Status Quo of Numerical Simulation of Friction Stir Welding After Deformation under Big Data Analysis

Chen Chen*
Qinghai Higher Vocational & Technical Institute, Haidong, 810799, China

*Corresponding author e-mail: chenchen@qhgzzy.com

Abstract. Friction stir spot welding is a new type of connection technology developed on the basis of the friction stir welding process. It uses a high-speed rotating stirring head to generate heat by friction with the plate to make the welding material reach a thermoplastic softened state, forming a lap joint similar to resistance spot welding. The purpose of this article is to analyze and analyze the current situation of numerical simulation of friction stir welding after deformation under big data analysis. Algorithm mining commonly used for analysis of big data. This paper proposes to use the classic algorithm FP-growth algorithm. The FP-growth algorithm has the widest application range. It compresses the transaction database into a FP tree for processing. It also uses the Apriori algorithm, which eliminates the need to generate candidate frequent itemsets, which improves the efficiency of use. In addition, this article uses data mining technology and data fusion technology commonly used in big data analysis, and their application strengthens the analysis of the current situation of numerical simulation after friction stir welding deformation under big data analysis. Experimental research shows that the dynamic FSSW technology used in this paper simulates the numerical change after friction stir welding deformation, and the simulated data effect is better than the traditional GPC algorithm by about 20%.

Keywords: Friction Stir Spot Welding, Big Data, Dynamic FSSW Technology, GPC Algorithm

1. Introduction
With the development concept of saving resources and protecting the environment gradually gaining popularity. Spot welding process is the most important way of splicing steel plates, and the process performance of spot welding joints will directly affect the overall performance of steel [1, 2]. Because magnesium alloy materials have the characteristics of high thermal conductivity, low melting point, large thermal expansion coefficient, and strong bonding with nitrogen and oxygen, the process requirements in the welding process are relatively high [3, 4]. The traditional point connection methods include resistance spot welding, riveting and laser welding [5, 6]. Resistance spot welding is one of the main connection methods in steel manufacturing. It has disadvantages such as high power consumption, large thermal deformation of the workpiece, short life of the spot welding electrode, and poor appearance of the solder joint. It is also easy to appear in the process of welding magnesium
aluminum alloy. Welding joint defects such as crystal cracks, shrinkage, incomplete penetration, and overburning, due to the surface oxide film leading to large contact resistance, are prone to splashing and electrode adhesion, which directly affect the strength of the welded joint [7, 8].

Scholars at home and abroad have different views and opinions on this. Domestic scholar Zhao believes that FWX is more distinctive than traditional resistance spot welding and riveting. As a new spot welding process technology with clean, high-efficiency, low welding thermal distortion, and simple process operation, it is used in the fields of automobile, shiFSSWulding, aerospace, etc. Wide application prospects are expected to replace traditional resistance spot welding and riveting techniques in some fields [9]. Foreign scholar Colakoglu also agreed with this. FSSW analyzed the temperature field distribution and material plastic flow in the friction stir spot welding process, established a complete database of process parameters and finite element model analysis, and provided theoretical technical support for the actual production process. It has important scientific research and practical application value [10].

In this paper, a finite element model of the transient temperature field of AZ31 magnesium alloy spot welding based on continuous solid mechanics is established, and the experimental data is used to verify the temperature change rule of the stirring head shoulder and the stirring needle during the spot welding process, and further establish the spot welding process materials based on the experimental data. The flow analysis finite element model analyzes the law of the temperature field and material flow field in spot welding by welding process parameters and mixing head design. Provide technical support and theoretical reference for establishing FSSW finite element analysis database and actual spot welding production process under different materials and process parameters within a certain range.

2. Technical Research on Current Situation Analysis of Numerical Simulation of Friction Stir Welding after Deformation under Big Data Analysis

2.1 Numerical Simulation Analysis Algorithm after Friction Stir Welding Deformation under Big Data Technology

The numerical simulation analysis algorithm of friction stir welding deformed under big data technology is to find all strong association rules from the source database, and the formula (1) is as follows.

