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Springback prediction for sheet metal forming based on GA-ANN technology

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Abstract

Springback is a very important factor to influence the quality of sheet metal forming. Accurate prediction and controlling of springback is essential for the design of tools for sheet metal forming. In this paper, a technique based on artificial neural network (ANN) and genetic algorithm (GA) was proposed to solve the problem of springback. An improved genetic algorithm was used to optimize the weights of neural network. Based on production experiment, the prediction model of springback was developed by using the integrated neural network genetic algorithm. The results show that more accurate prediction of springback can be acquired with the GA-ANN model. It can be taken as a reference for sheet metal forming and tool design.

Keywords: Springback; Sheet metal forming; Prediction; Genetic algorithm

1. Introduction

Punching is the main forming way of many sheet metals such as automotive panels, electronic components and devices. With the help of punching tool, the quick and efficient mass production can be achieved. But there was some deviation in sheet metal bending between the component angle and tool angle after unloading because of elastic deformation, that is springback. Because of the existence of springback, the precision of products and subsequent assembly operations were severely affected. How to effectively control springback has been the key to precision forming and ultra-precision design of tools.

As springback is too difficult to be calculated exactly by table checking and experience, artificial neural network (ANN) happens to map the non-linear relationship. It provides a new way to the complex, non-linear, polytropic springback problem. In recent years, many researchers have applied BP neural network into manufacturing for tool wear monitoring, for optimizing the forming process, and for parameter diagnose, etc. [1,2]. But the fatal drawbacks of BP neural network are the low speed of convergence and easy trapping in local optimization. Therefore, the present work intends to integrate ANN with GA to determine properly the weights of neural network, making up for the defects of BP algorithm.

The application of genetic algorithm into artificial neural network mainly includes two aspects [3]: one is to optimize the weights of network; the other is to optimize the topological structure of network. This paper mainly discusses the former, the learning process of network is regarded as the process of searching for optimum in the weight space. Genetic algorithm is a randomized search algorithm borrowing ideas from natural selection mechanism and genetic mechanism of living nature. Genetic algorithm does not require a gradient of the objective cost function as a search direction, it can automatically acquire and accumulate knowledge on search space and adaptively control the searching process, so as to acquire an optimal or sub-optimal solution.

In the present paper, springback of the typical U-shaped bending was taken as the subject investigated. Based on production experiment, the prediction model of springback was developed by neural network and genetic algorithm, further study on the relation of springback and various process parameters was carried out based on the model of springback, providing theoretical guide for sheet metal forming and tools design.

2. Neural network based on GA

The GA was used to optimize the weights of neural network. Before the genetic algorithm is conducted, a group of solutions

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were generated at random. Among them, the individuals with higher fitness were selected according to the principle of survival of fittest to do selection, crossover and mutation. After evolution from generation to generation, it will converge to the fittest individual at last. That is the solution of the problem.

2.1. Genetic coding for neural network

The weight learning of neural network is a heavy complex optimizing process of parameter system. In the process of optimizing weight with genetic algorithm, coding problem is the primary problem. Adopting real values coding can avoid transition between binary coding and the solution, at the same time, decrease the coding length, improve the efficiency as well as precision. Therefore, the real values coding mode was adopted in coding for the weights of neural network. The weights were made up of a set of real values that uniform randomly generated from −10 to 10, encoding as $(w_1, w_2, \ldots, w_n)$.

2.2. Fitness function and genetic operation

The squared error of hidden codes of back propagation can be used as objective function of optimizing weight. In this way, the problem transformed into finding a set of fittest weight for minimize objective function. Genetic algorithm could only evolve towards the increasing orient for fitness function, therefore the fitness function can be configured with the reciprocal of objective function:

$$f(l) = \frac{1}{\sum_{j=1}^{N} \delta_{\mathrm{h}}^2} \tag{1}$$

where δ_{h} is the error of hidden codes.

2.2.1. Selection operation

Generally, the selection operator of genetic algorithm is implemented by using the roulette-wheel algorithm. The main defect of the roulette-wheel algorithm is that the local optimal gene dominates the whole generation, while the global optimum would likely be eliminated before emerging. Therefore the elitist strategy was adopted, the generation whose fitness is within top 10% will be directly copied to the new generation. The others were selected from upper generation at random, using crossover and mutation, and then were copied to the new generation. As discovered from practice, the elitist strategy not only represents the principle of survival of fittest but also avoids trapping in the local minimum to some extend.

2.2.2. Crossover operation

Crossover is a mechanism of randomly exchanging information between two chromosomes. There are discrete crossover and arithmetical crossover in real coding scheme. In this study, arithmetical crossover was adopted because the arithmetical crossover is not like discrete crossover that simply exchange position and its search band of arithmetical crossover is larger. With the random initiated crossover probability P_{c}, crossover operation proceeds between two random selected individual $q_1 = (w_1^{(1)}, w_2^{(1)}, \ldots, w_n^{(1)})$ and $q_2 = (w_1^{(2)}, w_2^{(2)}, \ldots, w_n^{(2)})$. Then two new individuals, $q_z = (z_1, z_2, \ldots, z_n)$ and $q_v = (v_1, v_2, \ldots, v_n)$, are generated. A random array $R(a_1, a_2, \ldots, a_n)$ is generated from 0 to 1. If R_i is lower than P_{c} then crossover will take place in the corresponding position of q_z and q_v, as follows:

$$z_i = a_i w_i^{(2)} + (1 - a_i) w_i^{(1)} \tag{2}$$

$$v_i = a_i w_i^{(1)} + (1 - a_i) w_i^{(2)} \tag{3}$$

where δ_{h} is the error of hidden codes.

2.2.3. Mutation

The purpose of mutation operation is to make genetic algorithm obtain local random research capability through varying certain genes of chromosome. When genetic algorithm have access the optimal, mutation can quickly converge to optimal solution. A random array $R(a_1, a_2, \ldots, a_n)$ is generated from −1 to 1 when doing mutation. If R_i is between mutation probability P_v and $-P_v$ then add R_i to weight correspondingly. So the mutation operation is accomplished. Generally the span of P_v is from 0.005 to 0.05.

3. Establishing the springback model using the integrated neural network genetic algorithm

3.1. Experimental procedure

The U-shaped bending is a common procedure in sheet metal forming. As one of the sheet metal forming process, it is a high non-linear problem containing geometric non-linear, material non-linear and contact non-linear. So the typical U-shaped bending was chosen to demonstrate the problem of springback of sheet metal forming. The tool of U-shaped bending is shown in Fig. 1.

Although the material performance, blank dimension and tool topological structure of sheet metals all affect springback to some extend, the influence degree is various. On the base of orthogonal analysis [4], the five most significant influence factors were considered here (see Fig. 2):

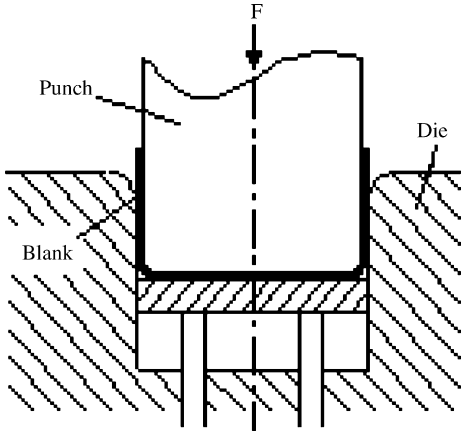

Fig. 1. The tool of U-shaped bending.