Intelligent Deformation Control Algorithms for Mechanical Metal Parts Based on Internet of Things

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Abstract: In order to solve the problem of serious damage during the operation of mechanical metal parts, the intelligent control algorithm of deformation of mechanical metal parts is studied based on the Internet of Things technology. Firstly, the characteristic parameters of deformation of metal parts are collected by the fuzzy algorithm, and the extreme value of damage degree of parts is evaluated and calculated by the artificial ant colony algorithm. According to the calculation results, the deviation parameters of the moving trajectory of the mechanical metal parts are corrected to alleviate the damage of the metal parts, so as to realize the intelligent control algorithm for the deformation of the mechanical metal parts. Finally, the experiment proves that the intelligent deformation control algorithm based on the Internet of Things has better practical value than the traditional algorithm.

1. Introduction
With the rapid development of modern economy, the mechanical industry is also growing. In order to ensure the stability of economic development and avoid wear and deformation during the operation of parts, the deformation control algorithm of mechanical metal parts is optimized by combining the Internet of Things technology in order to ensure the safety and stability of parts operation. Traditional metal parts deformation control algorithms usually use the principle of target-level reservation data fusion to control. This method can effectively collect the operation information of multiple parts, process the redundant and complementary information generated during the operation of parts, and combine the principle of non-linear discreteness to calculate the dynamic deformation coefficient of parts, and then process the data integration. This method can effectively control multiple parts, but it is difficult to meet the current requirements of efficient, convenient, accurate and effective part control because of the complexity and complexity of the calculation process. Therefore, on the basis of combining traditional algorithm and Internet of Things technology, the intelligent control method of mechanical metal parts deformation is studied. Through the standardization and classification of the relevant operational characteristics rules, we can achieve more accurate and rapid acquisition of target data, accurate description of target data and damage deformation data, thus ensuring the accuracy and convenience of the control algorithm, and improving the stability and safety of the operation of mechanical metal parts. Combined with the artificial ant colony algorithm, the related parameters such as wear degree and surface deformation degree of mechanical metal parts are collected and judged. Combined with modern electronic information technology, the quality and deformation control of metal objects is processed. In the process of processing, the potential factors such as physical deformation and chemical metamorphosis of mechanical metals should be analyzed and studied in combination with geometric deformation method, so as to facilitate the follow-up study. Deformation degree of mechanical metal parts is estimated and recorded [1]. Combined with the three-dimensional
model, the boring and chemical properties, density, mass, running time, inertia force field and other related factors of parts are standardized. The potential surface deformations of parts in the process of movement are calculated by constraint algorithm. Based on the calculation results, the response deformation control model of metal parts is created, and the corresponding deformation mapping relationship is established according to the results of calculation and fitting specifications. Based on the curve results, the discretization degree of deformation control is analyzed and integrated, and the integration results are recorded and drawn into a set of units [2]. According to the set parameters, the unit function of part deformation is calculated, and the unit stiffness of mechanical metal parts is obtained. After the stiffness values are superimposed, the total stiffness matrix is formed. According to the calculation results, the metal parts are optimized and repaired. According to the calculation results, the boundary setting conditions of metal parts are added, and the driving deformation of metal parts is carried out under the load geometric constraints. The control flow is optimized to complete the calculation of deformation control of mechanical metal parts.

2. Intelligent control algorithm of mechanical metal parts deformation based on Internet of Things

2.1 Characteristic Collection of Deformation of Metal Parts

In order to achieve the goal of intelligent control of mechanical metal parts, first of all, it is necessary to collect the deformation and wear degree of metal parts, and acquire and record the data characteristics of metal parts. In the process of mechanical operation, the data characteristic quantity of parts will increase with the increase of running time, and when parts are deformed, the characteristic data will appear aggregation phenomenon[3]. Using this feature, the deformability of metal parts is calculated, so that the trajectory of metal parts can be corrected according to the calculation results. Combining the fuzzy control method and the Internet of Things technology, the feature parameters of parts are extracted, and the friction parameters are input. The minimum friction value is set to P. If the maximum endurable friction degree of parts is e, when the wear degree of parts reaches the critical point E, the parts will be deformed. Among them, the deformation degree of parts is shown as follows:

\[
E = \begin{bmatrix}
\epsilon_{11}^{(p)}, \epsilon_{12}^{(p)}, \epsilon_{13}^{(p)}, \ldots, \epsilon_{1m}^{(p)} \\
\epsilon_{21}^{(p)}, \epsilon_{22}^{(p)}, \epsilon_{23}^{(p)}, \ldots, \epsilon_{2m}^{(p)} \\
\vdots \\
\epsilon_{m1}^{(p)}, \epsilon_{m2}^{(p)}, \epsilon_{m3}^{(p)}, \ldots, \epsilon_{mn}^{(p)}
\end{bmatrix}
\]

When the deformability of the part reaches R, it indicates that the part has been damaged and must be dismantled in time to avoid serious faults in the process of mechanical operation[5]. According to the process of collecting deformation characteristics of metal parts, in order to ensure the accuracy of information acquisition, it is necessary to collect and process part features according to the following steps:

- Combining with feature extraction algorithm, the minimum frictional numerical characteristic parameter p of parts is collected.
- Combining with the fuzzy control algorithm, the maximum endurable friction e of parts is calculated, and the range of e evaluation is standardized.
• According to the calculation of critical points E and R of part scrap, the range of value is determined.
• Applying Product-Sum reasoning method, the output results are obtained, and the deformation range of parts is obtained by synthesizing the analysis results parameters.
• To divide the damage and deformation grade of parts and to standardize the grade range;

Combined with the above steps, the operation frequency of the original metal parts, the components of the metal parts and the extreme values of the damage and deformation of the metal parts are calculated by using the fuzzy algorithm. In the calculation process, the potential wear degree of the metal parts in the running environment should be taken into account, and the parameters of the wear characteristic components of the environment should be extracted and cancelled, so that the deformation characteristics of the parts can be obtained more clearly. The specific feature acquisition and processing flow is shown in the figure.

![Flowchart](image.png)

Fig. 1Metal parts deformation feature acquisition and processing flow.

According to the above steps, the deformation characteristics and parameters of mechanical metal parts can be effectively collected and graded, so as to provide reference data in the follow-up processing, and to facilitate the revision and control of Parts' trajectory according to their deformation degree, thus simplifying the method flow of intelligent control of mechanical metal Parts' deformation[6]

2.2 Weighted Specification for Operating Track of Metal Parts

Through a large number of investigations and studies, it is found that the problem of excessive damage in the operation of metal parts can be effectively alleviated by controlling and modifying the trajectory of parts. Therefore, combined with the Internet of Things technology and artificial bee colony algorithm, the damage situation of mechanical metal parts during operation is analyzed[7]. On the basis of the research on relevant data, the standard setting parameters, average life, running time, vulnerable parts and damage degree of mechanical metal parts are set up to calculate the statistical and average range parameters. Fault detection and diagnosis for different parts are carried out, and records are made for subsequent reference and comparative use[8]. At present, there are many kinds of
mechanical metal parts, and the types of different parts are relatively complex. In the process of studying the operation and wear of mechanical metal parts, it is necessary to take into account the basic information of various data parameters and Part's power and distance in the operation of mechanical metal parts, and combine the geometric deformation method with the physical deformation of mechanical metals and part chemistry. Potential factors such as metamorphism are estimated and recorded. Combined with the three-dimensional model, the boring and chemical properties, running time, inertia force field and other related factors of parts are standardized. In addition, due to the different quality of metal materials and other related information, in the process of calculating the weighted operation control system of mechanical metal parts, the results of deviation trajectory calculation will also have a certain impact, so it is necessary to collect the material information of metal parts. Common material parameters of metal parts are shown in the following table:

| Material Science        | Specific strength(106cm) | Density(g/cm) | Specific modulus(108cm3) | Reliability index |
|-------------------------|--------------------------|---------------|--------------------------|-------------------|
| steel                   | 1.8                      | 7.80          | 2.8                      | 1.2412            |
| titanium alloy          | 2.2                      | 4.51          | 2.5                      | 1.4252            |
| Aluminium alloy         | 1.8                      | 2.88          | 2.5                      | 1.5353            |
| Aluminium              | 8.4                      | 2.10          | 9.5                      | 1.3534            |
| glass fibre             | 5.9                      | 2.00          | 2.1                      | 1.2423            |
| Boron fiber             | 5.9                      | 2.65          | 9.5                      | 1.2523            |
| silicon carbide         | 5.2                      | 2.90          | 7.2                      | 1.5353            |
| carbon steel            | 5.1                      | 2.00          | 6.4                      | 1.5756            |
| High carbon steel       | 7.2                      | 1.95          | 6.7                      | 1.7763            |
| carbon steel            | 7.1                      | 1.94          | 6.4                      | 1.8753            |
| Rimmed steel            | 7.6                      | 1.94          | 6.6                      | 1.8598            |
| Sedation steel          | 7.1                      | 1.64          | 6.1                      | 1.87689           |
| Carbon structural steel | 7.1                      | 1.84          | 6.6                      | 1.7369            |
| low alloy steel         | 7.6                      | 2.00          | 6.1                      | 1.9082            |
| Medium alloy steel      | 7.4                      | 1.20          | 6.4                      | 1.7803            |
| High alloy steel        | 7.4                      | 1.54          | 6.3                      | 1.8923            |
| Alloy spring steel      | 6.9                      | 1.84          | 6.5                      | 1.9484            |
| alloy carburizing steel | 7.2                      | 2.10          | 6.2                      | 1.9384            |
| Stainless steel         | 6.7                      | 2.02          | 6.5                      | 1.8498            |
| SVM                     | 5.1                      | 2.84          | 6.8                      | 1.8975            |
| PCA-BPNN                | 5.3                      | 2.94          | 9.1                      | 1.9342            |
| fault diagnosis         | 5.7                      | 2.45          | 7.2                      | 1.9001            |

The above information is used as the basis for calculating the angle change of the part's trajectory, so that the deviation of the part's trajectory can be mastered and traversed, the characteristics of the trajectory data can be roughly extracted, the metal parts can be positioned and detected by the common Multimeter in industrial technology testing, and the potential damage information of the part can be weighted according to the trajectory data of the part's operation. In order to study systematically and integrally, the data characteristics of mechanical metals can be extracted with fuzzy control algorithm [9]. According to the extracted parameters, the range coordinates of the Part's motion are set, and the
maximum and minimum horizontal and vertical coordinate parameters of the Parts' motion are set as follows: $\phi_1, \phi_2$ and $\lambda_1, \lambda_2$. Then the algorithm for calculating the potential damage degree of parts is:

$$d(A, B) = 2(\hat{R} - \hat{E})$$

$$= \log \left( \sqrt{\sin^2 \left( \frac{\phi_2 - \phi_1}{2} \right) + \cos \left( P_{\max} \right) \cos \left( e \right)^2 \sin^2 \left( \frac{\lambda_2 - \lambda_1}{2} \right)} \right)$$

If the damage of parts is relatively serious during the operation of machinery, which results in the deflection of the original trajectory of parts, it is necessary to calculate the deviation trajectory angle of parts. The calculation steps are as follows: Taking the revolving point of the standard trajectory as the center, the multi-path trajectory points are tracked and selected, and the minimum angle of the part moving offset trajectory is obtained, and the average weighted control parameters are obtained according to the information of the two parameters, which is set as the safety control threshold of the part. It is expressed by $\delta$, so that after obtaining the deformation degree of metal parts, the control and repair parameters of metal parts can be calculated according to the results. According to the above algorithm, the standard parameters of part trajectory are standardized and rearranged to effectively control the hierarchical integrated state of path management data. Through further calculation, it can be seen that the data integration center and the information sorting results can be used to judge the regional information transmission nodes based on the information sorting results.