I have to meet, $\text{conf}(A \Rightarrow B) \geq \min \text{conf}$ and $\text{Support}(A \cup B) \geq \min \text{sup}$, then $A \Rightarrow B$. This mining process includes the following two steps:

1) Search for frequent itemset: To search for itemset whose support degree is not less than the specified support threshold, to obtain frequent itemset, it needs to scan the transaction source database. This is the main step of association rule data mining, according to the scope, target, and direction of the search data format, different search algorithms can be constructed.

2) The generation of strong association rules: For any frequent item set L, detect each non-empty subset X in it, and generate the rule $L \Rightarrow L - X$, the corresponding support is recorded as Pr(L), and the confidence is recorded as $\text{Pr}(L) / \text{Pr}(X)$, delete those rules that do not meet the confidence level set by the user, and the rest are strong association rules.

Based on the nature of support calculation, the process can be simplified to find the largest subset of L first, and only when the confidence of its generation rule meets the conditions, other subsets are tested. For example, $L = \{A, B, C, D\}$, if the confidence of rule $\{A, B, C\} \Rightarrow D$ does not reach the confidence threshold, then $\{A, B\} \Rightarrow \{C, D\}$ also does not meet the confidence threshold (because of $\text{Pr}(\{A, B\}) \text{Pr}(\{A, B, C\})$).

2.2 FP-growth Data Mining Algorithm

(1) Data Mining Technology
Using data mining technology to deeply mine for item set \( X, \ X \subseteq I \), the support degree of item set \( X \) appearing in \( D \), denoted as

\[
Support(X) = \frac{\text{count}(X \subseteq T)}{|D|}
\]  

(1)

Where \( \text{count}(X \subseteq T) \) is the number of \( X \) contained in the transaction database \( D \). Association rule \( R : X \Rightarrow Y \), the confidence of rule \( R \) refers to the ratio of the number of transactions where \( X \) and \( Y \) appear at the same time to the number of transactions that only appear, denoted as

\[
\text{confidence}(X \Rightarrow Y) = \frac{\text{Support}(X \cup Y)}{\text{Support}(X)}
\]

(2)

The credibility reflects the probability that \( Y \) appears in the transaction if \( X \) is included in the transaction. The minimum confidence threshold is denoted as \( \min _{\text{conf}} \).

(2) Data Fusion Technology

The main problem that the fusion function solves is how and what algorithm the data will be fused. The simplest methods include the average method, the maximum (small) value method, and the intermediate value method. Of course, there are also more complex algorithms. It depends on the specific integration requirements. Assuming that there are \( n \) sensor nodes in a multi-sensor data fusion system, and their output data are \( X_1, X_2, \ldots, X_n \) respectively, then the fusion function of the system can be expressed as:

\[
F(X_1, X_2, \ldots, X_n) = y
\]

(3)

In the above formula, \( F \) represents the fusion function, and \( y \) represents the result of the data fusion of these \( n \) nodes. The fusion function should have the three properties of commutative and idempotent functions.

The tolerance function, as the name implies, describes the degree to which the data collected by two or more touch sensor nodes can be fused, which means the degree of similarity of the node data. The higher the similarity of the data, the closer the data is, the value of the tolerance function. The bigger it is. The value of the allowable function is specified in the interval \([0,1]\). When multiple data are waiting to be merged, the tolerance function is defined as follows:

\[
R: X \times X \times \ldots \times X \rightarrow [0,1]
\]

(4)

\[
R(x_1, x_2, \ldots, x_n) = \min \{R(x_i, x_j)\}
\]

(5)

\( R \) represents the tolerance function, \( R(x_i, x_j) \) represents the tolerance result of two sensor nodes, and \( R(x_1, x_2, \ldots, x_n) \) represents the total tolerance result of the data of \( n \) sensor nodes.

