AN EXPERIMENTAL STUDY AND DESIGNING PROCESS BY USING CAD/CAE: IN COMBINED OPEN DIE FORGING-EXTRUSION PROCESS OF DIFFERENT SHAPED GEOMETRIES FROM ALUMINUM ALLOY SAMPLES

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Abstract: This paper overviews the metal forming process which is called forging-extrusion process. The aim of this process is manufactured of near net shape of many produce. In this study, two different shaped upper dies were used. Al99.7 aluminum alloy was used for experiments. Aluminum billets which having same initial heights have been extruded with the same strokes. The forging loads were measured different deformation rate. Some of aluminum billets were lubricated and formed. Lubricated specimens were compared with the other specimens. The effect of metal forming process on the hardness distribution along the radial direction was investigated both of different geometries and lubricated conditions. In addition, the microstructures were investigated for clover shaped samples and rectangular shaped samples using transmission electron microscopy (TEM). It was found that both clover shaped samples and rectangular shaped samples have similar mechanical properties. The corresponding microstructure consisted of a mixture of elongated subgrains with dimensions similar to those observed in the initial billet. It is suggested that there is no considerable differences between two different geometries in terms of microstructure and lubrication. Also, the equivalent stress occurred at the container and the dies that resulted of extrusion load were determined a CAD/CAM program called SOLID. Stress values at the dies were determined by stress analysis method.
Key words: Metal forming, extrusion, hardness, Al99.7, clover, transmission electron microscopy, SOLID

1. INTRODUCTION

One of the important metal forming processes is extrusion. Extrusion process is a well-known forming method in which a punch applies pressure the samples, causing the work-piece to flow in the required direction. The relative motion between punch and die is obtained attaching either one to the stationary bed and the other to the reciprocating ram (1). The extrusion process can either be cold or hot. In cold extrusion the work-piece or perform enters the extrusion die at room temperature. Cold extrusion involves indirect, direct or combined indirect and direct displacement of metal by plastic flow under pressure. Forging-extrusion is a combined process as its name implies and mostly used metal forming process for manufacturing of perform or near net shape of many industrial parts used in many different and principal applications include parts for aerospace industries, automobile industries and aircraft industries (2). In the process, a cylindrical sample is compressed between two parallel overhanging dies. Material flows vertically through orifice as backward extrusion.

Aluminum and aluminum alloys are most commonly extruded metal. The control of extruded aluminum alloy grain structures is being driven by many applications, particularly those with in the difference industry. Aluminum provides the characteristics of good strength-to-weight ratio, machinability, corrosion resistance, attractive appearance, high thermal conductivity and high electrical conductivity. Approximately, all of the aluminum alloys can be cold extruded. Aluminum alloys are well adapted to extrusion.

Aluminum and aluminum alloys can be successfully extruded with such lubricants (for example, grease and high-viscosity oil). For slugs of the less extrudable aluminum alloys, for maximum extrusion severity surface preparation may be necessary for retention of lubricant. Extensive research studies, involving the effects of die geometry, loading rates, extrusion speeds and ratios of lengths to diameters of billet on the extrusion pressure of cold extrusion process have been undertaken, while research findings have been fairly restricted to developing processes and assisting lubricants for warm or hot extrusion processes.

Aluminum and aluminum alloys encompass a wide range of chemical composition and thus a wide range of hardness. Many recovery and precipitation processes in aluminum alloys can occur at relatively low temperatures, such as 150 to 250 ^{0}C , which are readily produced in such operation as cutting, grinding and mounting.

Because of industrial importance, the combined extrusion and forging processes have been investigated by many researchers. Brayden and Monaghan investigated closed die forging and open die forging complex flow processes (3). Hu and Hashmi investigated the metal flow behaviour during the forging-extrusion of rectangular billets with grooved dies having two different widths using FEM (4). Forward extrusion of clover sections from lead billet has been investigated and after this investigation a good agreement was found between the measured and the predicted loads (5). Maccarani and his friends have been studied the effect of orifice angle and fillet radius of upper die on the deforming body. For the cylindrical orifices and specimens, it has been shown that the fillet radius has no influence on the compression forces, but the friction had significant effect (15-20%) on extrusion forces (6). The lubrication characteristics of several tool materials and lubrications were investigated using injection upsetting combined with backward extrusion by Nishimura and his friends. The experiments were performed at various strain rates and temperatures. The learned that, for all of the lubrication conditions except for the use of a water-based BN lubricant adhesion was not observed at the lower tool surface (7). Mısırlı was investigated in his Master thesis, the early stage of forging-extrusion for two different (circular and square) orifice geometries. The upper bound analysis was used to predict the load requirement. It has been understood that, material flow was slightly restricted in square orifice due to its longer perimeters and sharp corners (8). Çan and Mısırlı were investigated the effect of forming method on the hardness distribution along the radial direction of the spur gears forms with tapered tooth profile (9).

