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Estimating Impact Strength and Flexural Strength of Vibratory Dissimilar Welded Joints using Machine Learning Technique

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Abstract

This paper explores the validation of generated equation through regression analysis for the weld joints mechanical properties were produced under vibratory weld technique. This type welding process yields the uniform and fine grain configurations due to dynamic solidification in the weld pool, which in turn enhances impact strength and flexural strength of the weldments. In this investigation, frequency of vibration has been considered as input parameter and impact strength and flexural strength as output parameters in order to develop the regression equation for estimating impact strength and flexural strength of vibratory dissimilar welded joints. The regression technique has predicted the results for the mechanical properties with an accuracy of around 98%. And identified the developed regression equation is valid for the current application with experimental work. A new approach termed regression technique has been applied and the results for the mechanical properties proved an accuracy of around 98%.

Key words: Vibratory welding, frequency, impact strength, flexural strength and regression technique

1. Introduction

Regression is one of the Machine Learning techniques for finding functional relationships between variables. The relation between the variable is given in the form of model linking the dependent variable and predictor variables or in the form of an equation. In the present process, input variable is frequency at which the specimens to be welded and output variable is mechanical property. With these dependent variables regression equations have been developed for impact strength and flexural strength of weldments with respect to frequency at which the specimens to be vibrated.

The dependent variables is denoted as Y variable response and the independent variables by $X_1, X_2, \ldots, Xp$, where p states the independent variables number. The actual relationship between Y and $X_1, X_2, \ldots l \ldots, Xp$, may be estimated with regression technique as in (1).

$$Y = f(X_1, X_2 \ldots, Xp) + \epsilon_1 \quad (1)$$

where E is presumed to a random error presenting the variance in the approximation. It is accounted for the failure of the model to fit the data with exactness. The function $f(X_1, X_2, \ldots, Xp,)$ gives the relationship between Y and $X_1, X_2, \ldots, Xp$. Further, example is given as model for linear regression

$$Y = \beta o + \beta_1 X_1 + \beta_2 X_2 + \ldots + \beta_p X_p + \epsilon_1 \quad (2)$$

Where βo, $\beta_1 \ldots, \beta p$ are referred to as the regression coefficients, square measure unknown constants to be found from the info. it's followed that it's used notational convention of representing unknown parameters by Greek letters.

The freelance variables are named by different names like predictor variables, factors, carriers and regressors. The name experimental variable, though sometimes used that it's the smallest amount most well-liked, owing to it's in apply the predictor variables might not be typically freelance of every different.

P.GovindaRaoet al., [1,2]developed setup of vibratory welding experimental system for improving the welded joints properties. From last few decades, moving techniques in attachment are utilised for mechanical properties improvement of weldments. Past experimental results shows that the specimens welded below exciting conditions exhibits increased mechanical properties than regular arc attachment processes. during this gift experimental work, moving attachment set-up ready for introducing mechanical excitations throughout the operation of attachment. The designed experimental set-up generates the desired acceleration and amplitude with frequency in terms of voltages. within the gift investigation, take a look at specimens were ready by sterilization the input parameters i.e, time of vibration and voltage. and also the alternative method parameters are kept constantlike current, speed, traveland other electrode parameters. Refined microstructure is studied with metallurgical propertiesand identified improved properties withspecimens welded with vibratory setup. The fine grain structure is the main reason for the enhancement in hardness, impact strength, tensile strength and flexural strength. Rao P. G. et.al.,[3]reported that pastresearches are introduced for development of vibratory setup for causing mechanical vibrations into the weld pool throughout fastening technique.The designed vibratory setup produces the desired frequency with acceptable amplitude and acceleration in terms of voltages. This helps in producing uniform associate degreed fine grain structure inside the welded joints that ends in an improvement inside the mechanical properties of the weldments at heat affected zone. This paper presents the event of a wise prediction tool by implementing generalized regression neural network to work out a relation between vibration parameters like input voltage to the vibromotor, time of vibration and impact strength of vibratory weld joints. Thus on validate the developed prediction tool, a comparison is created with the experimental results.

