# Properties of low carbon steel rods engineering essay

Engineering

Elsevier Editorial System(tm) for Materials and DesignManuscript DraftManuscript Number: Article Type: Original ArticleKeywords: (A) Ferrous metals and alloys, (D) Welding, Low Carbon Steel, Friction Welding, Tensile strength, ANOVA, Mathematical model. Corresponding Author: Dr. K Palanikumar, PhDCorresponding Author's Institution: Sri Sairam Institute of TechnologyFirst Author: K Palanikumar, PhDOrder of Authors: K Palanikumar, PhD, Selvamani S. T, M. E, Abstract: Joining of steels is faced with the problem of coarse grains in the weld zone and heat affected zone of fusion welds and consequent low toughness and ductility due to the absence of phase transformation during which grain refinement can occur. Carbon steels are prone to sensitization of their fusion welds. These problems have been addressed by solid state welding processes, such as friction welding. Because of the superior properties, it is pertinent to use carbon steels in various automotive, aerospace, nuclear, chemical and cryogenic applications. Continuous drive friction welding studies on carbon steel combination are attempted in this investigation. Friction welding method has extensively been used in manufacturing methods, because of the advantages such as high material saving, low production time and possibility of the welding of parts for a long time. Friction time, friction pressure, upset time, upset pressure and rotation speed are the most important, parameters in friction welding. The parameters are selected properly in the experiments, since these directly affect the welding quality. The present investigation attempts to understand the friction welding characteristics and the influence of process parameters which include Friction time, Friction pressure, upset time, upset pressure and rotation speed. This study also envisages the

Microstructure�" mechanical property correlation and analysis of scanning electron micrographs of the fractured surface of the welded joints is discussed

## Date: 20/11/2012

## To

The Editor-in-Chief,

## Materials and Design.

## Respected Sir,

Sub: Submission of manuscript-reg. Herewith I have enclosed the manuscript titled “ Analysing the effect of friction welding parameters on tensile properties of low carbon steel rods” to publish in your esteemed International Journal. I request you to kindly consider for publication. Also I declare that the submission is original and I have not submitted elsewhere for publication. Thanking you, Yours sincerely, K. Palanikumar

## Highlights

Low Carbon Steel rods are welded through Friction welding machine. Design of experiment is used for conducting the Friction Welding. Optimising Friction Welding Parameters To Maximize The Tensile Strength Of Low Carbon Steel JointsEmpirical relation is established between tensile strength and different input parameters. The microstructure of Friction welded Low Carbon Steel Rods are analysed using Optical Microscope.

# Analysing the effect of friction welding parameters on tensile properties of low carbon steel rods


## S. T. Selvamani

Research scholar, Department of Mechanical Engineering, Anna University, Chennai, Tamilnadu, IndiaDepartment of Mechanical Engineering, Vel Tech Multi Tech Engineering College, Chennai 600062, Tamilnadu, IndiaTel.: +91 9940540221; E-mail address: selva_balu@rediffmail. com

## K. Palanikumar

Department of Mechanical Engineering, Sri Sairam Institute of Technology, Chennai-600044, IndiaTel.: +91 44 22512111; Fax: +91 44 22512323; E-mail addresses: palanikumar@sairamit. edu. inpalanikumar_k@yahoo. com

## K. Umanath

Research scholar, Department of Mechanical Engineering, Anna University, Chennai, Tamilnadu, IndiaDepartment of Mechanical Engineering, Vel Tech High Tech Engineering College, Chennai 600062, Tamilnadu, IndiaTel.: +91 9840403231; E-mail address: umanath_me@rediffmail. com



# Analysing the effect of friction welding parameters on tensile properties of low carbon steel rods



## Abstract

Joining of steels is faced with the problem of coarse grains in the weld zone and heat affected zone of fusion welds and consequent low toughness and ductility due to the absence of phase transformation during which grain refinement can occur. Carbon steels are prone to sensitization of their fusion welds. These problems have been addressed by solid state welding

processes, such as friction welding. Because of the superior properties, it is pertinent to use carbon steels in various automotive, aerospace, nuclear, chemical and cryogenic applications. Continuous drive friction welding studies on carbon steel combination are attempted in this investigation. Friction welding method has extensively been used in manufacturing methods, because of the advantages such as high material saving, low production time and possibility of the welding of parts for a long time. Friction time, friction pressure, upset time, upset pressure and rotation speed are the most important, parameters in friction welding. The parameters are selected properly in the experiments, since these directly affect the welding quality. The present investigation attempts to understand the friction welding characteristics and the influence of process parameters which include Friction time, Friction pressure, upset time, upset pressure and rotation speed. This study also envisages the Microstructure�" mechanical property correlation and analysis of scanning electron micrographs of the fractured surface of the welded joints is discussedKeywords: Low Carbon Steel, Friction Welding, Tensile strength, Mathematical model.

