# Predictive Study of Uniformity of Variable Frequency Microwave Heating Based on PSO-SVM

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## 1. Introduction

Microwave heating is widely used in industrial production and daily life due to its high efficiency and energy-saving characteristics. However, uneven heating can lead to the proliferation and survival of harmful organisms, thereby causing food safety issues. This article proposes a method of using PSO to improve SVM model for predicting the uniformity of variable frequency microwave heating. Compared with the original SVM model, the prediction accuracy is greatly improved, providing new ideas for subsequent research on variable frequency microwave heating.

## 2. Prediction Model for Uniformity of Variable Frequency Heating Based on PSO-SVM

The fixed hot spot position generated during heating at a fixed frequency (2.4-2.5GHz), continuous heating will cause a greater temperature difference between the cold and hot spots, and the temperature uniformity of the material will continue to deteriorate. This study set the heating duration to 20 seconds and the step size to 2 seconds. Suitable frequencies were selected for each step size (with a step size of 0.01 GHz within 2.4-2.5 GHz), and the selective heating characteristics of variable frequency heating were utilized to move the hot spot position to the cold spot, thereby balancing the temperature difference of the material. The final frequency conversion curve is shown in Figure 1:

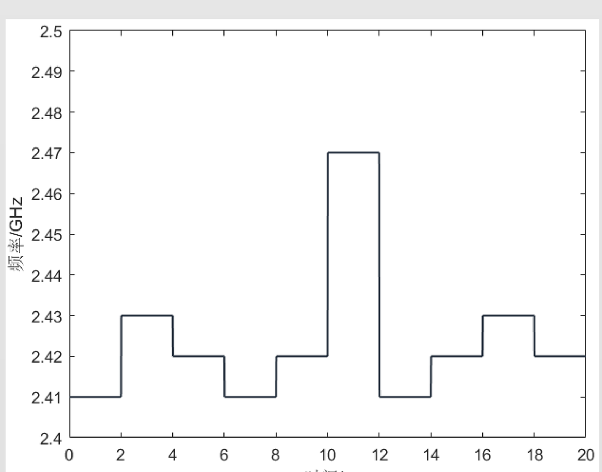

**Fig. 1.** Variable frequency curve

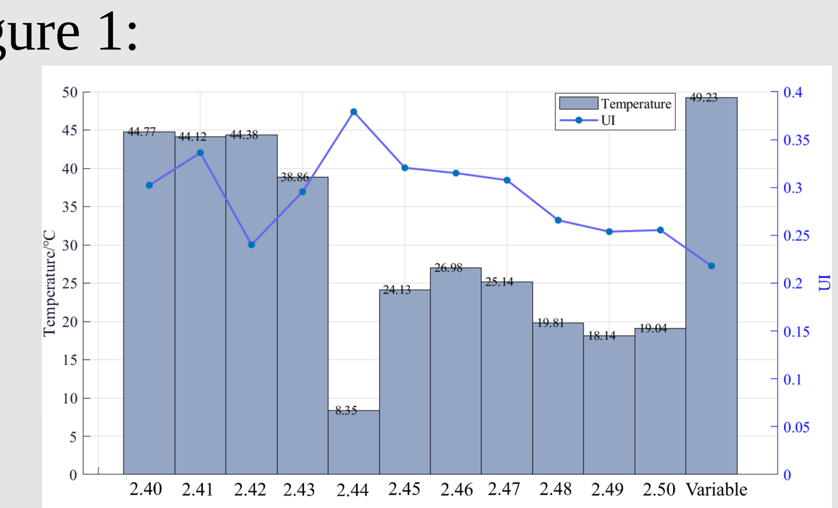

**Fig. 2.** Comparison of heating results

The heating results obtained by the frequency conversion strategy in Figure 1 are shown in Figure 2. From Figure 2, it can be concluded that the UI data is better than fixed frequency heating (2.40-2.50 GHz), and the uniformity is improved by 9.23% -42.5% compared to fixed frequency heating. The heating efficiency is improved by 4.46-40.88 ℃, proving that the frequency conversion strategy helps to improve heating uniformity.