P. G. Rao et al., [4] designed a vibratory table that generates the desired frequency along with appropriate acceleration and amplitude as voltages. This gives in manufacturing a consistent and structure with fine grain within the joints, which ends in associate degree enhancing of strength of joints. This paper shows the introducing of Generalized Regression Neural Network (GRNN) to determine a relation of the vibration parameters (like input voltage, vibration time, and bending strength of joints. so as to analyze the feasibleness of the produced prediction equation, a analysis is formed with experimentally produced results. Govind Rao et al., [5] stated that vibration techniques are employed in attachment for raising the metals mechanical properties within the previous couple of years. Within the work moving setup used for causation the mechanical excitations to weld pool throughout attachment. The manufactured exciting setup generates the required frequency with acceleration and amplitude of voltages. With flexural strength of weld pieces at HAZ has noted. The improved properties is analyzed, during the solid state of weld pool, the grains don't seem to be solely restricted in size. However, additionally the dendrites area unit breaks down into smaller size. Fine microstructure has determined. The higher than mechanism of the machine is accountable for advance in weldments flexural strength with exciting setup differentiated with while non-vibration throughout attachment.

Kalpana. J et al., [11, 22] presented data of GRNN to ascertain a relation between parameters of vibration and weldments properties. Throughout the welding at the side of mechanical excitations, uniform grain structures are created. This will improves hardness and toughness of metals, as a result surface of weld pool affected. So, manual experiments are done on the homogenized joints by giving excitations to the entire process. Voltage accustomed generates the excitations and therefore the vibration time is employed as one of the parameters. Hardness of joint is taken into consideration together of the properties of the joint.

P.G.Rao et al., [6] reported that vibration techniques are employed in joining for enhance the properties of the welded pieces within previous couple of years. Within the effectiveness of work the vibrating design is used for causing mechanical shaking during welding. The manufactured exciting setup generates the required frequency with acceleration and amplitude of voltages. With impact strength of weld pieces at HAZ has noted. The rise in properties is identified, grains aren't solely restricted in size however conjointly. Fine microstructure has determined. The higher than mechanism of the machine is accountable for advance in weldments impact strength with the exciting model and differentiated with the while non-vibration throughout attachment.

Rao.P.G.et.al.,[7] stated that the internal stresses in the specimens structures made by vibrating welding method has been mentioned. Material properties, structural and material manufacture mathematics, regression method; treatments when welding and repair conditions are thought of to analyze internal stresses distributions. Weld protective cover area unit the most effective examples to analyze residual stress distributions. Entire producing and repair processes of the vibrating joined structure and about its element area unit needed for higher understanding and analyzing the development in prediction and reduction of residual stresses. Microstructure of may be refined once the welded joints ready with the presence of vibration. During this study, mechanical excitations or vibrations got to the weld test specimens throughout welding for distinctive its impact on the hardness, science structure and residual stress of the fabric. Residual stresses were found to diminish in response to vibration whether or not it had been applied throughout welding or when welding. Additionally, grain growth method within the weld was exaggerated.

Rao P. G. et al., [8] mentioned that vibration techniques are utilized in joining for raising the properties of specimens within the previous couple of years. Within the effectiveness of work the vibrating design is used for causing mechanical shaking during welding. The manufactured exciting setup generates the required frequency with acceleration and amplitude of voltages. With impact strength of weld pieces at HAZ has noted. The rise in properties is identified, grains aren't solely restricted in size however conjointly. Fine microstructure has determined. The higher than mechanism of the machine is accountable for advance in weldments impact strength with the exciting model and differentiated with the while non-vibration throughout attachment. Rao P. G. et al., [9] reported that welded joints square measure utilized for development of the many structures. And Welding could be a change of integrity that induces more internal stresses, this is powerfully influencing the service characteristics of the welded joints. Antecedently a number of ways like peening and heat treatment techniques were identified for minimizing internal stresses. Those ways would like instrumentality and square measure time intense. We have a tendency to square measure explaining a brand-new methodology for minimizing internal stresses victimization excitations throughout welding. Mechanical excitations are going to be treated as load of vibration. During these processes, FEM are going to be used for analyze of welding stresses and comparison of manual results with FEM results welded joints.

