Development and Modelling of Hydro-formed circular sheet Using Neural Networks

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Abstract— ***Hydro forming process is one of the new technologies in the manufacturing process in which hollow pieces and sheet works are formed under fluid pressure. This paper deals with the development of a sheet hydro forming (SHF) set up and model to predict the deformation caused by the hydro forming using Artificial Neural Networks(ANN). During the sheet hydro forming (SHF) process, the hydraulic pressures were measured and simultaneously the required hemispherical products were obtained with dome height and specific thickness. To validate result of this set up work, a hemispherical part was formed in a fabricated hydro forming set up using single sheet. The data used to train the Artificial Neural Network (ANN) model was collected from sheet hydro forming (SHF) set up that was designed and built in our laboratory. Single- and two-hidden-layer feed forward neural network models were used to capture the nonlinear correlations between the input(hydraulic pressure, thickness and diameter of work piece) and output (dome height of deformed product). Neural network model was able to predict the deformed dome height, thickness of circular sheet with good accuracy.***

*Keyword***-** Sheet hydro-forming, ANN, Hydraulic pressure, Dome height.

Nomenclature

T Thickness of work piece
D Diameter of work piece
DH Dome height

1.0 Introduction:

Hydro forming is the technology that utilizes fluid pressure to form sheet and tube material into desired shapes inside the cavities. O. Kreis et al. [1] shorten the Process Chain for manufacturing of complex hollow bodies made of sheet metal by developing a manufacturing system that integrate the process steps as: hydro-forming, mechanical trimming, Laser beam, wielding and hydro-calibrating. Shi-Hang et al.[2] investigated the technology of sheet hydro forming with movable female die. In their work, the hydro forming process takes place without a movable male die and were investigated by experimental and elasto-plastic FEM method. S.H Zhang et al. [3] summarized the recent developments in sheet hydro forming. In this case, several key technical problems to be solved for the development of sheet hydro forming technology are analyzed and varied sheet hydro forming technology is discussed. Lihue Lang et al.[4] discussed uniform pressure distribution everywhere on to the blank. A multi stage sheet hydro forming with very thin middle layer was investigated. G Palumbo et al. [5] used properties of material in sheet hydro forming and gained to meet the reality based on the identification of parameters for constitutive model by inverse modeling, in which the friction coefficient were also considered. Takayuki Hama et al. [6] presented the development of an elasto-plastic finite element method, FEM program dedicated for sheet hydro forming process. The simulated result of the elliptical cup shape deep drawing process using the program was first development for SHF simulation program based on the static FEM code STAMP3D. Ahmed Assempour et al. [7] used oil as the pressurized medium in their experimental work with a pair of metal sheets. After obtaining the kinematically admissible velocity field, the pressure equation is obtained by upper bound analysis. The effect of parameters of work hardening, friction and blank size has been taken into consideration. Rosel et. al. [8] investigated that flange contact pressure and cavity pressure are restricted by three processes i.e. clamping limit, failure mechanism of bursting and sealing effect, in which sealing limits are decreasing by using magneto rheological fluid by adaptation of fluid viscosity [8]. M.A. Karkoub et.al [9] developed a model to predict the amount of deformation of circular plate caused by hydro-forming set up using an artificial intelligence technique known as neural networks. They also reported experimental result which is good agreement with ANN model. Forouhandeh et.al.[10] reported the development of a sheet hydro-forming set up and product characterization of aluminium and copper sheet.

An Artificial Neural Network is an information processing system that has certain performance characteristics in common with biological neural networks. Artificial neural networks have been developed as generalizations of mathematical models of human cognition or neural biology [11]. The basic processing elements of neural networks are called neurons. Neuron performs as summing and nonlinear mapping junctions. In some cases they can be considered as threshold units that fire when their total input exceeds certain bias levels. Neurons usually operate in parallel and are configured in regular architectures. The neurons are generally arranged in parallel to form layers. Strength of the each connection is expressed by a numerical value called a weight, which can be modified [12].The main purpose of this paper is to develop hydraulic pressure on circular sheet using fabricated sheet hydro forming set up and validate the deformation caused by hydro forming using neural network(ANN).