For the data samples of variable frequency microwave heating, the SVM regression method aims to establish an optimal hyperplane, classify the positive and negative samples, and maximize the edge distance between the two. The penalty factor *c* and kernel function parameter *g* play a decisive role in the performance of SVM classifiers. The particle swarm optimization algorithm is used to optimize the selection of SVM parameters *c* and *g*. Construct a variable frequency microwave heating uniformity prediction model based on the PSO-SVM algorithm, and obtain the flowchart shown in figure 3:

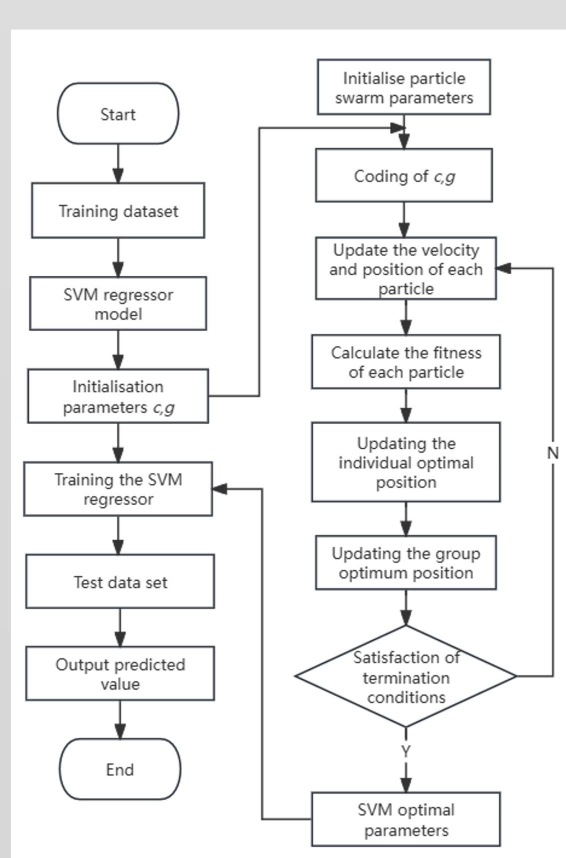

**Fig. 3.** Figure 4. Flow chart for predicting the uniformity of variable frequency microwave heating based on PSO-SVM

## 3. Experimental Results

If using empirical methods to test frequencies one by one within each step size is time-consuming and inefficient, utilizing the powerful learning ability of machine learning can quickly and accurately obtain the uniformity UI of microwave heating results for different frequency shift sequences. The average time taken by the finite element method is 652 seconds, while the method proposed in this article takes 38 seconds. This study uses MATLAB programming language to implement a prediction model for the uniformity of variable frequency microwave heating. Firstly, the sample data of variable frequency microwave heating is imported into the support vector machine (SVM) model for machine learning. Then, the support vector machine (PSO-SVM) optimized by particle swarm optimization is used to import the sample data into the model for machine learning. Multi-source information fusion is carried out on the temperature uniformity index parameters of variable frequency microwave heating, to accurately predict the frequency shift microwave heating change law of the entire process of heat conduction in the reaction chamber. Divide 1120 sets of data into an 85% training set and a 15% testing set. In PSO, the learning factors c1 and c2 respectively change the maximum step size for particles to move towards individual and population optima, set to 1.5 and 1.7, set the population size to 10, and set the maximum number of evolutions to 100. The range of variation of c and g in SVM is [0.1, 100].

Using RMSE and MAE as indicators to evaluate the trend of changes between the predicted values of the model and the actual measured values, the expression is:

$$RMSE=\sqrt{\frac{1}{n}\sum_{i=1}^{n}(\hat{y}_i-y_i)^2} \tag{1}$$

$$MAE=\frac{1}{n}\sum_{i=1}^{n}|\hat{y}_i-y_i| \tag{2}$$

Where: n is the total amount of measurement data, and are the actual and estimated values of microwave heating uniformity UI at time t, respectively. As a comparison the original SVM model was used to predict the UI as well, see figure 4.