Rao P. G. et al., [10] improved mechanical properties of steels, vibration techniques are utilized in the previous few decades. Throughout the joining process of specimens together with mechanical shakings, uniform grain structures will be made. It will increase the properties of metals, due to natural action effects at the weld pool surface. Because the weld pool solidifies, grains aren't solely restricted in size, however dendrites growing perpendicular to the fusion line area unit restricted. Whereas the method goes on, dendrites will be variable before they grow to become massive in size. Hence, the SEM analysis of the weld joints of specimens is enhanced throughout the solidifying process. During this work, we tend touse a dynamic natural action technology, by applying mechanical vibrations throughout the 'Arc welding' method. Analyses are administered for steel items having five metric linear units of thick butt joints. The results obtained from the present study observed that the butt welded joints made-up with vibrating condition area unit found to possess comparatively high hardness, with none considerable loss in its malleability.

J.Kalpana et al., [12] presented the amplitude result on enduringness of welded joints created with vibrating dissimilar TIG (Tungsten Inert Gas) welding method. During these processes, noval vibrating design has developed with the couple of engravers of metal for incurring of mechanical vibrations to specimens. Metal engravers area unit capable to provide completely different amplitudes of specimens by adjusting the knob provided on the metal engravers. Finally, analysis has been meted out on the result of vibration amplitude on enduringness of welded joints.

Rao et al. [13-33] proposed dynamic natural process technique throughout welding is projected to prompt the vibrations throughout fastening of welded joints. Butt welded specimens organized below vibrating parameters obtained the improved properties like hardness. Authors used the vibrating design to have an effect on the mechanical vibrations to the weld pool. Owing to vibrating fastening method, amendment of the properties has ascertained. Refined microstructure of specimen was answerable for amendment of mechanical properties of butt-welded joints. Past authors ascertained that post weld vibrating treatment won't influence the crystal structure, the rise all told properties area unit associated with the crystal structure solely. Finally, GRNN based tool has been developed for analyzing the mechanical properties for given input parameters. GRNN could be the well-tried prediction tool which is applied for the numerous producing applications together with fastening.

Dutta and Dilip [34] a standard regression supported experimental information of a TIG welding method, to search out its input-output relationship. an oversized information for neural network was created indiscriminately, by varied the input parameters inside several vary and results were calculated for every combined form of input parameters by the equations of response through the standard multivariate processes. The behaviour of the traditional multivariate approach, a (BPNN) back propagation neural network and a genetic-neural system (GA-NN) were differentiated on similar arbitrarily obtained data by experiments, that area unit totally different from the coaching cases.

Ganjigatti et al., [35] made a trial to determine input and output relationship during MIG fastening method through the processes of regression analyses meted out each globally still as cluster. It is necessary to say that another approach build used based on entropy mostly the fuzzy cluster. The entire process of this investigation was supported the information grabbed through experimental data. Results of greater than the two approaches were differentiated and also the equation wise multivariate analysis was done to perform a rather higher than previous approaches in estimated weld bead pure mathematics parameters.

Campbell et al. [36] used artificial neural network for estimated of key weld geometries exploitation GMAW. A comparison showed that the experimental and also the expected geometries were matched closely.With the exist the literature describes the development of enhancing the weld joint properties, the relation between weld joint mechanical properties and vibration parameters haven'tbeen developed. Thus this work is focused for building a relation between weld joint mechanical properties and vibration parameters. Finally, multivariate analysis has been accustomed build this model.

2. Regression Equation for Impact Strength

In the present case, frequency treated as the input parameter (X_1) and the Impact Strength (Y_2) as the output parameter. Hence, Impact strength of 1storder equation is as in (3):

$$\boldsymbol{Y_2} = \mathbf{C(0)} + \mathbf{C(1)} * \boldsymbol{X_1} \tag{3}$$

Where C(0)=222.683344736, C(1)=0.150256889016 are coefficients and correlation coefficient is 0.999705890589 and Standard error about the line = 0.46832785658.

