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EFFECT OF CHANGE IN FORMING DIES SHAPE AND METALS ON EXTRUSION FORCE - NUMERICAL ANALYSIS AND EXPERIMENTAL STUDY

M.M. Saeed M. Najeeb Abdullah A.D. Younis

Mechanical Engineering Department, College of Engineering, University of Mosul, Mosul, Iraq
majidsaeed@uomosul.edu.iq, moh_77@uomosul.edu.iq, alaayounis@uomosul.edu.iq

Abstract- This paper deals with some key parameters regarding extrusion technique using DFORM-3 D finite elements package and experimental results. Such as the shapes and material of die and the type of extrusion process forward or backward on the value of extrusion force. Three types of material's die are used steel, copper and brass, as well as the use of two shapes to extrude the workpiece made from lead in the cavity of the die square and circular outputs product and two kinds of extrusion processes are used forward and backward cold extrusion. The results revealed an acceptable result for both experiments and numeric values, which these values are clearly observed with die made from copper material compared with other selecting materials, which good indication was obtained when use backward extrusion process with circular die.

Keywords: DEFORM-3D, Extrusion force, Die Materials, Die Shape.

1. INTRODUCTION

Extrusion considers one of the effective production processes that used in industry due to wide capability for providing high energy, using less materials and good improvement of the properties for the selected components. [1]. A large or short length can be extracted by this process after setting it in the form manner of continues or discontinuous respectively. While, the molding process can be either hot or cold extrusion, this led the process to be applicable for metals, plastics ceramics and other products [2]. Extrusion process is considered as an important role in deforming metal in which the cross-section of billet area is deformed by influence of press and squeeze through a die cavity. However, the trials are followed by process parameters, loading and the shape of die profiles [3].

Normally, extrusion process depends on significant forming loads, which the process is enhanced the property of material through aiding by the large hydrostatic stress that created in process. Different shapes can be manufactured by using direct or indirect extrusion, as these processes are sometimes referred by forward or backward extrusion. During process the billet move toward the direction of ram and punch, and then sliding straightforward with the container wall that is always in touch with it [4]. This sliding led to increase friction between contact surfaces. In the other hand, the puch can move in opposite direction of the billet while the ram is penetrating directly to the work, which permit th enforce the metal to flow coincide the clearance inversely to the motion of ram, this process denoted by backrowers [5].

The solid and cup extrusion types are preformed numerically by using simulation program to allow a variance between them. This comparison is carried out after complete the simulation [6] Finite Element models of the extrusion process stainless steel tube were used. Simulations were done by three different materials and different tube dimensions: stainless steel one duplex (austenitic/ferritic) and two austenitic stainless steels [7] focus on any defects initiated after completing process and to avoid any things that are not favorable in extrusion [8]. This process may be considered to have good indicated if the material flow in the deformation region is as uniform as possible [9]. Grain size, grain orientation and direction of extrusion load are affected on the extrusion process [10].

2. NUMERICAL WORK

2.1. Finite Elements Method

In the current paper, the numerical model was created based on the concept of simulation program to calculate the number of forces for the suggested processes, that is cold forward and backward. The simulation test has benefits such as saving time and cost and avoid any increase in experimental trails prior to send the model to the production stage. [11, 12]. It is based on a simulation system designed to load various modulation operations that are Through it, costly practical experiences are reduced, the tool is improved and the design of Mold to reduce production and material costs [13].

2.2. Simulation Procedure

The simulation model started by set the creating part as a non-deformable plastic part which its dimensions were specified to have 10 mm height and 20 mm diameter. Other assembly parts such as billet is created as deformable parts to allow its plasticity behavior, while the container and the punch were designed as rigid parts.

The shape, dimensions and profiles of these parts are carried out using AUTOCAD program, this give accurate dimensions that is normally required in simulation. The extension of AUTOCAD fuel was exported in the STL format to be input file in DEFORM software (Figure 1). In simulation, selection of material modal [14] and mesh technique were designed and the number of elements is chosen based on type of elements (4-node tetrahedral element), after generating mesh the total number of elements is 110871 and the number of nodes is 24021. The finalized conical shape of the model allows to move the billet smoothly along the specified length.

