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Artificial neural network and experimental study of effect of velocity on springback in straight flanging process

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Flanging is one of the sheet metal forming processes that applies in various industries to bend the sheet at a particular angle in automobile and fabrication industries. Springback always remains a major concern in any sheet metal forming process. It is mainly due to elastic recovery of the materials. It is a major failure in any sheet metal bending process and it deviate the final product from the desired geometry. It depends on different geometrical, material and process parameters. This investigation is particularly address the one of process parameter, i.e., effect of velocity on springback in straight flanging process and it is carried out by conducting many experiments. It reveals from this study that the velocity of forming affects the springback in this process and springback angle varies nonlinearly with respect to punch velocity. Back propagation artificial neural network (ANN) model is also introduced to predict the springback angle. A three layered (3-6-1) network is selected and trained it by 32 set of the experimental results. The results of ANN model are compared with experimental results, which show a very good agreement.

Keywords: Springback, Velocity of forming, Artificial neural network (ANN), Straight flanging process

Sheet metal bending is a most common forming process that used in various industries such as automobile, aerospace etc to manufacture the curved parts. Flanging is a bending process in which one edge of the sheet is bent to the desired angle while the other end is restrained by the material itself or by the force of blank holder/pad. Flanges are generally used for rigidity, to hidden joints, to avoid sharp edge and strengthening the edge of a parts such as automobile front fenders and complex panels formed by drawing or stretch forming etc. Springback in flanging process is a very important and decisive parameter in obtaining the desired geometry of the part and in designing of the forming tools. Springback depends on many parameters such as material properties, sheet thickness, tooling geometry, forming velocity etc. The springback may introduce surface distortion and unexpected out-of-tolerance in shape and dimensions. Therefore, it is very important to predict the springback in designing the punch and the die[1].

In the past, some work has been carried out on sheet metal forming process such as Inamdar[2] studied springback in air vee bending process experimentally and applied artificial neural network method based on experimental data. Ruffini[3] developed a neural network model and used it to minimize the springback in a channel forming process. Many researchers[4,5] analyzed straight flanging using experiments as well as FEM. Coining was used to reduce the amount of springback in the flanging process and to improve the hemming quality. Taylor *et al*.[6] proposed a numerical solution for sheet metal forming process using implicit and explicit finite element method. Song *et al*.[7] studied the reliability of different methods in prediction of the springback. Kulkarni and Prabhakar[8] investigated the effect of strain rate on springback in T-temper (airframe). Vishwanathan *et al*.[9] and Cao *et al*.[10] presented an artificial neural network approach with stepped binder force trajectory to control the springback angle and principal strain in a steel channel forming. Muderrisoglu *et al*.[11] investigated experimentally the bending, flanging and hemming of aluminum sheets and concluded that the flange height has significant effects on deformation load as compared to flange ratio. Buranathiti and Cao[12] developed an analytical model to analysis the springback in the straight flanging and results were compared with experimental ones. Marciniak *et al*.[13] proposed an empirical moment-curvature relationship based on a material specific bending test. Livatyali

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et al.[14] proposed a solution for straight flanging process using advanced bending theory incorporating the geometric and material details of the process in a mathematical model. Leu[15] investigated the effect of strain hardening exponent and normal anisotropic value on springback angle in pure bending of sheet metal. Ling *et al.*[16] studied springback in L-bending of sheet metal by finite element analysis and find out the effect of die parameters like die radius, step height, die clearance and step distance on springback. Wagoner *et al.*[17] reviewed the recent challenges in springback. Tekaslan *et al.*[18] investigated the springback in V-shaped die bending process using a steel sheet.

Flanging is an important process in the sheet metal forming process. Springback always remains a major concern in this process which deviate the final product from the desired product. Springback depends on many geometric, material and process parameters. In the past, many researchers have been carried out work on this considering the various geometric parameters but a less focus has been paid on the process parameter like velocity of forming. This study is particularly carried out to find out the effect of velocity on springback in straight flanging process. ANN is also presented in this paper, in which 32 experimental sets are used to trained the ANN model and four unknown sets are used to predict the springback angle. ANN results are compared with experimental results, which show a very good agreement.