2.0 Material and Methodology

In this work, a working and suitable set up for sheet hydro forming (SHF) has been designed and fabricated along with all needed assemblies, subassemblies, essential tools, clamping devices etc. The purpose is to have an experimental setup for SHF with measuring pressure. The SHF setup is hydraulically operated by manual action using actuating levers through relieve valve and a pressure building cylinder as shown in the Fig 1.

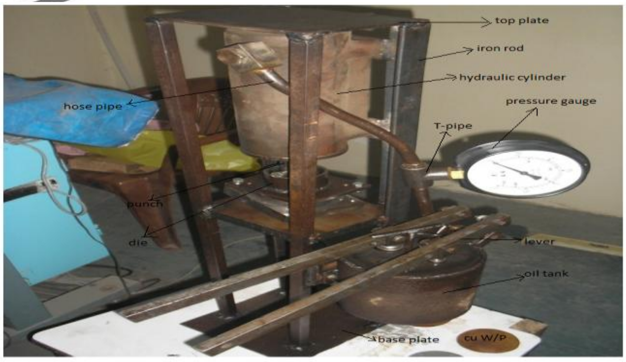

Fig. 1. Developed Sheet Hydro Forming Set Up

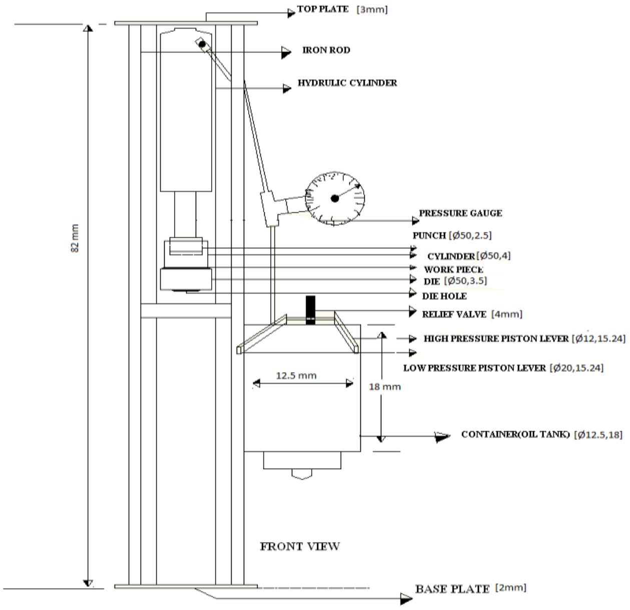

Fig. 2. Schematic View of SHF Set up

In this process of set up design and fabrication, at first four rod are taken and arc welded with base plate in a rectangular shape to hold the whole set up as shown in Fig 1. From base to some height (43mm) a rectangular plate is welded to contain the die set up and to support the blank holder, cylinder etc. The blank holder and cylinder are further welded to form the complete hydro form set up.

During the sheet hydro forming process, the work piece or sheet metal is placed over the die. The blank holder and cylinder combination is placed over the die. The bolts are properly tightened with the die and blank holder. Above the cylinder the punch is bolted with the piston of the hydraulic cylinder. The hydraulic piston is wounded by spring in the hydraulic cylinder and it moves by stroke of hydraulic pressure. The punch and piston are connected by bolts. The total hydraulic cylinder is welded on rectangular holding device. Above the hydraulic cylinder the top base plate is welded with a holding device. The container (oil tank) is connected to rectangular holding device by bolts. The container (oil tank) is built by two piston such as high pressure piston and low pressure piston. With this, a relief valve, four ball and threads are arranged inside the container (oil tank).The container (oil tank) and hydraulic cylinder are connected by a T-pipe through which oil flows during the sheet hydro forming process.