Ni and his friends investigated the development of deformation structures in commercial purity 1100 Al subjected to an orthogonal cutting process (10). Microstructures in different layers of two aluminum plates cold-rolled with either small or intermediatesize draughts were investigated by Mishin and his friend (11). It was found that the through-thickness variation in the microstructure is sensitive to the roll gap geometry. Ishikawa and his friends (12) studied on effect of extrusion conditions on metal flow and microstructures of aluminum alloys. In their investigation of behavior of extrusion billet skin and microstructure of products is indispensable to maintain qualities of extrusions.

In order to research the behavior, experiments and FEM analysis of clad billet extrusion were performed.

Nanhai (13) performed for the design of the die land in the extrusion of L section shape with a flat-faced based on the FE analysis. Giuliano (14) used commercial FE software for the multi-stage process design which could prevent the flow defect in the combined forward-backward cold extrusion of a billet in order to reduced the strains in work-piece and the stresses in the tools. Altınbalık (15, 16) performed serious studies containing the FEM and CAD/CAM analysis of extrusion of clovers section by using flat-faced dies. Lee et al. (17) studied a non-steady three di-mensional FE analysis of the flat die hot extrusion process with developed FE program. Flat and conical dies of H, T, L, elliptical and two-hole sections was designed on the basis of upper bound technique by the Kumar (18) for cold and hot extrusion of aluminum and lead alloy.

The aim of the present investigation is to determine experimentally the effect of metal forming process on the hardness distribution along the radial direction for different geometries and lubrication conditions. The effect of die geometry on the extrusion pressure and the hardness measurements after open die forging-extrusion of Al99.7 aluminum are also investigated and presented.

Then, deformation structures developed in the samples which were shaped at different geometries and friction conditions were investigated in this study. Furthermore, the equivalent stress occurred at the container and the dies that resulted of extrusion load were determined a CAD/CAM program called SOLID.

Table 1. Chemical composition of the Al99,7 used in experiments [9]

Si(%)	Fe(%)	Cu(%)
0.0643-0.0733	0.136-0.174	0.00343-0.00384
Mn(%)	Mg(%)	Zn(%)
0.00265-0.00307	0.00146-0.00401	0.00564-0.00766
Ni(%)	Cr(%)	Pb(%)
0.00046-0.00141	0.00099-0.00123	0.00008-0.00040
Sn(%)	Ti(%)	Na(%)
0.00004-0.00152	0.00479-0.00520	0.00014-0.00072
V(%)	Zr(%)	Sr(%)
0.0129-0.0247	0.00015-0.00040	<0
	Al(%)	
	99.71-99.77	

2. EXPERIMENTAL METHODS

2.1 Materials preparations and equipments

Commercially pure aluminum (Al99.7) was used for open die forging-extrusion experiments. Chemical composition os Al99.7 is given Table 1. The billets, sand cast and machined to billet sizes of 26,1mm in diameter and of length 26,4mm, were used for the extrusion tests. Experimental set up consisted of two flat dies made from DIN 1.2344 steel and hardness of 48 HRC.

In order to investigate the influence of the orifice geometry, two different upper dies were used. Rectangular shaped upper die and clover shaped upper die have a same area. Area is equal to 171.87mm^2. Prior to open die forging-extrusion experiments, half of work-

pieces were lubricated with grease.
Photographic views of rectangular shaped upper die and clover shaped upper die are shown in Fig. 1. Produced experimental work-pieces are shown Fig. 2.