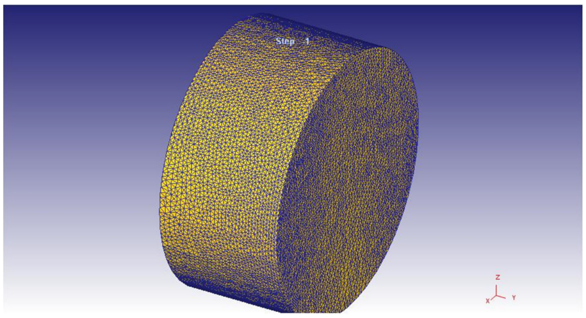

Figure 1. Mesh generation of billet using DEFORM-3D

3. EXPERIMENTAL WORK

3.1. Experimental Work Procedure

The experimental part includes performing of two types of the extrusion process, forward and backward in different molds of certain dimensions. A laboratory model with miniature dimensions will be made and implemented on lead metal by cold extrusion because the lead is formed at room temperature. In order to obtain the products (round and square bars) dies are designed and manufactured according to the required dimensions for the extruded metal. A quantity of lead metal was prepared to be melt in such a mould equipped with two halves to produce cylindrical piece of the required measurements diameter (20 mm) and height (60 mm) for the purpose of conducting practical experiments to produce the bars by cold extrusion in the dies manufactured for this purpose as shown in the Figure 2. The parts of the extrusion die are designed with required dimensions as shown in Figure 3 for forward extrusion and Figure 4 for backward extrusion and manufactured by high-precision machining from alloy steel and then hardened by heat treatments, while Figure 5 shows the photographic pictures of parts manufactured for the die.

The hardening process of the die was carried in metallurgical lab, which the electric furnace is used to examine thermal properties of the die. The furnace was pre-set the temperature to 870 °C and a time of two hours inside the furnace and then it was followed by performed process of the hardening oil. The stages of hardening die can be viewed by Figure 6.

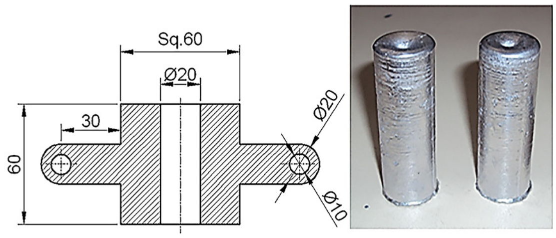

Figure 2. Sample processing die

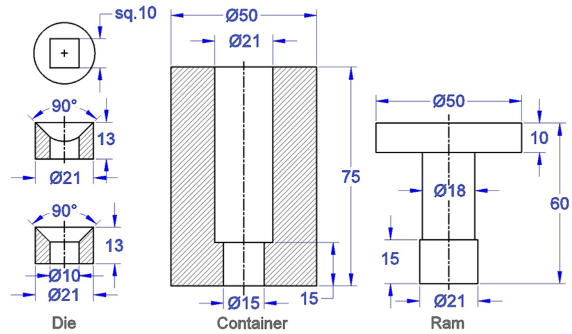

Figure 3. Sketch (parts and assembly) of the die used in frontward extrusion process

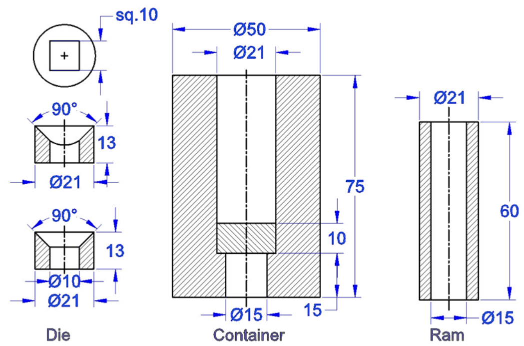

Figure 4. Sketch (parts and assembly) of the die used in backward extrusion process

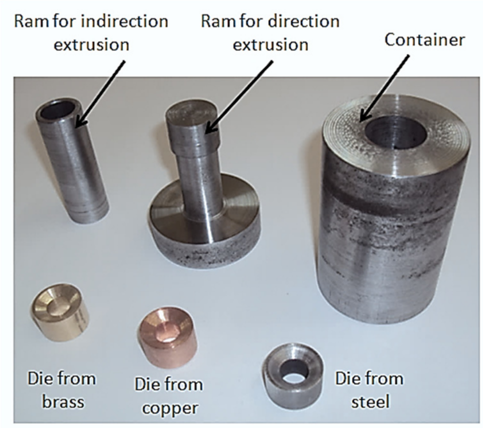

Figure 5. Photographic of parts manufactured for the die

In the forward and backward extrusion operations, a hydraulic press machine with a capacity of 100 tons was used with its accessories of load and displacement measuring devices, as well as a computer device that draws a relationship between data load and the displacement during the time period of the extrusion process.