In the middle portion of the T-pipe, the pressure gauge is connected to measure the hydraulic pressure during the process. The fluid is poured through the relief valve .The relief valve is connected to the container (oil tank) by ball and thread. In this experimental work, Mobile oil was used as working fluid. In order to collect the oil from the container, there is bolt connected to the bottom of the container placed. In this set up, two rods are connected to oil tank (container), one is high pressure piston lever and another is low piston lever.

In this work, oil pours into the container by removing the relief valve, the relief valve is closed. After closing the relief valve, pressure gauge is connected to T-pipe. The work piece is placed over the die, then cylinder and blank holder arrangement are placed over the work piece. Oil is poured into the cylinder, then low pressure piston lever of the container (oil tank) or high pressure piston lever which is connected to rod outside the container is moves up and down. By the movement of the piston inside the container, the oil is pressurized and it rises through the T-pipe. Then the pressurized oil goes to the hydraulic cylinder and then moves the spring wounded piston downward.

The punch which connects to piston of hydraulic cylinder also moves downward and it applies pressure on the oil of the cylinder, then the oil provides the uniform pressure on the work piece (sheet) and the work piece deform under the application of hydraulic pressure. At the same time pressure reading is recorded by the pressure gauge. After deformation of the work piece, the required product is removed and the oil above the product also removed. During the process proper clamping, positioning of the work piece and pressure gauge are very essential. In this work, hemispherical products of the sheet metal have made. The aluminium and copper have used as work piece and Mobile oil as fluid medium.

3.0 Result and Discussions:

To carry out experiments on the fabricated setup, two types of job materials are used for different set of the experiments for cup shape products. Several experiments are carried out on the fabricated SHF setup (Fig 1) with Aluminium and Copper work pieces. Tooling material, Dies and clamping devices are also suitably selected as required as the integral part of the setup.

Both Aluminium and Copper (Fig3 and 4) are used as the job (work piece) to get the desired shape product. The mechanical and physical properties of both Aluminium and Copper used are taken into consideration using electron scan microscopes. Fig 4 shows the deformed Aluminium work on the setup. Fig 5 shows the Copper work pieces of two different thicknesses and Figure 6 shows the corresponding deformed pieces on the setup. Fig 7 and 8 shows the failed pieces due to improper blank holding force and high stain rate applications.

Fig. 3: Aluminium work piece

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Fig. 4: Deformed piece through the SHF setup.

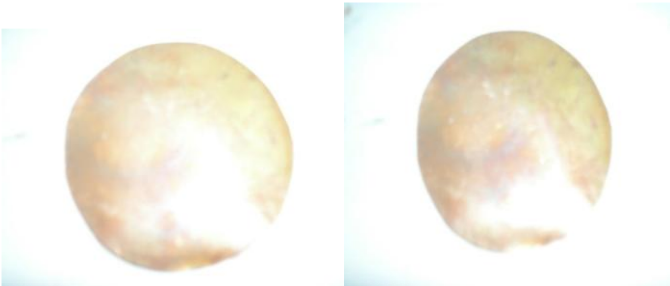

Fig. 5: Copper work pieces

Fig. 6: Deformed one on the setup.

Both Aluminium and Copper sheet are used in this work by using blanking process. In this process Aluminium/Copper pieces were deformed to get the required work piece as per the die (hemispherical die). The thickness of the work pieces (Al/Cu) are taken into consideration. In case of sheet metal, it is very difficult to resist the transverse load. The thickness is considered in mm and it varies for Aluminium and Copper experiments.

A Matlab based artificial neural network (ANN) toolbox was used for prediction of dome height of aluminium and copper piece after applying hydraulic pressure. Experimental data was used for training and testing of ANN.

