

Unified Expert Database of Aluminium Alloy Welding Based on Matlab Curve Fitting

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Abstract. In this article, curve fitting is conducted on the original data of aluminum alloy via matlab. Then, to find out a fitting curve with optimal effect, comprehensive analysis is made on the judgement quantitative index of curve fitting. The wire feed rate of other given current is obtained with such fitting curve so as to complete unified expert database. At last, aluminium alloy welding test is conducted in the multifunctional and digital welding machine developed by the laboratory. The test result shows that the expert database generated by 8-order fitting curve can meet the requirement of wire feed rate under the condition of random given current and within the scope of welding current. The unified regulating function is realized as a result.

1. Introduction

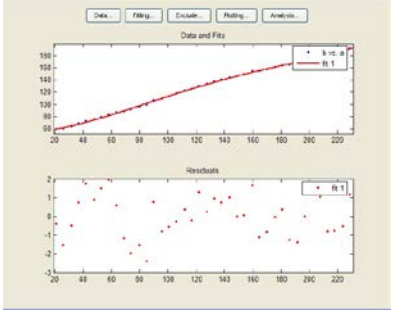
As embedded system has become increasingly powerful and is constantly applied into the area of arc welding power source, welding technology has also entered into the multifunctional digital era in a rapid manner. The core technology of multifunctional digital welding machine lies in the unified expert database, which is integrated with various welding materials, wire diameters, and welding manners. Expert database is regarded as the core of multifunctional digital welding machine, and whether its design is rational or not will directly influence the welding technology. Thus, it is of great significance to debug the optimum matching relation of each parameter via matlab curve fitting, so as to establish a unified expert database that can be readjusted continuously.

2. Unified Algorithm of Expert Database Curve Technological Parameter Curve Fitting

The welding of aluminium alloy has low requirement on the intensity and hardness of aluminium wire, but demands a lot in the sensitivity of wire feed rate. Thus, it is very important to match the wire feed rate and given electricity. Due to the fact that accidental error exists in original data acquisition, the test data is shown in the two-dimensional surface in the form of discrete points. To obtain a complete and continuous curve diagram with well-matched welding current and wire feed rate, curve fitting can be adopted to impend over the test data according to merger result acquired from the discrete data. Based on this diagram, find out wire feed rate that is corresponding to the respective current, and establish unified database.

The MATLAB Curve Fitting Tool interface is a visualized graphical interface with powerful graphic fitting function and powerful curve fitting tool, which can be applied into the curve fitting of various complex models. Exponential fitting, Fourier fitting, Gaussian fitting, Polynomial fitting are included in Type of fit. On the premise of enough fitting precision, this article adopts simple and clear Polynomial fitting.

With Curve Fitting Tool, the selection of certain order curve fitting can generate intuitive curve fitting effect and residual plot. Complete polynomial fitting equation, evaluation indexes of fitting effect, such as SSE, R-square, will be listed in the results of the Fitting interface, as shown in Fig.1.

	<pre> Results Linear model Poly4: f(x) = p1*x^4 + p2*x^3 + p3*x^2 + p4*x + p5 Coefficients (with 95% confidence bounds): p1 = 1.128e-007 (7.5e-008, 1.506e-007) p2 = -6.071e-005 (-7.972e-005, -4.17e-005) p3 = 0.01045 (0.007183, 0.01372) p4 = 0.03048 (-0.1902, 0.2511) p5 = 54.7 (49.95, 59.44) Goodness of fit: SSE: 46.61 R-square: 0.9993 Adjusted R-square: 0.9992 RMSE: 1.154 </pre>
(a) Curve Fitting Effect Diagram and Residual Plot	(b) Polynomial Fitting Equation and Evaluation Index

The quantitative criteria of the judgement of MATLAB fitting toolbox on curve fitting are as follows:

R-square multiple correlation coefficient, explains the degree of data variation. The value range is 0~1. If the value is closer to 1, it indicates that the variance explained by the curvilinear model will be better.

