Prediction of springback effect by the hybridisation of ANN with PSO in wipe bending process of sheet metal

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Abstract: In sheet metal forming springback is a phenomenon that occurs slightly due to residual stresses in the material, while bending the sheet metal. Hence it should avoid improving the metal quality by the prediction of springback angle. By predicting the springback angle, can reduce the angle by changing those parameters. Therefore, a suitable prediction method is required to predict the springback angle. One of the best prediction methods is the artificial neural network (ANN) to predict the springback angle in sheet metal. So this paper aims to improve the prediction efficiency of ANN by integrating particle swarm optimisation (PSO) algorithm. The PSO algorithm is used to train the ANN, so it can predict the springback angle efficiently. The proposed technique is compared with the experimental results and the conventional prediction techniques such as conventional ANN and Genetic algorithm based ANN.

Keywords: sheet metal forming; spring back effect; artificial neural network; ANN; particle swarm optimisation; PSO.


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1 Introduction

The material building is a craft of making different items by utilising the bland materials to various procedures, for example, outline, and manufacture. Individually working with sheet metal is developed since the Iron Age, for instance, making of decorations from
crude gold and silver (Cristina et al., 2015). Sheet metal shaping is the most utilised procedures for many assembling businesses (Odejobi and Umoru, 2009). The sheet metal surrounding has gotten an extensive measure of thought in display day development by effortlessness with which metal may be moulded into appropriate shapes by plastic distortion frames in which the volume and mass of the metal are ensured, and metal is ousted (Chua et al., 2015; Milewski, 2017). Moving production lines can easily make sheet metal, and the parts that are formed from sheet metal have the favoured point of view that the material has a profoundly elastic modulus and exceptional yield quality so that they can be both strong and have a better than average quality to-weight extent (Hao and Duncan, 2011; Khan et al., 2015).

New progressions are depended upon to respond to new mechanical solicitations, which are hoping to correct and exact information concerning parts design and formability of metal sheet (Aljibori and Hamouda, 2009). While in sheet metal arranging process, a couple of hazards are caused on account of wild conditions, for instance, metal suppliers, confining conditions, and numerical botches which ought to be considered in the sketched out methodology. Throughout the years, imaginative advances have allowed the era of significantly complex parts. Regardless, because of obfuscated sheet metal twisting, the disgraceful arrangement of process parameters may provoke deformations. Like this, it is critical to pick the most legitimate process conditions. Nevertheless, it is up till now a great degree troublesome issue to gain the perfect result.

Sheet metal confining proliferation accepts a critical part in consolidating creating necessities into the thing arrangement process at a starting period. In conjunction with the synchronous building, sheet metal forming re-authorisation is ended up being a necessary contraption in associating plan and amassing (Mohammadi et al., 2011). The computerised amusement of sheet metal moulding strategies is particularly charming to decrease the pointless activity and cost because of the system showing for PC generation by a virtual experimentation process (Zhang et al., 2016). In this manner, quick tooling progress has made advances into the customary pass on creation techniques (Karagöz and Yıldız, 2017). One class of agile tooling development incorporates the utilisation of bleeding edge polymers and composite materials to make sheet metal confining passes on. Regardless, there are various components which are dark yet which can control the surrounding (Park et al., 2017). Headway speculation gives a convincing way to deal with furthermore analysing the relations among the sheet metal surrounding quality effect factors and tentatively controlling (Xie et al., 2008).

2 Related work

A portion of the current scholarly works that arrangement with the optimisation of sheet metal development is examined in this section.