Three parameters (thickness, diameter and applied pressure) as input and dome height (DH) as target of aluminium and copper plate were used for training of ANN. Eighty percent data were used for training of ANN. Remaining twenty percent data were used for testing of ANN.

Figure 7 shows the architecture of ANN. This ANN architecture contains two hidden layers (containing 6 and 2 neurons respectively) and one output layer (containing 1 neuron).

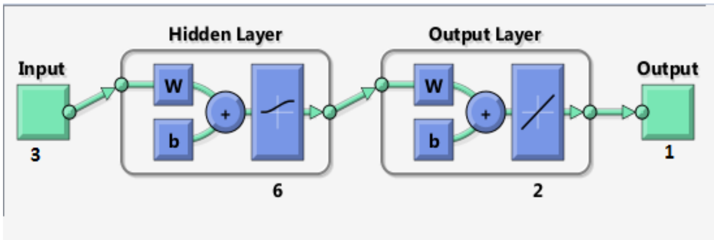

Fig.7: Feed forward architecture of a neural network.

Figure 10 and 11 shows the linear regression analysis between observed and simulated dome height for aluminium and copper sheets respectively. The linear regression analysis committed for good result for prediction of dome height by ANN after applied hydraulic pressure for both aluminium and copper sheets. The regression analysis showed coefficient of determination (R^2) for aluminium was .99732 and for copper .94997.Therefore, the ANN best suitable for prediction of dome height of aluminium sheet than copper sheet.

Fig. 8 and 9 showing failure of aluminium work piece due excessive axial load or blank holding force. Hence by applying appropriate hydraulic pressure these mode of failures can be avoided.

Fig. 8: Wrinkling and tearing of Aluminium work piece

Fig. 9: Wrinkling and Bursting of Aluminium work piece.

The basic issue for estimation of fluid pressure in sheet metal hydro forming is the instantaneous geometry fitting of the deformed sheet in the die zone with analytic equations. The hemispherical shape seems to be a good approximation for the instantaneous geometry fitting of the deformed sheet in the die zone for production of spherical parts and also all parts in which the entrance of the die is circular. These equations can be applied for estimation of fluid pressure in all parts in which the instantaneous geometry of deformed sheet during deformation can be analytically expressed.

From the experimental work, it shows that the deformed hemispherical part of work piece depends on the thickness of work piece, young's modulus and velocity of the punch. It also leads to the failure parameters of the hemispherical product.

To calculate the required axial load(Fa) which applies on the fluid medium, area of fluid contact to the work piece are considered as per experimental setup blank holding force(Fb), sealing force, friction force(Ff) are also taken into consideration.

Total force = axial force + blank holding force+ friction force

F= Fa + Fb + Ff ....(1)

In above equation, the blank holding force (Fb) and friction force (Ff) assumed to be neglected for the estimation of axial force (Fa) acting on the circular sheet. The required hydraulic pressure are directly measured from pressure gauge mounted on the experimental SHF setup.

Axial load= hydraulic pressure(p) x area upon which the hydraulic pressure is acting

Fa= p x A........(2)
With the help of equation (2) axial force can be easily calculated.

Table 1 Experimental result of Aluminium work piece during SHF

Sr. No	Job	T in mm	D in mm	DH in mm	Hydraulic pressure obtained and calculated axial force	
					MPa	Newton
1	job-1	0.41	73.8	7.73	2.316	9906.97
2	job-2	0.41	73.8	7.78	2.779	11887.50
3	job-3	0.42	73.8	6.44	3.088	13209.32
4	job-4	0.42	73.8	6.92	3.861	16515.90

Least count=0.1ton/in^2

Table 2 Experimental result of copper work piece during SHF

Sr. No.	Jobs	T in mm	D in mm	DH in mm	Hydraulic pressure obtained and calculated axial force	
					MPa	Newton
1	job-1	0.29	73.8	12.32	4.324	18496.44
2	job-2	0.29	73.8	12.51	4.633	19818.23
3	job-3	.30	73.8	11.95	4.860	20789.25
4	job-3	.30	73.8	12.21	5.468	23390.04