# 1 Introduction

Friction welding is a process in which the heat for welding is produced by direct conversion of mechanical energy to thermal energy at the interface of the workpieces without the application of electrical energy or heat from other sources to the workpieces.

## R. G. ELLIS, Continuous drive friction welding of mild steel. Welding J. April, 183 (1972).

Friction welding is divided by two ways as continuous drive friction welding and inertia friction welding [2, 3]. In continuous drive friction method shown in Fig. 1, one of the components is held stationary while the other is rotated at a constant speed (s). The two components are brought together under axial pressure (Pf ) for a certain friction time (tf ). Then, the clutch is separated from the drive, and the rotary component is brought to stop within the braking time while the axial pressure on the stationary part is increased to a higher upset pressure (Pu) for a predeterminedupset time (tu).[2] W. Kinley, Inertia welding: simple in principle and application, Weld. Met. Fab. (1979) 585�" 589.[3] N. I. Fomichev, The friction welding of new high speed tool steels to structural steels, Weld. Prod. (1980) 35�" 38.

## 3 Experimental work

A large number of trial runs were carried out using 12 mm-dia extruded rod of low carbon steel to find out the feasible working limits of FW process parameters. The chemical composition and mechanical properties of low carbon steel are presented in Tables 1 and 2. Different combinations of process parameters were used to carry out the trial runs. This was carried out by varying one of the factors while keeping the rest of them at constant values. The working range of each process parameter was decided upon by inspecting the macrostructure (cross section of weld) for a smooth appearance without any visible defects. The Friction welding machine setup was shown in Fig. 1 which was used to fabricate the joints. The chosen levels of the selected process parameters with their units and notations are presented in Table 3. The extruded rods of 12 mm in diameter were cut into the required sizes (100 mm length) by power hacksaw cutting machine. The design matrix chosen to conduct the experiments was a central composite face centered design, which is listed in Table 4. An indigenously designed and developed machine of continuous drive friction Servo controlled Friction welding machine (Model: Rexroth, R. V. Machine tools, Cap. 20kN Tools) was used to fabricate the joints. The welded joints were turned using a CNC lath to the required dimensions as shown in Fig. 3(b). American Society for Testing of Materials (ASTM E8M-04) guidelines were followed for preparing the test specimens. Three tensile specimens were prepared from each joint to evaluate the transverse tensile strength. Tensile test was carried out on a 100 kN Electromechanical controlled universal testing machine (FIE-Blue Star, India; Cap. 0-100KN, Model: Instron-UNITEK-94100). The specimen was loaded at the rate of 1. 5 kN/min according to the ASTM specification and the average of the three results is presented in Table 4.

## 4 Developing empirical relationship

In the present investigation, RSM has been applied for developing the mathematical model in the form of multiple regression equations for the quality characteristic of the friction welded low carbon steel. In applying the response surface methodology, the independent variable was viewed as a surface to which a mathematical model is fitted. The second order polynomial (regression) equation used to represent the response surface Y is given by [15]Balasubramanian M, Jayabalan V, Balasubramanian V. A mathematical model to predict impact toughness of pulsed current gas tungsten arc welded titanium alloy [J]. Journal of Advanced Manufacturing

Technology, 008, 35(9/10): 852???? 858. As the range of individual factor was wide, a central composite rotatable Three-factor, five-level factorial design matrix was selected. The experimental design matrix (Table 4), consisting of 20 sets of coded conditions and comprising a full replication Three-factor factorial design of 8 points, 6 star points, and 6 center points, was used. The upper and lower limits of the parameters were coded as +1. 68 and −1. 68, respectively. The coded values for intermediate levels can be calculated byXi= 2[2X−(Xmax+Xmin)]/(Xmax−Xmin) (1)where Xi is the required coded value of a variable X and X is any value of the variable from Xmin to Xmax. The friction welds were made under every condition dictated by the design matrix in random order so as to avoid the noise creeping output response. As prescribed by the design matrix, 60 joints were fabricated. Relationship between tensile strength (σ) of the friction welded low carbon steel joint is a function of the friction welding parameters such as a friction pressure/time (A), forging Pressure/time (B) and Rotational Speed (C) which it can be expressed as: σ= f{A, B, C} (2)The second-order polynomial (regression) equation used to represent the response surface σ is given by: where b0 is the average of the responses, and b1, b2, b3, …, b44 are regression coefficients [8] that depend on the respective linear, interaction, and squared terms of factors. The value of the coefficient was calculated using Design Expert Software. The significance of each coefficient was determined by Student’s t test and p values, which are listed in Table 5. [8] MURTI K G, SUNDERESAN S. Structure and properties of friction welds between high-speed steel and medium carbon steel for bimetal tools [J]. Mater Sci Technol, 1986, 2: 865−870. The values of “ Prob> F” less than 0.