Kakandikar et al. (2009) have discussed the utilisation of formative philosophies to enhance the geometry parameters. Kazan et al. (2009) have talked about the gauge model of spring back in the wipe-winding strategy of sheet metal was made using made neural framework approach. Firat et al. (2010) have proposed an approach in perspective of the numerical re-sanctioning of stamping shapes by using explicit–incremental and implicit–iterative restricted part frameworks. Volk et al. (2011) have discussed the finite element method (FEM) which was required for relentless thing change and stable
creation process. A champion among the tremendous parameters in the sheet metal forming technique was the reasonable holding power. The conceptual works have dealt with the curving methodology of sheet metal surrounding process by focusing on the showing of bowing strategy. They have proposed an artificial neural network (ANN) approach to desire show and differentiated the results and FEM strategy. Sun et al. (2011) have suggested a two-mastermind multi-steadfastness method to better exchange of the businesses of low-consistency and high-commitment courses of action.

3 Proposed PSO-ANN for the prediction of springback angle

The wipe-twisting or bending is one of the procedures the most much of the time utilised as a part of the sheet metal item industry. Moreover, the springback of sheet metal, which is characterised as the flexible recuperation of the part amid emptying, ought to be contemplated to deliver twisted sheet metal parts inside adequate resistance limits. Springback is influenced by the variables such as, sheet thickness, grease conditions, tooling geometry, and material properties and preparing parameters. In this paper, the expectation model of springback in wipe-twisting procedure was created utilising ANN. Here, a few digital reproductions using FEM were performed to acquire the display information of the neural system. The educated neural system is numerically tried and can be effectively executed springback expectation for new cases.

The wipe-bending process is one of the mostly applied bending operations for flanging. In this study, the bending process was simulated using finite element (FE) software Ansys. In the simulation modelling; the tooling is defined geometrically by rigid surfaces. The sheet is represented by a deformable mesh. In the process, the sheet is clamped between the die and blank holder, and then the punch moves downward to bend the sheet. After the release of the load by the withdrawal of the punch, the springback took place and the change in the wall angle ‘a’, is defined to be a measure of distortion.

A parametric finite element model was developed such as variable geometry parameters and hardening characteristics. The simulation carried in two groups, the first group simulates, geometry parameters are the sheet thickness (t) and die shoulder radius (R). In the second group of simulations, the strain hardening component, n and material strength coefficient, K are changed. The die clearance set to 0.01 t in all simulations.

Abundant advances have been made in developing intelligent systems, and a few of them are inspired by the biological neural networks. The researchers have developed the ANN to resolve the multiple problems in pattern recognition, prediction, optimisation, associative memory and control. Conventional approaches have been proposed for solving these problems.

Even though successful applications can be found in confident and well-embarrassed environments, nothing is flexible sufficient to perform well in situations exterior to its domain. ANNs provide exciting options, and many applications could promote by using them. Back propagation (BP) algorithm is frequently used for learning in ANNs. Back propagation neural network consists of a collection of inputs and processing units known as neurons, also termed as neurodes or nodes. A simple feed forward ANN is shown in Figure 1. The neurons in every layer are completely interconnected by connection strengths, called weights, which along with the network architecture store the information of a trained network. In addition to the processing neurons, there is a bias neuron connected to each processing unit in the hidden and the output layers. The bias neuron
has a value of positive one and serves a similar purpose as the intercept in regression models. The neurons and bias terms are arranged into layers. There is an input layer, one or more hidden layers and an output layer. The number of hidden layers and neurons within each layer can vary depending on the size and nature of the dataset.

**Figure 1** Feed forward neural network

Neural networks are comparable to linear and non-linear least squares regression and can be viewed as a different statistical approach to solving the least squares problem. Both the neural networks and the conventional regression analysis attempt term in a regression equation. The number of input neurons is equal to the number of independent variables, while the output neurons represent the dependent variable. Linear regression models may be viewed as a feed-forward neural network that contains no hidden layer and one output neuron with a linear transfer function. The weights connecting the input neurons to the single output neuron are equivalent to the coefficients in a linear least squares regression. Networks with one hidden layer look like nonlinear regression models. The weights represent the regression curve parameters.