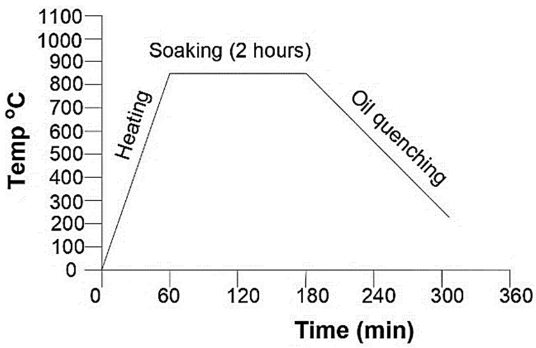

Figure 6. Stages of the die hardening process

3.2 Calculate the Volume of the Metal Used

In order to calculate the size and the volume of the metal used in the forward and backward extrusion process, the dimensions of the product were adopted in order to obtain a product with a length of 8 mm, except for the dead zone, the work piece height is remained above the area of pigmentation within limit of 5 mm, which is shown in Figure 7. The size of the metal (diameter 20 mm and height 10 mm) was calculated for circular product, while the square product was calculated with dimension (diameter 20 mm and height 11 mm), by using AutoCAD software.

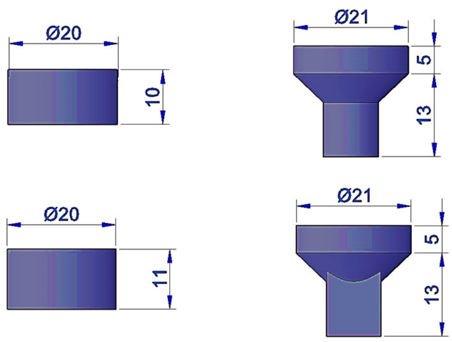

Figure 7. Sample of volume calculation

The forward extrusion process includes pressing the sample with a constant volume (20 mm diameter, 10 mm height) by applying load to the designed die ram, thus obtaining a circular product with a diameter of 10 mm and a square product with dimensions (10×10 mm) as shown in Figure 8.

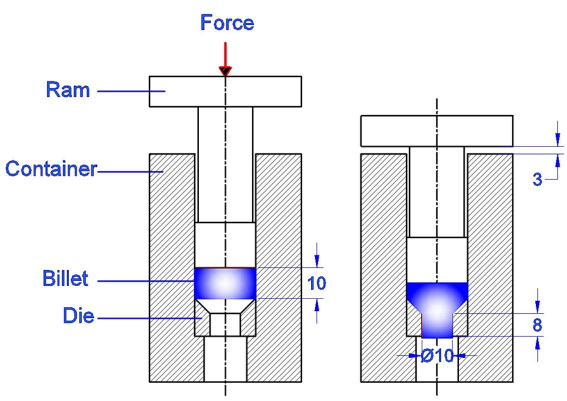

Figure 8. Forward extrusion process

The backward extrusion process involves pressing the work piece with a constant volume (20 mm in diameter, 18 mm in height) by applying load to the designed die ram, thus obtaining a circular product with a diameter of 10 mm and a square product of dimensions (10×10 mm) and shown in Figure 9.

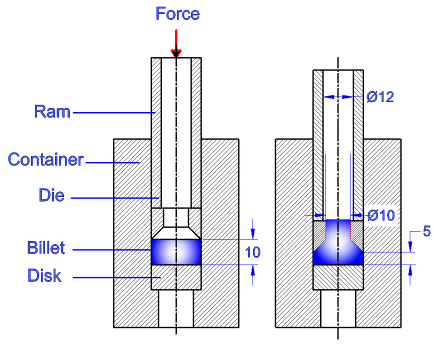

Figure 9. Backward extrusion process

The extrusion process shown in Figure 10 for the bars were designed and manufactured in two types of the workpiece, which are the forward and backward extrusion process.

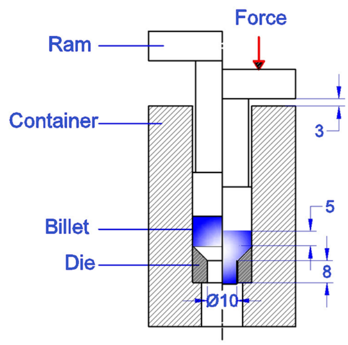

Figure 10. Extrusion process

4. RESULTS AND DISCUSSIONS

Practically twelve specimens were prepared and each model was extruded in a different way. Three types of dies from different metals (steel, brass and copper) were used to extrude the work piece made from lead in two different forms (round and square) by two extrusion methods (front and back) as shown in Figure 11.