3. Experimental Research of Computer Technology in the Work of College Party Branches in the Information Age

3.1 Experimental Research on Numerical Simulation of Friction Stir Welding Deformed under Big Data Analysis

The system reference input is a square wave signal. The sensor node is time-driven, sampling the stepper motor regularly, the sampling period is 10ms, and the sampling signal is transmitted to the controller node through the network node. The controller node adopts an event-driven method. After receiving the information from the sensor node, it calculates the control value and transmits the result to the actuator node through the network.
3.2 Generalized Predictive Control Based on Error Correction

The error predicted by the dynamic FSSW network is $y_e(k+j)$, which is used as the error compensation to correct the generalized predictor:

$$y(k+j) = y_m(k+j) + y_e(k+j)$$ (6)

In the formula, $y_m(k+j)$ is the predicted value of the traditional generalized prediction algorithm at time $k$. Introduce (5) formula:

$$y(k+j) = G(z^{-1})Δμ(k+j-1) + F(z^{-1})y(k) + y_e(k+j)$$ (7)

The optimal solution after error compensation is:

$$ΔU = (G^T G + λI)^{-1}G^T(Y - F - Y_e)$$ (8)

The FSSW network can perform error correction once the network weight is determined after training.

3.3 Big Data PID Controller

Adaptive PID control uses the basic theories and methods of linear algebra to express the conditions and operations of the rules in fuzzy sets, and express these fuzzy rules and related information in a knowledge base. Then, according to the response of the system, fuzzy inference is applied and online PID parameters are adjusted.

4. Experimental Analysis of Numerical Simulation After Deformation of Fiction Stir Welding under Big Data Analysis

4.1 Big Data Smith Predictive Controller System Experiment Simulation Analysis

This paper designs a Smith predictive PID controller and simulates the system. The experimental results are shown in Table 1.

| Table 1. Experimental Simulation Analysis of Smith Predictive Controller System |
|---------------------------------|---------------------------------|---------------------------------|---------------------------------|
| Time(s) | Smith predictive control step response | Smith predicts fuzzy PID controller when graphics are accurate | Smith predictive fuzzy PID controller described in this article |
| 1 | 0 | 0 | 0 |
| 3 | 0.42 | 0.56 | 0.35 |
| 5 | 0.73 | 0.98 | 0.61 |
| 7 | 0.84 | 1.35 | 0.71 |
| 9 | 0.91 | 0.89 | 0.93 |
| 11 | 0.99 | 0.97 | 0.98 |
Smith predictive control step response
Smith predicts fuzzy PID controller when graphics are accurate
Smith predictive fuzzy PID controller described in this article

Figure 1. Experimental Simulation Analysis of Smith Predictive Controller System
As shown in Figure 1, the experiment shows that this method can speed up the system response speed when the system model is accurate, and the steady-state performance is better.

4.2 Dynamic BP Simulation Experiment Analysis
In the simulation system, the second-order object transfer function model is selected, the controller side adopts a generalized predictive control algorithm based on dynamic FSWW error correction, the sensor side adopts a time-driven method, and both the controller side and the actuator side adopt an event-driven method. Experimental results as shown in Table 2.

Table 2. Generalized Predictive Control Algorithm for Dynamic FSWW Error Correction

| Time (s) | Traditional GPC | Modified GPC |
|---------|----------------|-------------|
| 0       | 0              | 0           |
| 5       | 0.46           | 0.36        |
| 10      | 0.83           | 0.72        |
| 15      | 1.24           | 1.21        |
| 20      | 0.91           | 0.95        |
| 25      | 0.97           | 1.01        |

Figure 2. Traditional GPC and Dynamic FSWW Error Correction GPC Experimental Analysis
The numerical simulation model designed by FWSW technical error correction GPC algorithm has faster response time and smaller overshoot, and the simulation effect is better than the traditional GPC algorithm by about 20%.
5. Conclusions
This paper takes the process of sheet friction stir spot welding as the research object, and analyzes the temperature field distribution and the flow law of material thermoplasticity during the spot welding process through a combination of theoretical analysis, experimental testing and finite element numerical simulation. A finite element model of the transient temperature field of spot welding based on continuous solid mechanics was established, and the experimental data was used to verify the temperature change law of the stirring head shoulder and the stirring needle during the spot welding process. Based on the experimental data, the finite element analysis of the material flow in the spot welding process was further established. The model analyzes the law of welding process parameters and stirring head design on the temperature field and material flow field in spot welding. It provides a method for establishing a FSSW finite element analysis database under different materials and process parameters within a certain range.

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