For developing above equation, two sets of data are required for regression analysis: training data set and validation data set. From the prepared welded joints of 21, 17 sets are chosen randomly for training while the rest of them, 4 in numbers, are taken for validation. The training data set and the validation data set including percentage of error deviation are given in Tables 1 and 2 respectively.

Table 1 Training data set with Error Deviation for Impact Strength

Expt. No	Frequency (Hz)	Impact Strength (Joule)	Impact Strength from Regression (Joule)	% Error Deviation
1	600	312.87	312.837478	0.010395
2	620	315.87	315.842616	0.008669
3	640	318.96	318.847754	0.035191
4	680	324.87	324.858029	0.003685
5	700	327.87	327.863167	0.002084
6	720	330.96	330.868305	0.027706
7	740	333.86	333.873443	-0.00403
8	780	339.96	339.883718	0.022438
9	800	341.87	342.888856	-0.29802
10	820	345.15	345.893994	-0.21556
11	840	349.13	348.899132	0.066127
12	860	352.42	351.904269	0.14634
13	900	358.56	357.914545	0.180013
14	920	361.37	360.919683	0.124614
15	940	364.12	363.92482	0.053603
16	960	367.12	366.929958	0.051766
17	1000	372.13	372.940234	-0.21773

Table 2 Validation data set with Error Deviation for Impact Strength

Expt. No	Frequency (Hz)	Impact Strength (Joule)	Impact Strength from Regression (Joule)	% Error Deviation
1	660	321.97	321.852891	0.036372
2	760	336.97	336.87858	0.02713
3	880	355.35	354.909407	0.123988
4	980	370.56	369.935096	0.168638

The deviations in the output values predicted by regression analysis for the training data set and the validation data set are graphically represented in Figure 1 and Figure 2 respectively.