Experimental Study

A standard 400 ton hydraulic press is used to carry out the experimentation of straight flanging process, which has the maximum velocity of 50 mm/s. Therefore, all experiments are performed up to a maximum velocity of 50 mm/s. The aluminum alloy 5052 material sheet with a thickness of 0.5 mm is used in performing the experiments. The die and punch are manufactured with mild steel material and have the well polished surfaces to minimize the friction between sheet and tools. The length of blank is considered constant, i.e., 160 mm and different widths of blank is used, i.e., 25 mm, 50 mm and 75 mm in this study. The nose radius of die and punch are considered 3 mm and 6 mm respectively and a constant blank holder force of 25 kg is applied in performing the experiments. The experimental setup on hydraulic press comprising the punch, die and blank is shown in Fig. 1. In this study, total 36 experiments are performed with different combinations between velocity, flange length and width of blank and each combination is repeated for three times to get the average result.

Fig. 1 – Initial setup of the experiment

The sheet is freely placed on the die and blank holder force is applied on it to restrict the upliftment of the sheet during bending of the sheet. Downward displacement is given to the punch at the velocity of 20, 30, 40 and 50 mm/s to bend the sheet. A constant gap of 1.5 mm is maintained throughout the experiments between the die and the punch. An upward displacement is given to the punch to release the bending load and sheet is allowed to elastically relax itself without any external influence. The springback angle was calculated by measuring the angle of the deformed flange in the straight portion. These experiments are conducted in unlubricated condition and performed at room temperature under normal atmospheric conditions.

Artificial Neural Network

The artificial neural networks are presently using in various manufacturing processes. It has ability to offer helpful results in designing the parameters involved in the process. Easy handling and shortest time are very noticeable in application of ANN. The main objectives of ANN are to develop models and method from experiments and examples for solving problems, usually solved by the conventional techniques such as the analytical algorithm and the programming software that enhance the intellectual activity of humans, for example: prediction, image recognition, classification, etc.[19]. ANN's are a type of artificial intelligence that attempts to intimate the way a human brain works. Brain contains about 10^{10} basic units called neurons. A neuron is composes of a nucleuses, which makes connection with other neurons with a network of a fibers called dendrites. Each neuron in turn, is connected to about 10^4 other neuron. A neuron is a small cell that receives electrical chemical signals from its various sources and in turn responds by transmitting electrical impulses to other neurons.

In an ANN the processing unit may have several input paths corresponding to the dendrites. The units combine usually, by a simple addition, the weighted values of these paths. The weighted value is passed through the neurons to modify by threshold function such as sigmoid function and this modified value is directly presented to the next neuron. Figure 4 shows a 3-6-1 back propagation artificial neural network. The connections between various neurons are strengthen or weakened according to the experiences obtained during the training.

Proposed ANNs structure

In this work, three layered network is selected for a good performance, which consists of an input layer, an output layer and one hidden layer as shown in Fig. 2.

Results and Discussion

Experimental results

The different experiments are carried out to analysis the springback. In these experiments sheet is initially bend by 90° to form the flange. The final flange after release the load is shown in Fig. 3 for different width of sheet.

Experimental results are presented in terms of variation of springback angle with respect to punch velocity in Figs 4-10. Figures 4-10 show the variation