Fig. 1. A photographic view of clover and rectangular dies

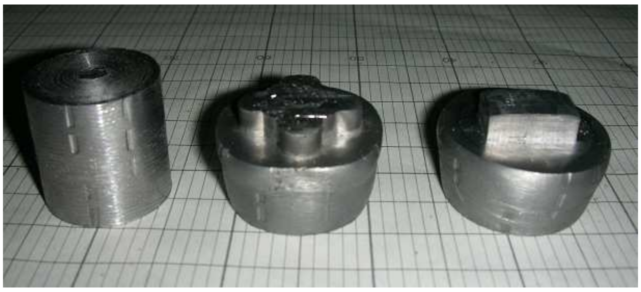
Fig. 2. Initial billet, clovered shaped work-piece and rectangular shaped work-piece

2.2 Open die forging-extrusion experiments
The experiments were carried out on a 1500 kN hydraulic press (Fig. 3.).


Fig. 3. Hydraulic press

Before each experiment the dimensions of the billet were measured by micrometer with 0.001 accuracy. After centrally positioning the billet on the lower die, the upper die was compressed downwards with 5 mm/sec ram speed. The percentage height reduction (%) was calculated when the upper platen touched the upper part of the billet. Then immediately the gauges located in the system sent a start signal and the process was executed. The required stroke of press was adjusted by a vernier ruler which has an inductive switch at the end. Graphics of the load-stroke were drawn by software as well.

2.3 Hardness tests
Hardness measurements of work-pieces produced from Al99.7 by open die forging-extrusion process were carried out using Brinell hardness tester. The specimens polished using 0.5% HF. Hardness values were averaged over six measurements taken at different points on the cross-section.

2.4 Microstructural evolution
The microstructure observed in the open-die forging extrusion process during forming different geometries. The microstructure was investigated by optical microscopy and transmission electron microscopy (TEM). TEM studies were conducted with a HITACHI H-800 microscope operated at 200 kV.

2.5. Using Cad/Cae in dies design
The forging-extrusion for different geometries were modeled by SOLID. SOLID is very popular software especially in manufacturing industry. Drawn models from different CAD/CAM programs can be saved or opened in SOLID form. Stress analysis in SOLID is succeeded by acting loads on a part or a complex system. SOLID supports multiple stages of product development, from concept-tuatlization, design, manufacturing and analysis. In this study, different die geometries were designed. Von Mises equivalent stresses which occurred in the dies are also determined by SOLID. Problems can be solved easily by seperating the system into parts in CAD/CAM programmes, but, sometimes load or stress values are not determined accurately in this way. It should be carried out the assembly analysis for achieving more sensitive results (19).
The schematic views of different geometries which were designed by SOLID were shown in Fig.8. and Fig.9. SOLIS analysis of dies was given in Fig. 10. and Fig.11.
Figure 12 and Figure 13 are for displacement of different die geometries.

3. RESULTS AND DISCUSSIONS

The die shape and friction is a important factors in such forming operations, therefore two different die shapes, rectangular and clover orificed, and various friction factors have been compared to experiments.

35% deformation was applied to samples. From the experiments, it has been seen that the deformation forces become more significant on the edges of the clover shaped orifice after deformation. But, the deformation forces in rectangular shaped orifice had less effect than clover orifice along the whole section. As the dies moves upwards and downwards to shape and extrude the workpiece, bulging occurs due to the friction occurring between the dies and the material. The total deformation for the billet which was extruded through the clover shaped orifice appeared to be slightly higher than that of the rectangular shaped the orifice. Effect of lubrication factor on forging-extrusion was also investigated compared with experiments. The hardness values of the Al99.7 before extrusion-forging was measured as 33 HB. The friction factor for both rectangular and clover orifices the role of friction becomes more significant. As it is expected, the hardness distribution from center of the work-piece to the tip of the work-piece is not uniform. The hardness values of not lubricated samples is slightly higher than lubricated samples for different geometries. As shown in Fig. 4., the friction has great effect on required forming forces. But, it has seen that in Fig. 4., the die shape has no significant effect in required extrusion force. As shown in Fig. 5, the die shape is an important factor for hardness tests. The view of microstructures which have been shown in Fig. 6. and Fig. 7. describe that the boundaries between the elongated subgrains with 35% deformation rate is similar to two different shaped samples and also for lubricated samples. Fig. 10.-11. shows that Von Mises equivalent stress for clovered shaped dies is higher than rectangular shaped die. Fig. 12.-13. shows that, for clovered shaped die, the displacements are higher than rectangular shaped die.

4. CONCLUSIONS

The open die extrusion-forging process has been applied to Al99.7 cylindrical samples for different geometries. Forging and hardness tests were applied to samples which were lubricated or not lubricated with grease. From the experimental results for pressure tests, it may be concluded that pressure is strongly depent on the lubrication condition. Not lubricated extrusion tests have given higher forging pressure than lubricated extrusion tests. Hardly enough hardness values were recorded for not lubricated tests. There are no considerable hardness values between lubricated and not lubricated samples. In additional to this, there is no considerable difference between two alternative die geometries for forging pressure. It has been concluded that the hardness tests for clover shaped samples more than rectangular shaped samples. The present results clearly demonstrate that the microstructure is similarly affected by the different die gap geometry for open-die forging extrusion for 35% deformation rate. Different deformation rate can be investigated in future work.