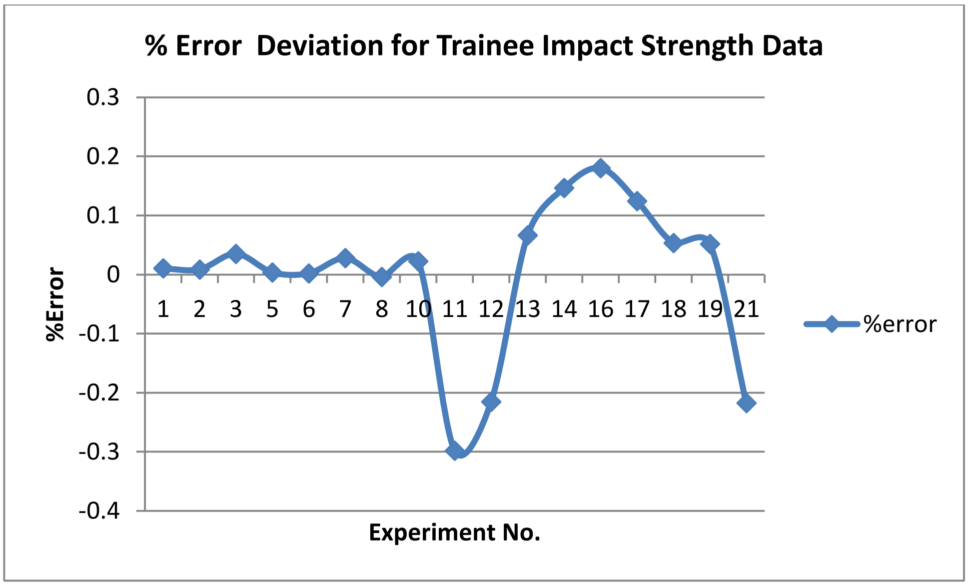

Figure 1Error percentage of training dataset for impact strength

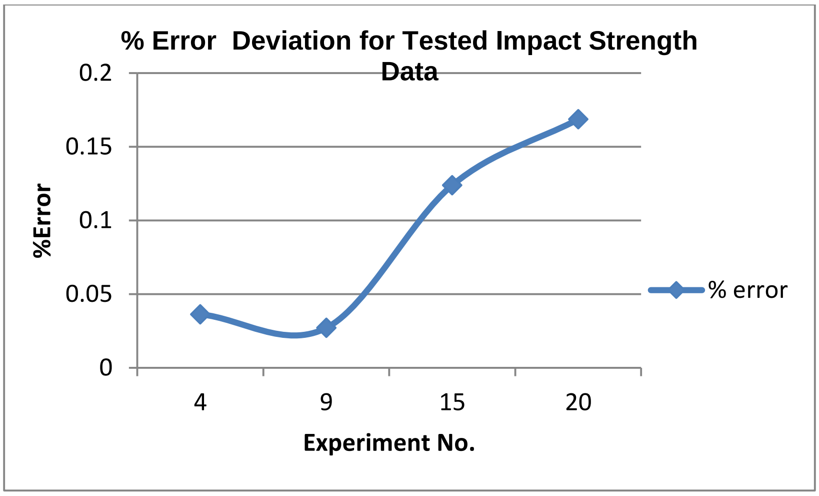

Figure 2Error percentage of validation dataset for impact strength

The proposed regression equation for impact strength has predicted the values with 99.6% accuracy for the training dataset implying that the deviations from the actual values fall within ±0.4% limits. The validation data set is predicted with 99.82% accuracy making regression a worthy equation for prediction of impact strength.

3. Regression Equation for Flexural Strength

In the present case, frequency treated as the input parameter(X_1) and the Flexural Strength (Y_3) as the output parameter. Hence, Flexural strength of 1st order equation is as in (4):

$$\boldsymbol{Y_3} = \mathbf{C(0)} + \mathbf{C(1)} * \boldsymbol{X_1} \quad (4)$$

Where C(0)=365.430186241, C(1)=0.144515298366 are coefficients and correlation coefficient is 0.999329940285 and Standard error about the line =0.680070973186

For developing above equation, two sets of data are required for regression analysis: training data set and validation data set. From the prepared welded joints of 21, 17 sets are chosen randomly for training while the rest of them, 4 in numbers, are taken for validation. The training data set and the validation data set including percentage of error deviation are given in Tables 3 and 4 respectively.

The deviations in the output values predicted by regression analysis for the training data set and the validation data set are graphically represented in Figure 3 and Figure 4 respectively.

Table 3 Training data set with Error Deviation for Flexural strength

Expt. No	Frequency (Hz)	Flexural Strength (Mpa)	Flexural Strength from Regression (Mpa)	% Error Deviation
1	600	452.53	451.92198	0.134361
2	620	455.45	454.80504	0.14161
3	640	458.56	457.6881	0.19014
4	680	464.58	463.45422	0.242323
5	700	467.02	466.33727	0.146188
6	720	468.85	469.22033	-0.07899
7	740	471.07	472.10339	-0.21937
8	780	477.34	477.86951	-0.11093
9	800	480.58	480.75257	-0.03591
10	820	483.34	483.63563	-0.06116
11	840	486.12	486.51869	-0.08202
12	860	489.76	489.40175	0.073148
13	900	495.17	495.16787	0.00043
14	920	498.45	498.05093	0.080062
15	940	501.89	500.93399	0.190482
16	960	504.98	503.81705	0.230296
17	1000	510.47	509.58317	0.173728

Table 4 Validation data set with Error Deviation for Flexural strength

Expt. No	Frequency (Hz)	Flexural Strength (Mpa)	Flexural Strength from Regression (Mpa)	% Error Deviation
1	660	461.56	460.571155	0.21424
2	760	474.23	474.986454	-0.15951
3	880	492.87	492.284812	0.118731
4	980	507.18	506.70011	0.094619