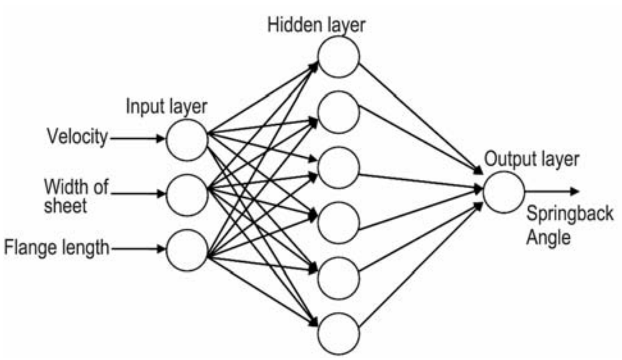

Fig. 2 – A schematic illustration of an artificial neural network

Fig. 3 – The sheet blank after the bending process

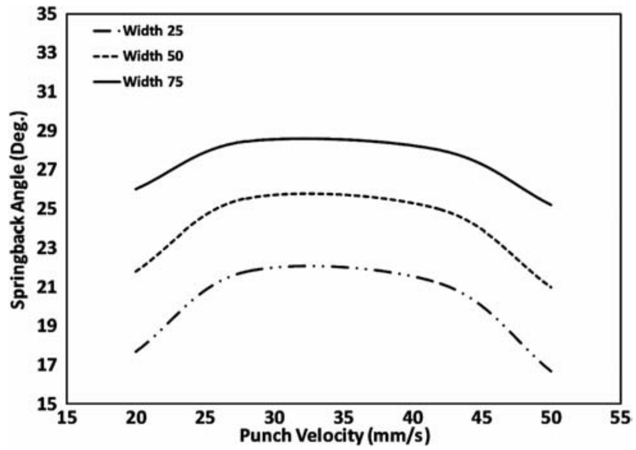

Fig. 4 – Springback angle for different velocities of punch for flange length 30 mm

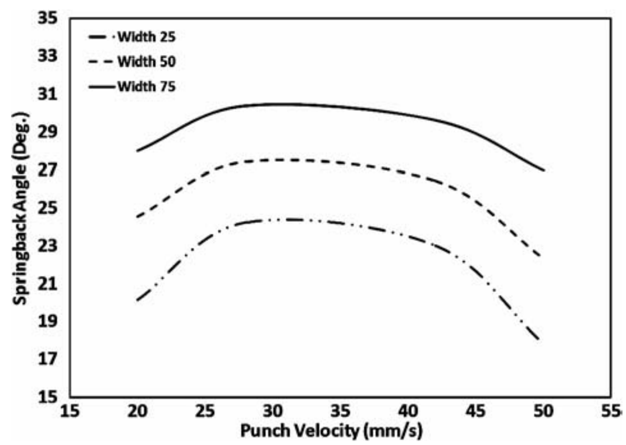

Fig. 5 – Springback angle for different velocities of punch for flange length 40 mm

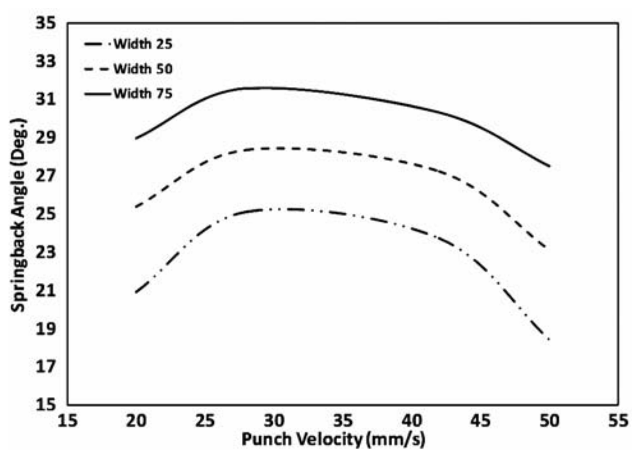

Fig. 6 – Springback angle for different velocities of punch for flange length 50 mm