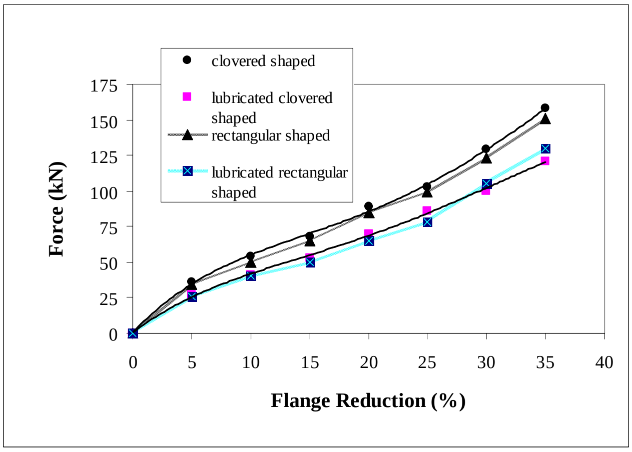

Fig. 4.Force comparison

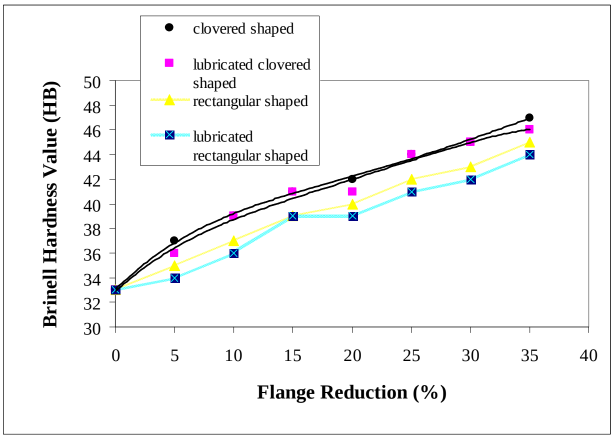

Fig. 5.The hardness distribution

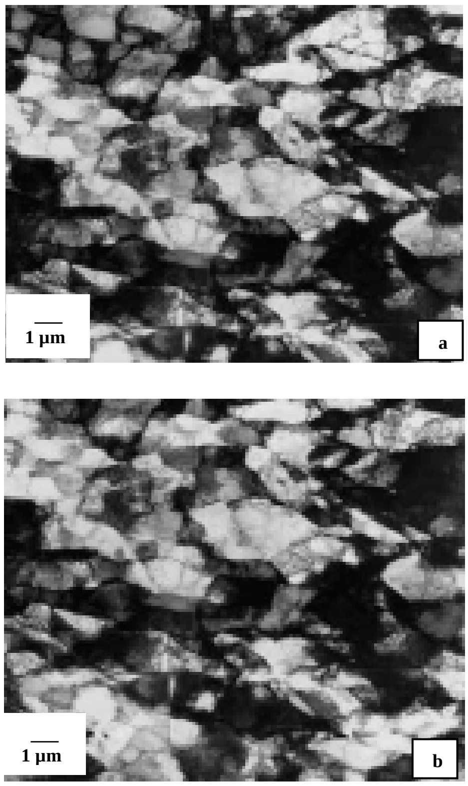

Fig. 6.TEM micrograph showing a general view of the subgrains formed in the clovered shaped work-piece (a) and rectangular shaped work-piece (b)