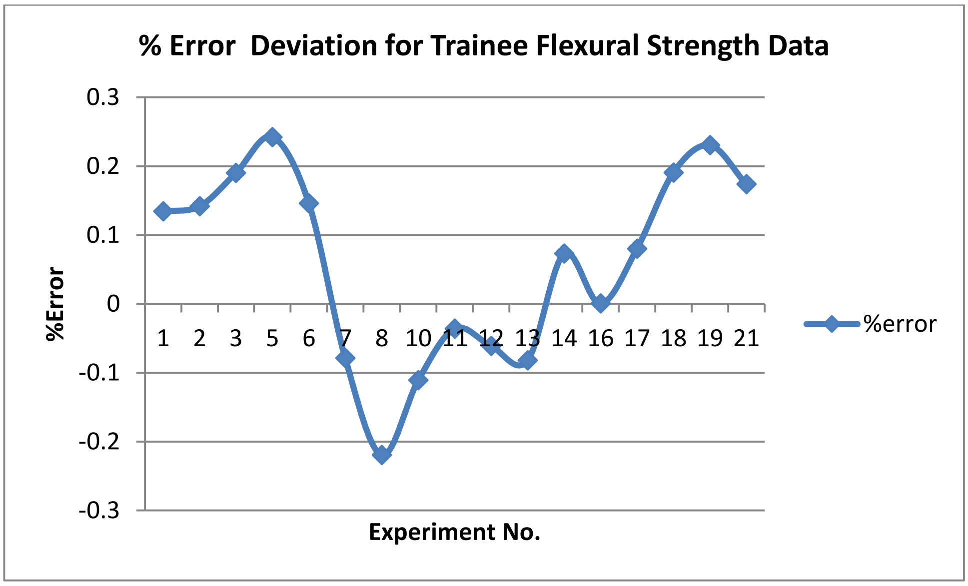

Figure 3 Error percentage of training dataset for flexural strength

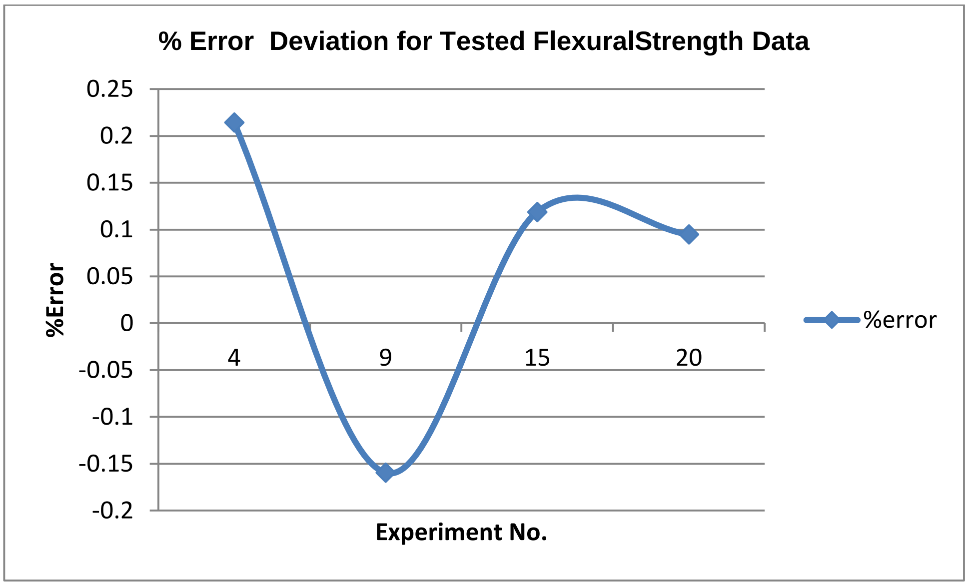

Figure 4 Error percentage of validation dataset for flexural strength

The proposed regression equation for flexural strength has predicted the values with 99.7% accuracy for the training dataset implying that the deviations from the actual values fall within ±0.3% limits. The validation data set is predicted with 99.75% accuracy making regression a worthy equation for prediction of flexural strength.

Conclusions

A regression technique has been used to show a relation between the chosen vibration parameter (frequency) and the mechanical properties impact strength and flexural strength of weld joints through vibrations. To validate the feasibility of the developed prediction tool comparison is made with the results of experimental data. The regression technique has predicted the results for the mechanical properties with an accuracy of around 98%. Hence, the developed equations are to be used to find unknown values of impact strength and flexural strength of weld joints without conducting actual tests.

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