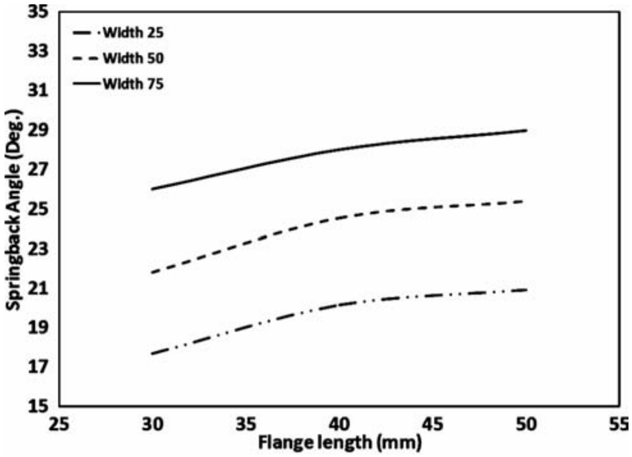

Fig. 7 – Springback angle at the velocity of 20 mm/s

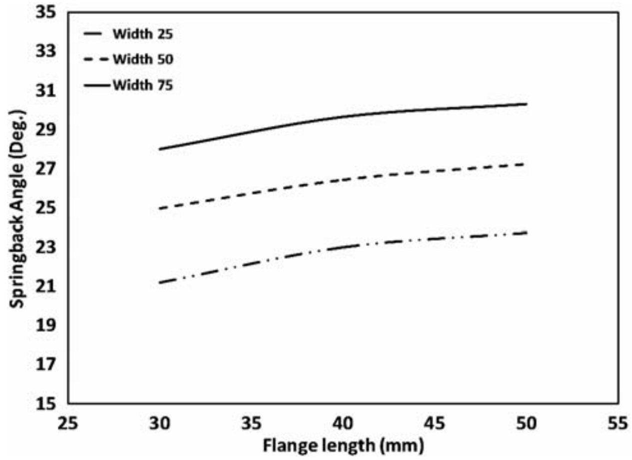

Fig. 9 – Springback angle at the velocities of 40 mm/s

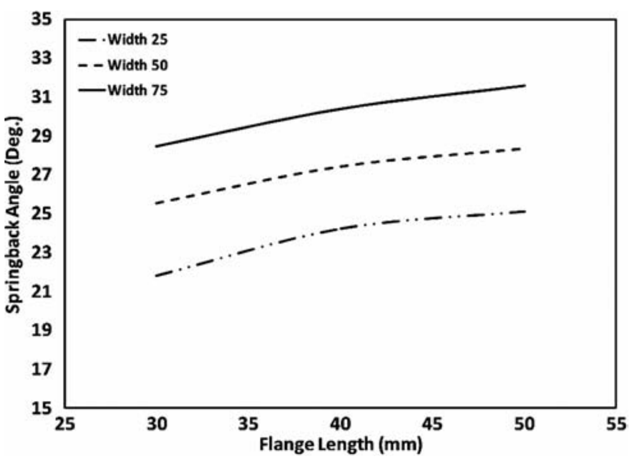

Fig. 8 – Springback angle at the velocity of 30 mm/s

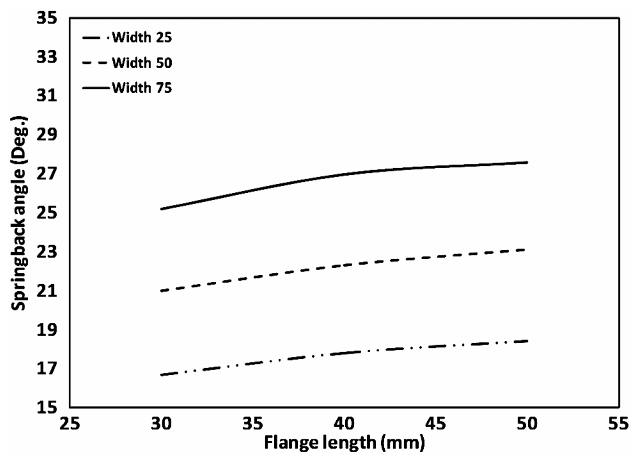

Fig. 10 – Springback angle at the velocity of 50 mm/s

of springback angle at different punch velocities. Figures 4-6 show the plots between springback angle and punch velocity at different widths of sheet for 30, 40 and 50 mm flange length, respectively. Since the machine has the limitation of maximum velocity, i.e., 50 mm/s therefore experiments are performed up to the punch velocity of 50 mm/s. It can be seen from these figures that springback angle is minimum at 20 mm/s for each width of sheet. Springback angle increases with increase in punch velocity and it reaches maximum at 30 mm/s approximately and it remains nearly constant up to 40 mm/s and it reduces beyond it. Springback angle is found minimum at velocity of 50 mm/s. The similar trends are found in all three widths of sheet, i.e., 25, 50 and 75 mm. The maximum springback angle is found at the velocity of 30 mm/s in all three widths of sheet. It can also be seen from these plots that springback angle depends on width of sheet and it increases with increase in width of sheet.