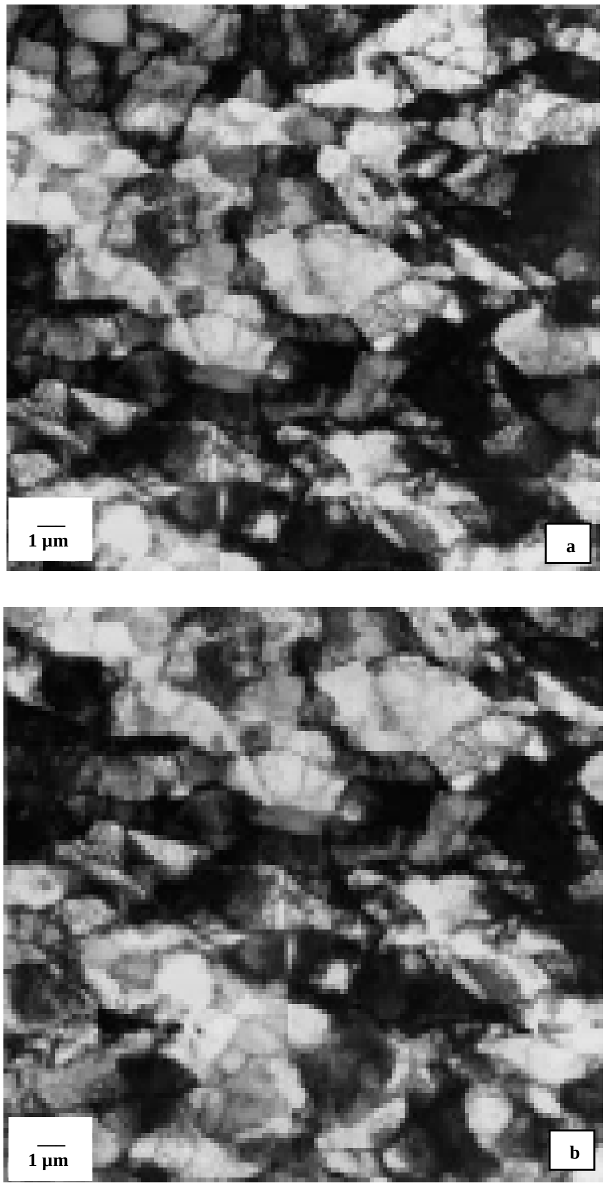

Fig. 7. TEM micrograph showing a general view of the subgrains formed in the lubricated clovered shaped work-piece (a) and lubricated rectangular shaped work-piece (b)