2.3 Implementation of Intelligent Control Algorithms Based on Internet of Things

Through the above steps, the wear deformation characteristics and trajectory control parameters of mechanical metal parts are clustered and analyzed, and then the intelligent control algorithm of part deformation is studied based on the calculation results. In order to avoid the interference of environment and improve the accuracy and validity of metal deformation control of parts, further analysis and research are made on the trajectory and deformation control of parts. In the process of controlling parts, environmental impact factors should be fully considered. In order to ensure the stability of parts, the motion control system of parts should be carried out in combination with the previous ideas. Planning, through accurate acquisition and analysis of environmental data, combined with the operation environment of machinery and equipment, formulate the corresponding parts operation specification trajectory and deformation parameters. Intelligent control algorithm of mechanical metals is designed by combining Internet of Things technology and LMD feature extraction method. If the general life of the part is $x(t)$, the steps of extracting the deformation characteristics of the mechanical metal parts are as follows:

- Calculate the local extreme point of $x(t)$, obtain the local mean function $m11(t)$ of the part trajectory and separate the local envelope function $a11(t)$ of the metal part from the mean function.
- The standard demodulation control parameters of metal parts can be accurately obtained by dividing $h11(t)$ by $a11(t)$. It is recorded that the range of the original signal iterative control parameters can be obtained by uninterrupted multiplier calculation of $s11(t)$. $-1 \leq s11(t) \leq 1$.
- Combined with formula (1), the mechanism points in $S11(t)$ are separated and $PF1(t)$ is terminated. The average $u1(t)$ is obtained as the reference value of intelligent control through repeated superposition calculation of $PF1(t)$.
- In the process of calculating the intelligent control of part deformation, $u1(t)$ should be taken as the original data, the reference value should be regulated repeatedly, and the k-order deviation data $PF$ should be calculated, which is set as a monotone function $f(x)$.

Combining with the constraint algorithm, the potential surface deformability in the process of part movement is calculated, the corresponding deformation mapping curve is established by fitting the normative results, and the discretization degree of deformation control is analyzed and recorded. The
data information is integrated into a set of units according to the above steps. Using relaxation factor, the quadratic optimization equation of part intelligent correction can be established. As follows.

\[ RUL = \min PF(t) \ast f(x) \]

\[ = \frac{1}{2} \left\| k - f\left( x \right) \right\|^2 + u_i(t) \sum_{i=1}^{n} \left[ s_{11}(t) - a_{11}(t) \right] \]

\[ = s.t. PF_i(t) \ast k(u_i(t) \cdot f(x) + s_{11}(t)) \]

\[ RUL \geq 1 - s_{11}(t) \]

\[ k \geq 0, i = 1, 2, \ldots, n \] (3)

Combined with the above algorithm, the automatic control parameters of metal parts of mechanical equipment are standardized. By simplifying and decomposing the complex trajectory parameters, three closed-loop series sets are obtained. The closed-loop series sets can ensure the rapid and accurate control and management of the operation of parts. Three standard control parameters are defined in the trajectory range, and the fuzzy adaptive control processing rules are formed to control the operation of parts. The trajectory deviation value is budgeted in order to detect and correct the path of metal parts in time when they are deformed, so as to ensure the accurate and effective control of the operation of metal parts of mechanical equipment. If \( C \) denotes the penalty parameters of the deformed parts and \( a \) is the evaluation coefficient of the mechanical fault diagnosis, and the control multiplier (ai) is established by Lagrange principle, then the deformation control algorithm of the metal parts can be obtained.

\[ \max Q = \sum_{i=1}^{l} RUL - \frac{1}{2} c \sum_{i=1}^{l} a_i f(x) \cdot Ee \]

\[ s.t. PF(t) \]

\[ \left\{ \begin{array}{l}
\sum_{i=1}^{l} a_i = 0 \\
C \geq a_i \geq 0, i = 1, 2, \ldots, l
\end{array} \right. \] (4)

Intelligent control method is used to control the operating power of mechanical metal parts, so that the mechanical equipment always keeps constant power working state. This method mainly simulates human behavior and then memorizes it. Under certain conditions, the power of the lifting device is controlled. After the power is standardized, the deformation degree characteristics of mechanical metal parts are classified and divided into < a, b, c, d, E > five grades. According to the above algorithm, the control correction rules of five grades are designed respectively. Because the damage degree of parts is different in the process of mechanical movement, the deformation degree characteristics of parts are not arranged regularly, so the intelligent control process is not a regular one. According to the actual operation of metal parts, the grade judgment and fitting processing must be carried out. In order to ensure the accuracy and rapidity of intelligent control of metal parts, the deformation control principle of mechanical metal parts is displayed, which is illustrated in the following figure.
Parameters to be predicted

Degree of deformation

control structure

Figure 2. Deformation control process of mechanical metal parts

By acquiring the wear parameters of metal parts and extracting and standardizing the features of the correction algorithm for the trajectory of metal parts, the deformation degree of metal parts can be quickly and accurately obtained and corrected effectively according to the previous algorithm, thus effectively achieving the research goal of the deformation control algorithm for mechanical metal parts.