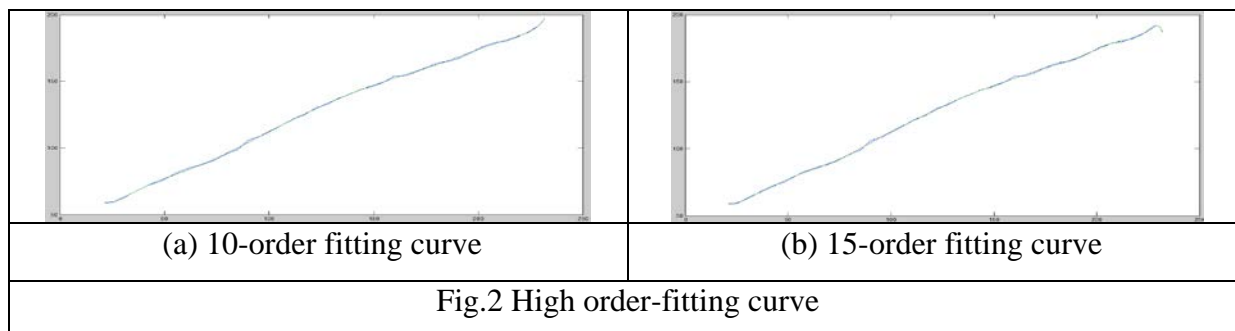
Adjusted R-Rsquare: residual's square after adjusting the degree of freedom. The value range is 0~1. If the value is closer to 1, it indicates that the linear fitting effect of the curve will be better.

RMSE fitting standard deviation, or radical's mean-square error, is an estimation of random component standard deviation in data, reflecting the error of fitting. The smaller RMSE is, the error controlling ability of curve fitting will be higher.

3. Analysis of Curve Fitting Effect

3.1 Exclude Runges Phenomenon Fitting Curve

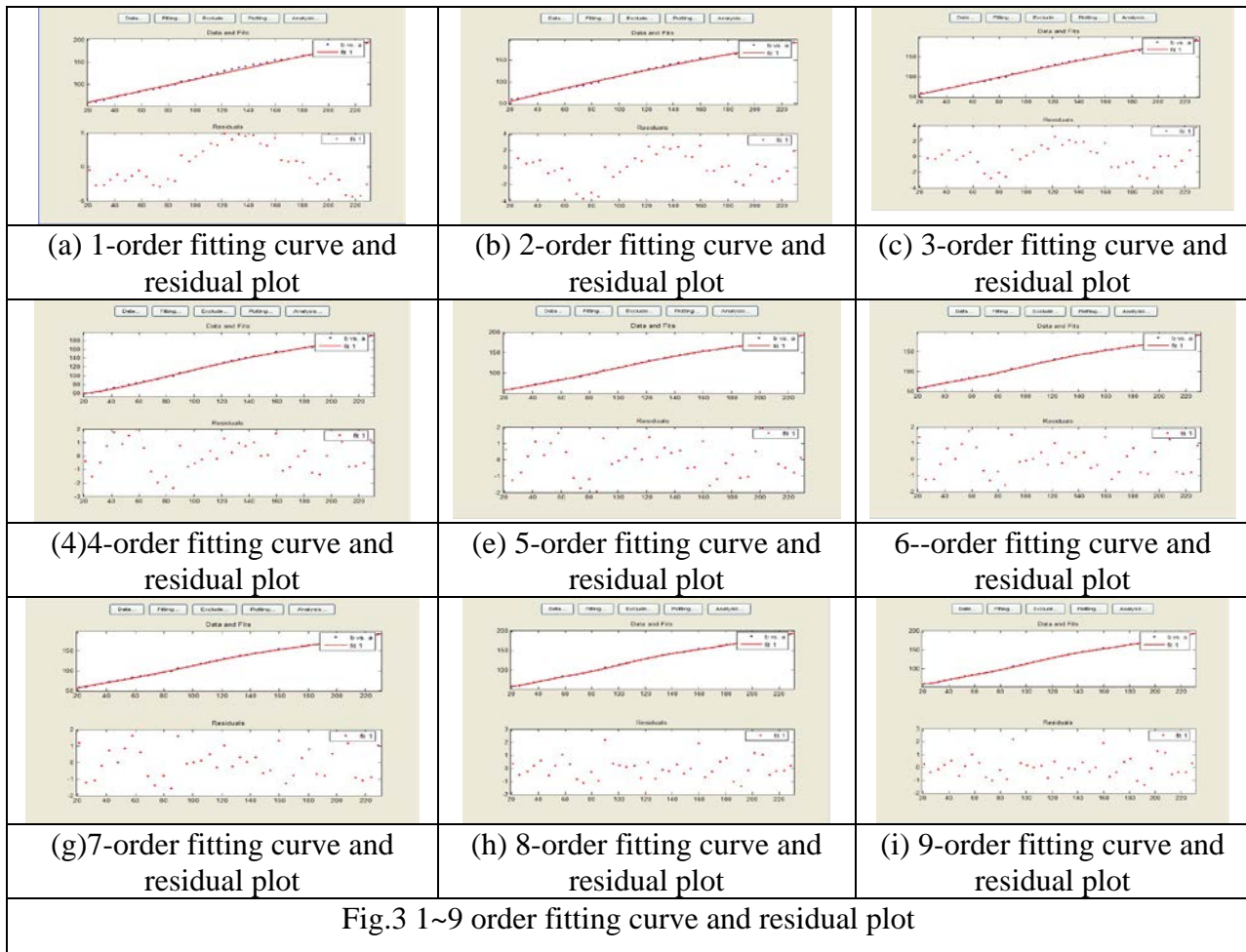
Different orders of fitting curve are conducted on raw data with MATLAB platform. As shown in the fitting result, when the order number is 10, evident Runges phenomenon will appear at the end part, and distortion exists in data fitting. With the increase of fitting curve orders, the distortion of fitting curve will be increasingly severe as shown in Fig.2.