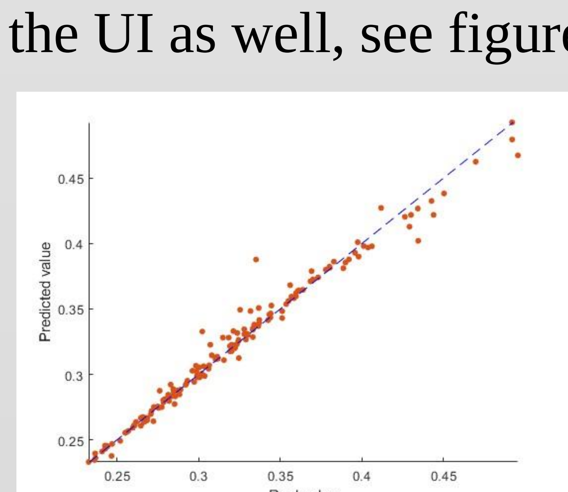

**Fig. 4.** Test set prediction results based on SVM

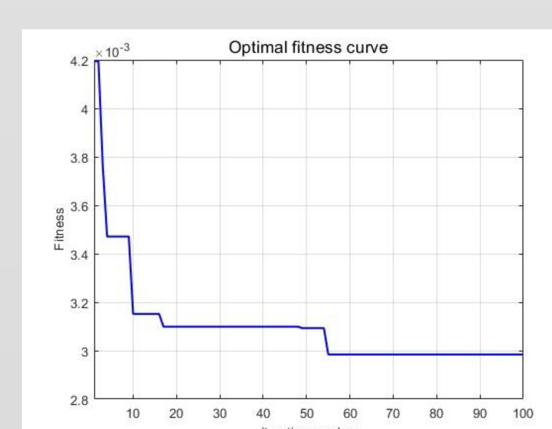

**Fig. 5.** Fitness curve

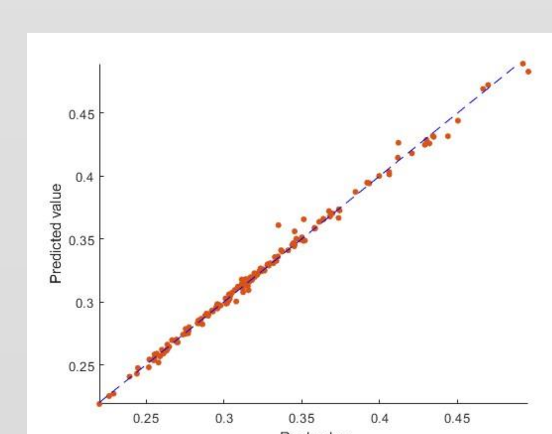

**Fig. 6.** Test set prediction results based on PSO-SVM

In PSO-SVM, the particle swarm algorithm can find the optimal parameter combination after approximately 54 iterations, and the fitness curve is shown in figure 5. The comparison between the predicted and actual values of the test set of the PSO-SVM based variable frequency microwave heating uniformity prediction model is shown in figure 6.

As can be seen in figure 6, the PSO-SVM prediction model has a very good prediction effect on the uniformity of inverter microwave heating, and the majority of the data are accurately predicted, except for some data with a slight error. Its RMSE reaches 0.0044, which is 51.65% higher than the 0.0091 of the SVM-based model, and similarly, the MAE increases by 50% from 0.0027 to 0.0054. The optimization effect of PSO-SVM is very obvious, and the two models can predict the UI more accurately in most cases, with PSO-SVM obtaining a better fitting effect.

## 4. Conclusion

Choosing the appropriate frequency sequence can effectively improve the uniformity of microwave heating. It is time-consuming and laborious to test each frequency in the finite element method, and using the PSO-SVM model can quickly obtain the uniformity index value.

(1) The variable frequency heating of microwave has improved the uniformity by 9.23% -42.5% compared to fixed frequency heating, and the heating efficiency has increased by 4.46-40.88 ℃, proving that the variable frequency strategy helps to improve the heating uniformity.

(2) The variable frequency microwave heating uniformity prediction model based on PSO-SVM can quickly and accurately obtain UI values, and PSO-SVM has a better fitting effect than the SVM model.