Plot between springback angle and flange length at velocity of 20 mm/s is shown in Fig. 8. This is a plot to find out the effect of width of blank and flange length on springback angle. It shows a non linear behavior of springback angle with respect to flange length at different width of sheet. It can be seen that springback angle increases with increase in flange length and width of sheet at velocity of 20 mm/s. Similar graphs are plotted between springback angle and flange length for punch velocity of 30, 40 and 50 mm/s, which are shown in Figs 8-10. The trend and observation of springback angle with respect to flange length at different widths of sheet is found similar as observed at punch velocity of 20 mm/s.

ANN results

A 3-6-1 back propagation neural network is used for training in this study. Weight and bias factors are selected randomly between 0.06 to 0.08. The neural network is trained for error tolerance of 0.003. The

Table 1 – Training patterns

S. No.	Input parameters			Output	S. No.	Input parameters			Output
	Velocity (mm/s)	Width of sheet (mm)	Flange length (mm)	Springback angle		Velocity (mm/s)	Width of sheet (mm)	Flange length (mm)	Springback angle
1	20	50	30	21.8	17	42	25	30	21.19
2	20	75	30	26.01	18	42	50	30	24.97
3	20	25	40	20.14	19	42	75	30	28.01
4	20	50	40	24.54	20	42	25	40	23.01
5	20	75	40	28.01	21	42	50	40	26.45
6	20	25	50	20.93	22	42	75	40	29.64
7	20	50	50	24.4	23	42	25	50	23.74
8	20	75	50	28.98	24	42	50	50	27.23
9	28	25	30	21.8	25	50	50	30	21.02
10	28	50	30	25.53	26	50	75	30	25.19
11	28	75	30	28.46	27	50	25	40	17.82
12	28	25	40	24.22	28	50	50	40	22.33
13	28	75	40	30.38	29	50	75	40	26.98
14	28	25	50	25.12	30	50	25	50	18.43
15	28	50	50	28.36	31	50	50	50	23.14
16	28	75	50	31.58	32	50	75	50	27.51

Table 2 – Testing patterns

S. No.	Input parameters			Output (Springback angle in degrees)		
	Velocity (mm/s)	Width of sheet (mm)	Flange length (mm)	Experiments	Neural network	Percentage er
1.	20	25	30	17.69	18.46	4.36
2.	28	50	40	27.43	27.08	1.26
3.	42	75	50	30.31	29.66	2.13
4.	50	25	30	16.69	16.10	3.51

neural network is trained on the basis of 32 cases of experiments as shown in Table 1 and it is used to predict the responses of four unknown pattern. Velocity of sheet, width of sheet and flange length is used (shown in Table 1) as input parameters to an unknown pattern and prediction of presented neural network is shown in Table 2. It can be seen from Table 2 that the predicted neural network results are very close to experimental one. A maximum error of 4% is found in case II out of the predicted cases. It can be seen that in most of cases network predictions are very close to the experimental results. Therefore, one can say that artificial neural network method is a very appropriate approach to predict the springback angle which helps in quick determination of process design parameters.

Conclusions

The variation of springback angle using different parameters in straight flanging process with aluminum alloy 5052 sheet has been carried out by experiments and ANN. The trends of springback angle with flange length, width of sheet and velocity of punch are studied extensively. The effect of springback cannot be eliminated completely, but it can be minimized by selecting the suitable geometrical and process parameters. The following conclusions emerged from this study:

(i) The springback angle increases gradually with increase in flange length at constant velocity.

(ii) The springback increases linearly with increase in width of flange at constant velocity.

(iii) The springback angle first increases gradually with increase in velocity afterwards it decreases gradually with increase in velocity. It may be due to change in mechanical properties of material at higher velocity.

(iv) An ANN model is trained and tested with experimental results, which shows a very good agreement. Therefore, it can be concluded from this study that ANN method can be effectively used in designing the process parameters of flanging.

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