05 indicate that the model terms are significant. In this case, A, B, C, D, AC, A2, B2, and D2 are significant model terms. The values greater than 0. 10 indicate that the model terms are not significant. The results of multiple linear regression coefficients for the second- order response surface model are given in Table 6. The final empirical relationship was constructed using only these coefficients, and the developed final empirical relationship is given below: σ in Mpa = +530. 35 -19. 67A+18. 18B-4. 72C+12. 25AB+11. 50AC+3. 00BC +6. 60A2-12. 67B2-16. 74C2(5)Analysis of variance (ANOVA) technique was used to check the adequacy of the developed empirical relationship. In this investigation, the desired level of confidence was considered to be 95%. The relationship may be considered to be adequate, which provides that 1) the calculated F value of the model developed should not exceed the standard tabulated F value and 2) the calculated R value of the developed relationship should exceed the standard tabulated R value for a desired level of confidence. It is found that the above model is adequate. Each predicted value matches well with its experimental value, as shown in Fig. 6.

# 5 Results and discussion:

5. 1 Effect of process parameters

# Conclusions

The following important conclusions are obtained from this investigationEmpirical relationships were developed to predict the Tensile strength of the friction welded low carbon steel rods incorporating process parameters. The developed relationship can be effectively used to predict the tensile strength of friction welded joints at 95% confidence level.

## Acknowledgement

The authors are grateful to the Center for Materials Joining and Research (CEMAJOR), Department of Manufacturing Engineering, Annamalai University, Annamalai Nagar, India for extending the facilities of metal joining and material testing to carry out this investigation. Also wish to thank Vel Shree Dr. R. Rangarajan, Chanceller, Vel Tech Dr. RR and Dr. SR Technical University, Avadi, Chennai, Tamilnadu, India for the support and facilities provided for the preparation of this paper.

## List of Figures



## List of Tables

Experimental detailsFig. 9 Optical micrographs of friction welded Low Carbon Steel

## List of Tables

Table. 1 Nominal Chemical composition of base metalsTable. 2 Mechanical properties of Low Carbon SteelYieldstrength/MPaUltimatetensilestrength/MPaElongation/

## %

Reduction incross sectionalarea/%Hardness(Hv)Table. 3 Feasible working limits of friction welding parameters. ParameterNotationUnitLevel-1. 68(-1)(0)(+1)+1. 68FrictionPressure/ Friction TimeAMPa/sec0. 060. 160. 330. 50. 6Forging Pressure/ Forging TimeBMPa/sec0. 060. 160. 330. 50. 6Rotational SpeedCRpm11001200140016001700Table. 4 Design matrix and corresponding output responseStandard orderRun orderCoded valueReal valueTensile Strength in (Mpa)Yield trengt in(Mpa)% of ElongationABCABC13-1-1-10. 20. 21200458271-1-10. 50. 21200406316-11-10. 20. 5120048541711-10. 50. 5120047859-1-110. 20. 21600430681-110. 50. 2160042674-1110. 20. 516004438111110. 50. 51600480912-1. 682000. 10. 3140043510201. 682000. 60. 3140044311140-1. 68200. 30. 11400406121001. 68200. 30. 61400435131500-1. 6820. 30. 31100441142001. 6820. 30. 317004301550000. 30. 314004501660000. 30. 3140043017190000. 30. 3140043118130000. 30. 314004291910000. 30. 3140043220180000. 30. 31400430Table. 5 ANOVA test resultsANOVA test result for Ultimate Tensile strength (df is degrees of freedom; F is Fisher’s ratio; p is Probability)SourceSum of SquaresdfMean SquareF Valuepvalue(Prob > F)Model18404. 8692044. 98467. 07178 < 0. 0001significantA5285. 91815285. 918173. 3685 < 0. 0001B4513. 3814513. 38148. 0307 < 0. 0001C278. 481278. 489. 1336410. 0128AB1200. 511200. 539. 37423 < 0. 0001AC10581105834. 700490. 0002BC721722. 361470. 1554A2632. 94081632. 940820. 759320. 0010B22329. 93112329. 93176. 41752 < 0. 0001C22877. 52712877. 52794. 37767 < 0. 0001Residual304. 89481030. 48948Lack of Fit244. 8948548. 978974. 0815810. 0744not significantPure Error60512Cor Total18709. 7519Std. Dev. = 5. 52, Mean= 515. 75, C. V. = 1. 07%, PRESS= 1903. 32, R2 = 0. 9837, Adj R2 = 0. 9690, Pred R2 = 0. 8983, Adeq. Precision= 32. 89Table 6 Estimated regression coefficients for tensile strength. FactorEstimated regression coefficients/Tensile strengthIntercept530. 353A-Friction Pressure/Friction Time-19. 674B-Forging Pressure/ Forging Time18. 1792C-Rotational Speed-4. 72AB12. 25AC11. 5BC3A26. 60197B2-12. 667C2-16. 739