Thus, fitting curve result of 10-order or above are abandoned. With MATLAB Curve Fitting Toolbox, fitting curves of 1-order to 9-order are only needed for drawing. Select the best fitting curve by comparing the indexes of fitting result of each curve fitting.

3.2 Analysis of Curve Fitting Result

By applying the Curve Fitting Tool of MATLAB platform, the corresponding residual plots of fitting curves of 1-9 order based on the raw data are obtained as shown in Fig.3. Fitting curve reflects the fitting effect of different-order curves; if the points of residual plot are closer to the centre shaft, the curve fitting effect will be better.



As shown in the diagram, 1-order fitting curve has strong rigidity, and many of the generated fitting results have deviated from the original point, resulting in a larger error. The points distributed in residual plot also have severe shocks. With the increases of fitting orders, the fitting result gradually draw near to the raw data.

To accurately analyze and compare different orders of curve fitting effect, quantitative curve fitting index is tested and table is made for analysis. By applying the Curve Fitting Tool of MATLAB, R-square、 Adjust-square and RMSE index that are generated by different orders of fitting curve will be obtained, and are arranged as shown in Tab.1.

As shown in the evaluation indexes of curve fitting from 1-order to 8-order in Tab.1, the multiple correlation coefficients will move to 1 with the increase of order sequence. The adjusted R-square will also tend to 1 gradually, while the fitting standard deviation RMSE shrinks gradually, indicating that with the increase of order sequence from 1-order to 8-order curve fitting, if the linear fitting and error control of the curve fitting is better, the curve of fitting result will draw near to the true value gradually.

Tab.1 Curve Fitting Evaluation Index Table

Orders of Curve Fitting	R-square	Adjusted R-square	RMSE
1-order	0.9952	0.995	2.856
2-order	0.9981	0.998	1.804
3-order	0.9985	0.9984	1.629
4-order	0.9993	0.9992	1.154
5-order	0.9994	0.9993	1.059
6-order	0.9995	0.9994	1.005
7-order	0.9995	0.9994	1.016
8-order	0.9996	0.9996	0.8588
9-order	0.9996	0.9995	0.8675