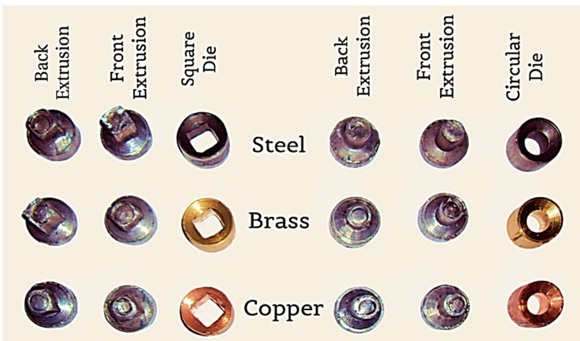

Figure 11. Photographic images of samples formed by different conditions

The final results were recorded, as shown in Figure 12 which includes the apply load (N) and the amount of piston displacement by a constant value (5mm). Thus, different curves were obtained which indicate the relation between the applied load and the displacement of the piston.

Figure 12 shows the highest load with the die metal used (steel, brass, copper) for the both selecting processes (forward and backward) of the circular and square bars for Numerical and Experimental results. It is observed that the products resulting from backward extrusion process whether they are the product is circular or square needs less load than the products resulting from the forward extrusion process.

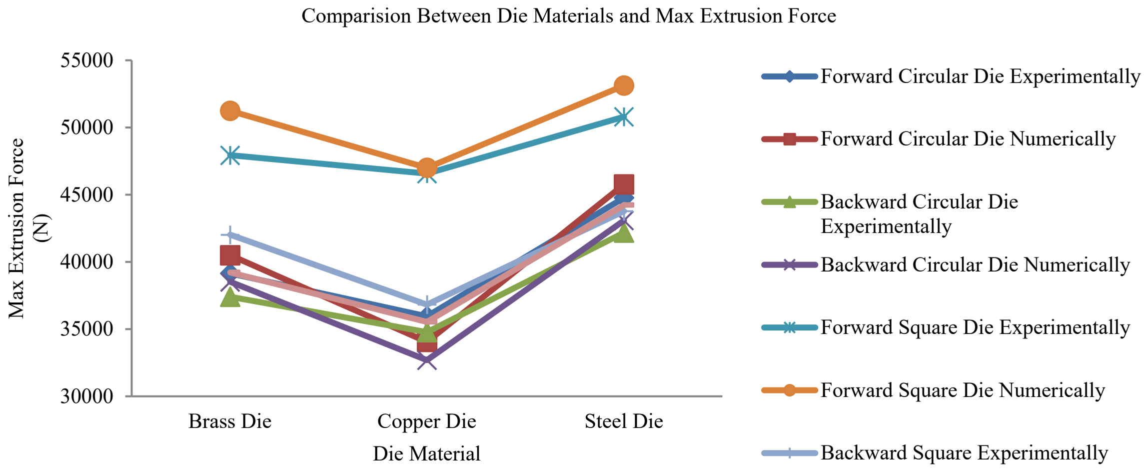

Figure 12. Load vs die metal for selecting processes and different bars profiles

Figures 13-16 show the connected link between load and displacement for extrusion of work piece, using dies from different metals in the front extrusion process of a circular rod. It is observed that the steel die used takes the maximum load, then the brass and copper, this is because the steel yield coefficient is greater than the rest of the die metals (brass and copper), also brass and copper considered soft materials and have low coefficient of friction so that the sliding bearing are made from brass and copper therefore extrude steel needs a greater load due to the presence of high friction between the metal and the die. Also, the load; displacement figure for produce work piece by forward is illustrate the variations through using variable metals with different processes and different bars.

It is noticed from the figures that in the process of forward and backward extrusion the load of the square die is greater than the circular product, because the square die contains corners and thus requires greater force due to the presence of shear stress resulting from the friction in the corners of the square die with the metal. In addition, the figures above illustrate the link of the load with displacement to extrude a work piece under using variable metals of a circular rod and a square rod in the forward extrusion and backward extrusion process.

