. CONCLUSIONS

Experimental results demonstrated that flow of metal has inhomogeneity for these two bimetallic parts particularly for solid block materials. The flow of ring and solid cylinder materials together also has many effects load requirement and metal flow.

A failure occurred at %40 reduction of Model 2 as observed in Fig.6. It has been considered that because of the high speed of hydraulic press this failure has occurred.

As considered the load-stroke and load-reduction graphs, Model 2 or Steel-Copper bi-metallic sample needs lower load to produce or use. Also it can be seen that Model 2 has better material flow than Model 1. Copper and steel are more useful to produce bi-metallic materials.

This work has shown that under certain conditions, in a range of tolerances, bimetallic cylindrical components may be forged while carrying on an agreeable contact interface among the two parts. As a pre-forming operation just before more processing or a finished part, this offers the opportunity of producing bi-metallic parts via this process.

In future works, flow curves of single metals copper, brass and steel will be obtain and investigate how effect the flow curves to form of bi-metallic samples. For obtaining more information in order to produce different bimetallic parts with any materials, experimental studies and theoretical analysis are considering.

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