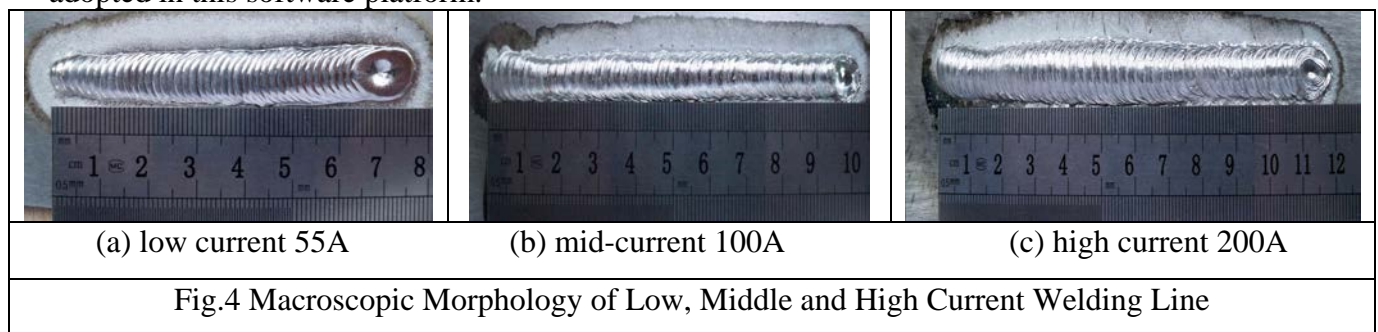
The Adjusted R-square of 9-order fitting curve is smaller than that of 8-order fitting curve, indicating that its linear fitting effect is worse than that of the 8-order fitting curve. In the meantime, the RMSE index of 9-order fitting curve is greater than that of 8-order curve fitting, indicating that its error control ability is worse than that of 8-order fitting curve.

By analyzing residual error, the rule of periodic system error will be easily discovered. In the meantime, residual error can be applied for regression diagnosis. In “residual plot”, the independent variable is served as the horizontal coordinate of independent variable, and residual error is taken as the vertical coordinate. The residual error of each independent variable is drawn in the plane coordinate and a graph is formed, which can reflect the curve fitting effect directly. If the points are randomly scattered around the straight line in which the residual error is equal to 0, it indicates that the matching condition of regression line on the matching condition is sound. In contrast, the regression line has an unsatisfactory fitting on the original observed value. It can be observed from the residual plot in Fig.3, the random distribution condition of above 5-order residual plot is better than that of residual plot below 5-order, indicating that the fitting effect of above 5-order is better.

To sum up, after excluding the fitting curves which are above 9 orders with evident Runge phenomenon, and after the evaluation of three curve fitting indexes, it summarizes that 8-order fitting curve has best effect. To adopt 8-order fitting curve, welding current can be adjusted as the independent variable. By using MATLAB platform, the corresponding wire feed rate with high precision can be easily obtained. Unified data is imported for generating complete and continuous expert database. After the test experiment, it can be regarded as a stable and reliable unified expert database.

4. Experimental Result and Analysis

Multifunctional and digital welding machine which is developed by the laboratory is adopted in the test. The modulation frequency of dipulse LF is 2.5Hz; the adjustable range of welding current: 50A ~ 300A. Test piece: 2mm~12mm aluminium; $\Phi 1.2$ mm ER4043 Al-Si Alloy Welding wire is adopted; shielding gas: 99.99% high-purity argon; gas flow: 15 L/min; extension of welding stick: 12mm; board surfacing welding. The complete expert database generated by 8-order fitting curve is adopted in this software platform.



During the welding process, the stick stretches in a stable rhythm; the low-frequency noise is gentle; no current interruption burn-back, and jackscrew phenomenon; few splashing or undercut phenomenon in welding; the welding line is beautiful with clear figure of fish scale. It is worth mentioning that the low current range (50A~100A) of such design solution can totally realize free-splashing, bright welding line and sound welding line. Due to large current is characterized by large output energy, fast wire feed rate and more severe weld pool, water-cooling gun is recommended for better effect. Fig.4 (a), (b), (c) is the welding macroscopic morphology of low current 55A, mid-current 100A and large current 200A respectively.

The test result shows that the expert database generated by 8-order fitting curve can meet the requirement of wire feed rate under the condition of random given current and within the scope of welding current. The unified regulating function is realized as a result. It fully proves the effectiveness and reliability of curve fitting on disperse data fitting, saving the development cost of expert database as a result.

5. Conclusion

To develop dipulse MIG welding expert database, the application of Curve Fitting Tool of MATLAB toolbox can fit the raw data into a smooth curve with high precision. By evaluating the quantitative curve fitting index on fitting effect, optimum fitting curve will be obtained. The optimal matching of given current and wire feed rate are obtained for effective expert database. The test result shows that the expert database generated by 8-order fitting curve can meet the requirement of wire feed rate under the condition of random given current and within the scope of welding current. The unified regulating function is realized as a result.

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