It is noted that the products resulting from the backward extrusion process whether the product is circular or square needs less load, this is because motion between workpiece and die is restricted, therefore the required forces are reduced to the extrusion force only and it does not require a force to resistant friction, which leads to reduction 25% to 30% of the friction force, thus it is possible to use a larger amount of raw material, as well as increase the speed, and increase the ability to extrude smaller section areas. As for the forward extrusion process, it requires more force compared to the backward, as the extrusion force of workpiece and the force to resistant friction resulting from the formation of the work piece along the die.

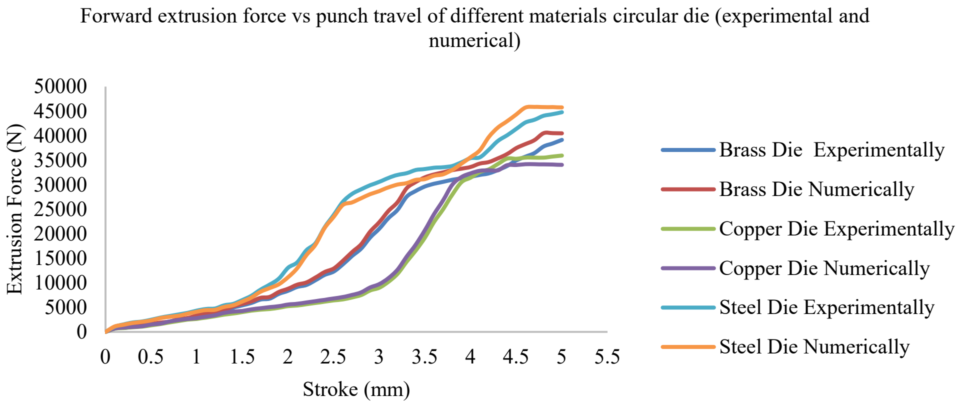

Figure 13. Force vs punch movement of different materials circular die (Forward extrusion)

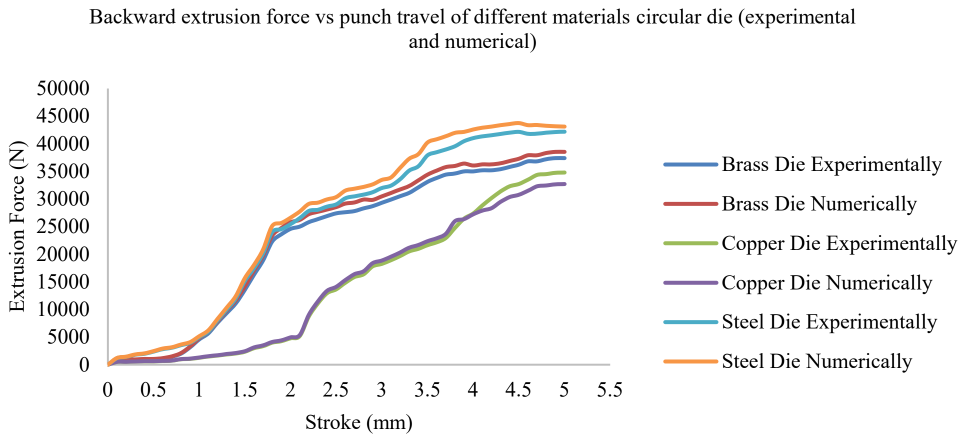

Figure 14. Force vs punch movement of different materials circular die (Backward extrusion)

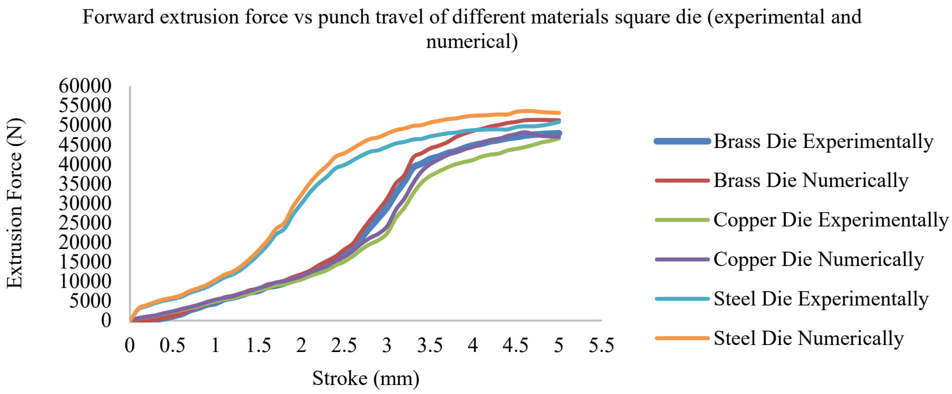

Figure 15. Force vs punch movement of different materials square die (Forward extrusion)