BP networks are a class of feed forward neural networks with supervised learning rules. Feed forward refers to the direction of information flow from the input layer to the output layer. Inputs are passed once through the neural network to determine the output.
3.1 ANN weight optimisation by PSO

The particle swarm optimisation (PSO) method is a self-educating optimisation algorithm that can be applied to any nonlinear optimisation problems. The PSO is an optimisation algorithm, which is based on the behaviour of the swarm to select the best food sources. In PSO, the potential solutions, called the particles, fly through the problem space by following the best fitness of the particles. It exhibits some evolutionary computation attributes such as initialisation with a population of random solutions and searches for optima by updating the generations.

The main concern for each swarm is the velocity and the position of the individual swarm. Each time a swarm finds a food source, its velocity is calculated, and its position is updated. Similarly, the pbest (personal best) of each swarm and gbest of the entire population are also updated for all the iterations. The operation of PSO is given below. Initially, the population is generated randomly, and each swarm in the population is assigned a food source. Each swarm travels to the food source and records the amount of food present in that particular position.

- Then, based on the amount of food source, the fitness value is evaluated. Once the fitness values for the swarm are evaluated, the pbest and gbest values must be updated.
- PSO makes use of a rank based update. Based on the fitness of each swarm in the current iteration and the previous iterations, the ranks are assigned for each swarm using equation (1).
- If the rank of a particular swarm has improved, then the pbest value of that particular individual is replaced with its current fitness value.
- Similarly, the fitness value of the individual having highest rank, i.e., rank 1, is set as the gbest.
- Then, the velocity and the position values of each are evaluated using equations (1) and (2), and the iteration continues till the termination criterion is reached.

\[ V = a \times V + C_1 \times r_1 \times (pbest - X) + C_2 \times r_2 \times (gbest - X) \]  

(1)

where, ‘\(a\)’ is the inertia weight that decreases linearly from 0.9 to 0.4 in each iteration, ‘\(C_1\)’ and ‘\(C_2\)’ are accelerator coefficients that are set to 2.0 and ‘\(r_1\)’ and ‘\(r_2\)’ are random numbers between 0 and 1.

\[ X = X + V \]  

(2)

‘\(X\)’ is the position vector and ‘\(V\)’ is the velocity vector of the individual.

4 Result and discussion

The proposed method is implemented in the working platform of Matlab, and the performance is evaluated. The result of the proposed method for spring back angle prediction is given below. From the given below results, we can see the performance of the proposed method. The training structure of PSO-ANN is shown in Figure 2.
A new technique to predict the spring back angle in the wipe bending process of sheet metal is proposed. In this work, a new mutation operator was introduced to overcome the drawbacks occurs in the existing method. The proposed method is the ANN prediction model using PSO algorithm with Cauchy mutation operator. The proposed method is very helpful in predicting the spring back angle in the wipe bending process of sheet metal.

The proposed method will improve the prediction efficiency in the predicting spring back angle in the wipe bending process of sheet metal. Thus, our proposed method has high performance in predicting spring back angle in wipe bending process of sheet metal. The performance of the proposed technique is compared against the conventional methods such as ANN, ANN with GA.

The performance comparison graph is shown in Figure 3, where the proposed PSO-ANN is compared with the experimental results and the conventional prediction techniques such as GA-ANN and ANN. Comparatively the proposed technique shows the better prediction performance than the other prediction techniques.

Figure 2  ANN structure (see online version for colours)
Figure 3  Comparison graphs showing spring back values using proposed and conventional ANN approach with Nh = 5, for (i) case G1, (ii) case G2 and (iii) case H (see online version for colours)

5 Conclusion

This paper proposed an effective ANN approach to predict the springback angle of wipe bending in sheet metal forming process. The proposed approach exploited two ANN architectures, one with $K$-value and $n$-value as inputs (for case H) and the other with $R$, $t$ and $R/t$ as inputs (for case G). The intention of using GA is to overcome the problems in conventional BP algorithm in such a way that the error was reduced to the minima compared to the conventional techniques. The validations results have shown that the proposed PSO ANN outperformed the conventional approaches. This, in turn, directs that the proposed ANN approach is more suitable for predicting the springback angle of wipe bending process.
References