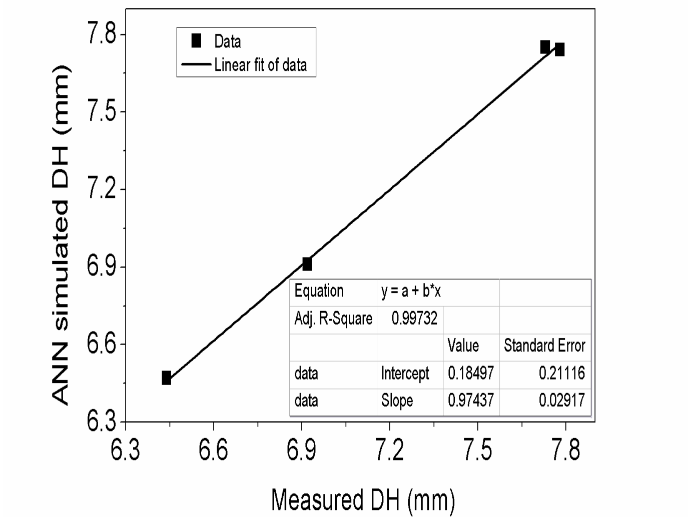

Fig. 10: Linear regression of ANN simulated Dome Height (DH) and experimetal Dome Height (DH) data for Alluminium work piece.

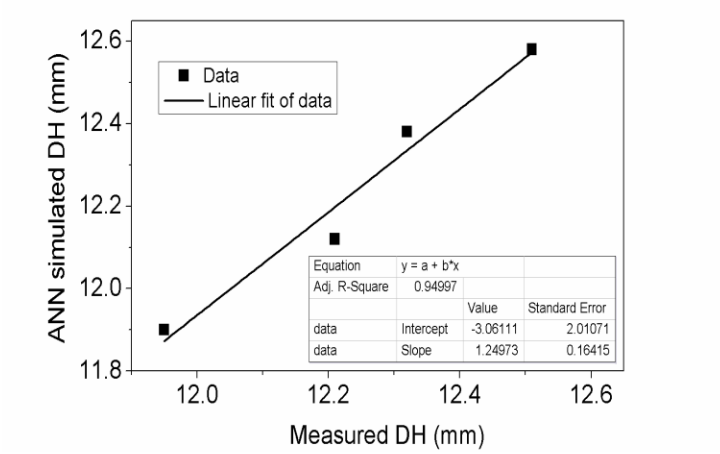

Fig.11: Linear regression of ANN simulated Dome Height (DH) and experimetal Dome Height (DH) data for Copper work piece.

4.0 Conclusion

A manually working SHF setup has been fabricated to work hydraulically for the analysis of sheet hydro forming process in IIT BHU. After fabricating and establishing the required parameters for experimental work, the setup is used to calculate the hydraulic pressure needed for deforming of hemispherical (cup shape) product. Based on the pressure gauge reading and desired hemispherical product, it is possible to form hemispherical with hydraulic pressure. The calculated pressure profile shown by the setup is good; sometimes it turns to be high causing sheet to fracture and wrinkle free (Fig 7& 8).

The cause of wrinkling is attributed to the error in the pressure gauge used in the experimental set up. It is shown that, hydraulic fluid pressure cause the deformation to the sheet in the flange area and therefore pushing the strain above the wrinkling limit[]. In the setup there is provision for change of applied load, selection of material and pressure gauge for new and future developments in the setup.

Due to the uniform deformation of work piece the dent resistance of hydroformed part improves and tendency of tearing reduces due to free bulging compare to conventional stamping processes. Out of these advantages the main advantage of sheet hydroforming process is the greater range of pre- instability strain obtainable.

The critical hydroforming parameters can be easily predicted using ANN model because of its accuracy and simplicity.

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