3. Test of simulation experiment

In order to verify the validity of the intelligent deformation control algorithm for mechanical metal parts based on the Internet of Things, simulation experiments were designed. In the process of intelligent control test for metal parts, it is difficult to track many metal parts for a long time due to environmental constraints. Therefore, the accuracy and validity of the algorithm are reflected by detecting the interference of multiple Parts' trajectories of unified equipment in the process of detection.

In the process of experiment, the test results are recorded and displayed by Prefix TP software. The part trajectory and correction intervention are taken as the experimental observation and recording targets. In the same environment and time range, the traditional algorithm and the algorithm in this paper are compared, and the trajectory prediction is taken as the goal to predict the trajectory. In the course of testing, it is found that the total number of trajectory points of mechanical metal parts is obviously larger than 24000000, which indicates that failure to correct the trajectory in time will lead to the verification of wear and deformation of metal surface. In order to ensure the accuracy of the experiment, the average time interval of acquisition trajectory data points is 20 seconds. After setting the experimental environment and parameters, the trajectory interference of the two algorithms is recorded, and the following figure is obtained.
It is not difficult to find that if the distance between the two trajectories is wider, the constraint of the algorithm on the trajectory of the part is insufficient and the degree of interference is too low, then it is difficult to ensure the accuracy of the part operation when the metal surface is damaged. On the contrary, the closer the trajectory curve is in the process of the experiment detection, the calculation is illustrated. The method has a relatively high degree of interference control over the Parts' trajectory, and it is not easy for the parts to deviate from the trajectory during operation, so the wear impact and deformation probability of the parts during operation are greatly reduced. According to the above principles, the results of comparative experiments show that:

- Different control algorithms for mechanical metal parts have different degree of interference to the trajectory of parts, so the effect of restraining part deformation is also different. Compared with the traditional target-level reservation data fusion principle prediction algorithm and the Internet of Things intelligent control algorithm for mechanical metal parts deformation can be replaced to restrain part deformation. Thus, the detection results of this algorithm can be seen. It is obviously superior to the traditional algorithm.

- In the process of detecting the two algorithms, it is difficult to detect the metal parts by single support vector because of the interference of external noise and environment, so the results of the test
are different from the real results, but the error of the experimental results is small, so it can be neglected.

- Although the results of the calculation method in this paper are obviously better than the traditional ones and meet the design requirements, due to the limitation of environment and technology level, it is still difficult to completely achieve the research goal of optimum restraint of mechanical metal parts deformation. Therefore, the algorithm still needs continuous optimization and improvement for the development of technology.

Compared with traditional algorithms, the proposed intelligent deformation control algorithm for mechanical metal parts based on Internet of Things can effectively reduce the serious wear and deformation caused by the deviation of trajectory during the operation of mechanical parts, overcome the shortcomings of traditional algorithms, and has higher practical application value.

4. Concluding remarks
With the rapid development of modern industrial technology, people have higher and higher requirements for production safety and production efficiency of mechanical industry. In order to meet people's requirements for safe production and improving modern industry, the intelligent control algorithm of mechanical metal parts deformation is studied by combining Internet of Things technology. Traditional metal parts deformation algorithm is mainly based on the principle of target-level reservation data fusion. Although this method can accurately obtain the operation parameters of mechanical parts and equipment, it is relatively complex and cumbersome, and the calculation process is prone to errors, so it is difficult to meet the research requirements. Therefore, based on the traditional method, the analysis and research are carried out, combining the fuzzy algorithm and human beings. Artificial ant colony algorithm (ACO) is used to set up the intelligent control method for parts. Through extracting the wear degree and trajectory parameters during the operation of parts, the control algorithm is optimized by synthesizing the characteristics of relevant parameters. Finally, the experiment proves that the algorithm has higher practical value than the traditional algorithm.

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