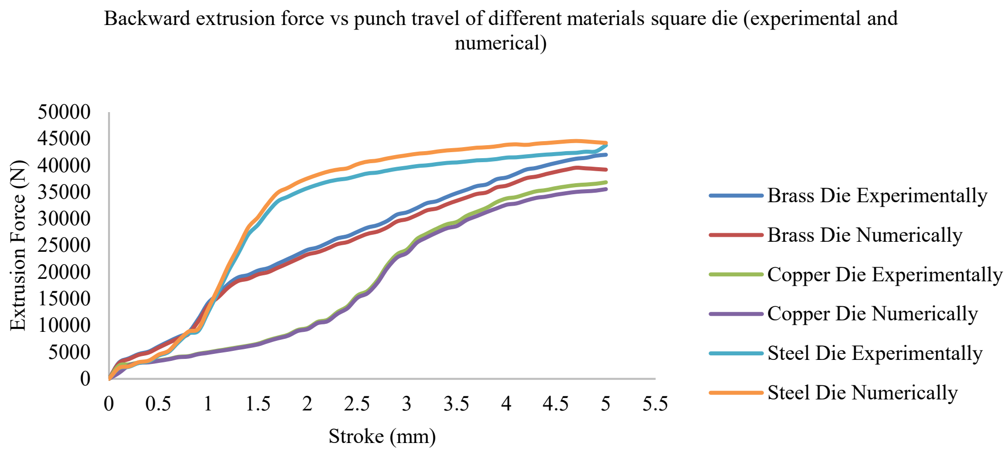

Figure 16. Force vs. punch movement of different materials square die (Backward extrusion)

5. CONCLUSIONS

The main conclusions can be summarized as following:

1) The use of copper metal die to extrude a work piece of lead metal into a circular and square die require less press by machine compared to other dies made of steel by 17% for extruding a circular product by forward extrusion process, and 7% for extruding a square product by forward extrusion process, also 15% for circular product extrusion by backward extrusion process and 21% for circular product extrusion by backward extrusion process.

2) It was noticed that back ward extrusion process is better than forward extrusion process due to its ability to produce circular and square bars with lower force, especially when using a square die from copper metal when extruding a cylindrical work piece, as the percentage of reduction in the load reached 21%.

3) As for the same extrusion process, whether forward or backward, it was found that the extrusion of circular bars requires less for applying press than extrusion of square bars, especially when using a circular die made of copper metal when extruding a cylindrical work piece, as the percentage decrease in the load reached 23%.

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BIOGRAPHIES

Majid Midhat Saeed was born in Mosul, Iraq, on August 5, 1981. He received the B.Sc. degree in Mechanical Engineering and the M.Sc. degree in Applied Mechanics from University of Mosul, Mosul, Iraq in 2003 and 2006, respectively. Currently, he is a Faculty Member at Mechanical Engineering Department, University of Mosul, Mosul, Iraq. He teaches mechanics of materials, machine design, mechanical vibration and engineering physics. He is a reviewer in many scientific and academic journals like Springer, Nature. He is now the manager of planning and studies division in College of Engineering, University of Mosul. His research interests are in the area of manufacturing processes, finite element analysis and stresses analysis.

Mohammed Najeeb Abdullah was born in Mosul, Iraq on September 16, 1975. He received the B.Sc. and M.Sc. degrees from University of Mosul, Mosul, Iraq and the Ph.D. degree from Lipetsk State Technical University, Lipetsk, Russia, all in Mechanical (production and metallurgy) Engineering, in 1996, 2002, and 2011, respectively. Currently, he is a Lecture of Mechanical Engineering at University of Mosul, Mosul, Iraq. He is also an academic member of Mechanical Engineering Department, University of Mosul. He teaches computer aid drawing, computer aid mechanical drawing, workshop technology and manufacturing processes. His research interests are in the area of manufacturing processes.

Alaa Dahham Younis was born in Mosul, Iraq on October 10, 1972. He received the B.Sc. and M.Sc. degrees in Mechanical Engineering in 1994 and 1999 and the Ph.D. degree in production engineering from University of Technology, Baghdad, Iraq in 2007. Currently, he is an Assistant Professor at Mechanical Engineering Department, University of Mosul, Mosul, Iraq. His research interests are in the application of metal forming and applied mechanics. He is a lecturer staff member of University of Mosul and the manager editor of Al-Rafidain Engineering Journal (AREJ).