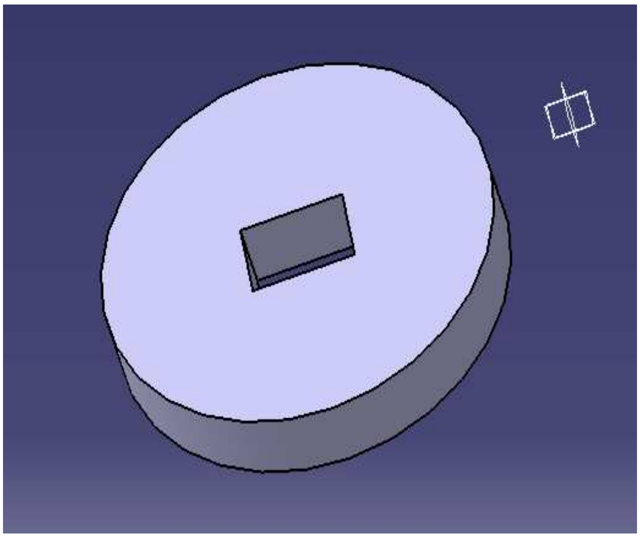

Fig. 8. Schematic view of rectangular shaped die configuration

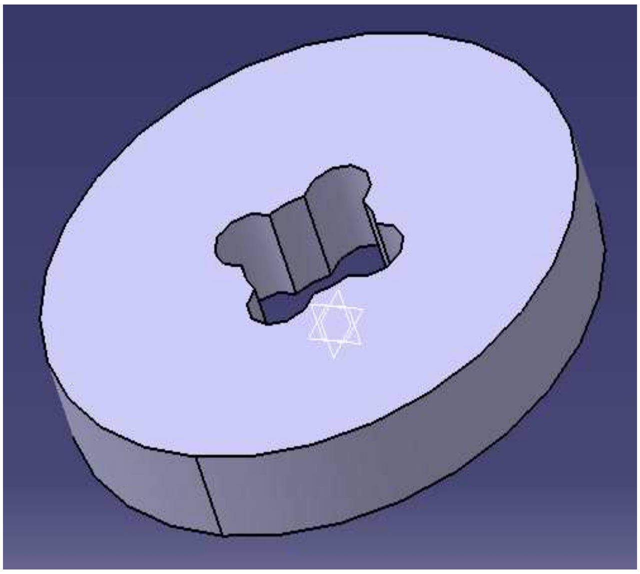

Fig. 9. Schematic view of clovered shaped die configuration

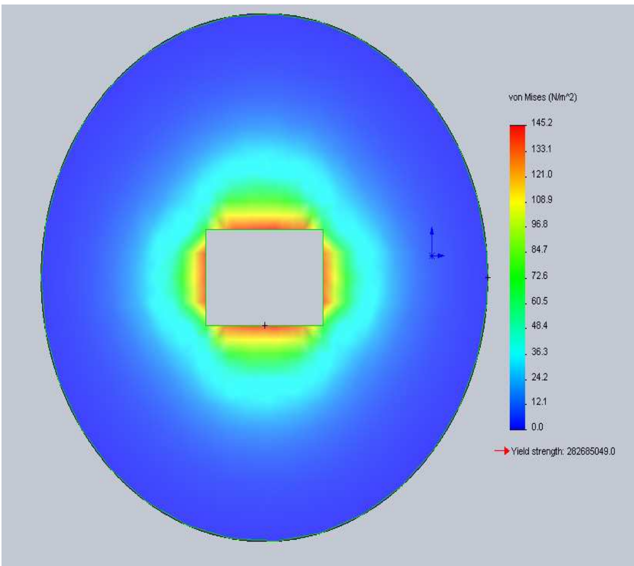

Fig. 10. SOLID analysis of rectangular shaped die

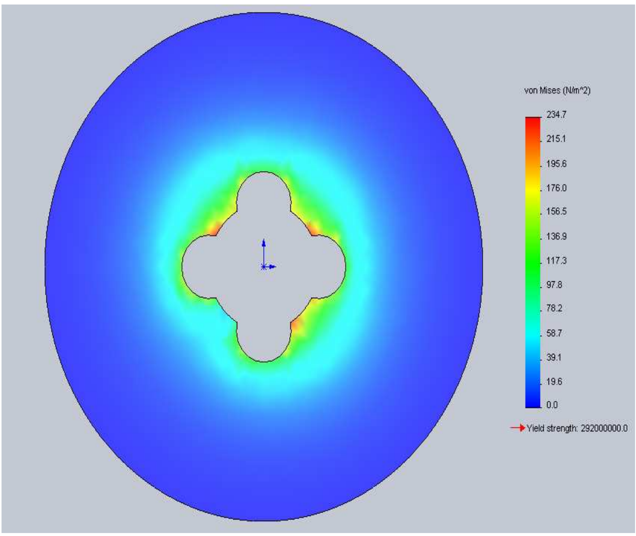

Fig. 11. SOLID analysis of clovered shaped die

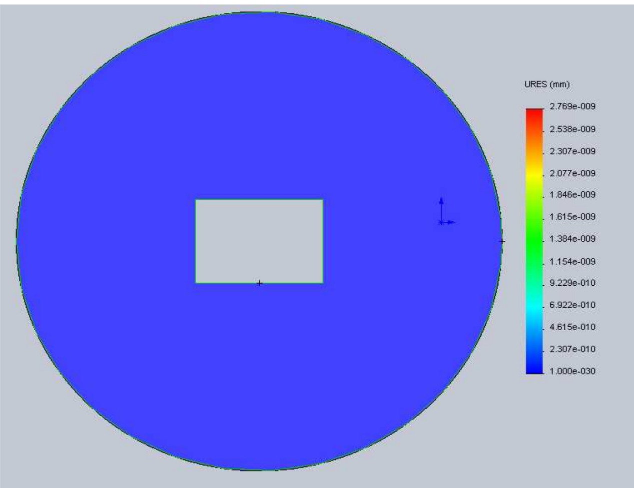

Fig. 12. Displacement of rectangular shaped die

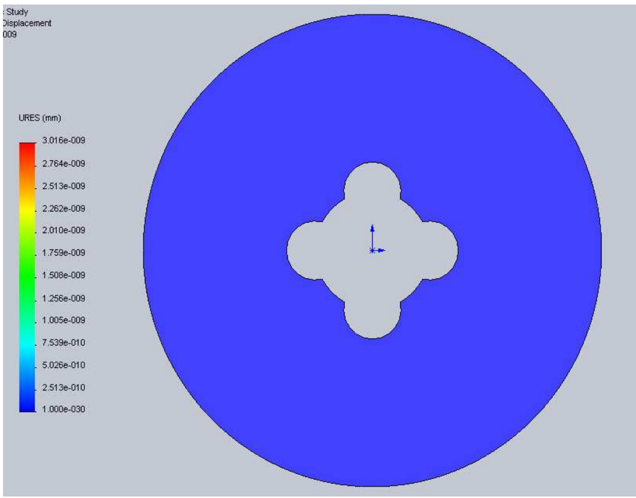

Fig. 13. Displacement of clovered shaped die

5. ACKNOWLEDGEMENTS

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