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EVALUATION OF AXIAL SHORTENING OF FRICTION WELDED JOINTS OF EN-24 AND ETP-COPPER CYLINDRICAL ROUNDS USING DOE CONCEPT

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ABSTRACT

Welding of dissimilar materials has grabbed the attention of various industries and made them to utilize this application in manufacturing of automotive components like axle, shaft, gear, poppet valve and HT-cable. EN-24 is a high tensile alloy steel with specific Mechanical and Metallurgical properties. ETP-copper has high electrical & thermal conductivity, since EN-24 & ETP copper cylindrical rounds demonstrate variance in physical properties, mechanical properties & metallurgical properties, detecting proper welding process and practices is difficult. To overcome these difficulties friction welding is utilized in this work. In this experimental work EN24 and ETP – copper cylindrical rounds are welded by rotary friction welding using KUKA machine. There is an atomic bonding created in the joints of the welded materials at solid state. The objectives of the experiment are to weld two dissimilar materials and to evaluate the axial shortening.L9 Design of Taguchi technique which utilized in this work. The joints are welded by keeping the speed at constant rate and varying the Upset pressure, friction pressure, and friction time. S/N ratio in taguchi method and ANOVA table technique is used for the evaluation of axial shortening. The result of this experiment will be identifying the dominating parameters in axial shortening and to provide good welded joints for this dissimilar material.

Keywords: *Friction welding, EN-24 steel, ETP copper, welding parameters, axial shortening, Taguchi method.*

1. Introduction

Friction welding is a process in which atomic bond is created between two materials in a solid state due to friction that produces heat. In this experiment rotary friction welding is used to weld the joints (fig1). The machine in this setup was manufactured by KUKA, it is horizontal type. The input variables are friction time, friction pressure and forging pressure and the output variable is axial shortening. The possibilities of welding two dissimilar materials like EN-24 and ETP- copper is difficult other than this type of welding. In literature survey 'technically, because no melt occurs, friction welding is not actually a welding process in the traditional sense, but a forging technique'. (Sahin M and Erol Akata H, 2003) et al investigated, the effects on the welding zone of plastic deformation material such as carburizing steels. It has various applications like shaft, gear and poppet valve. In power transmission like HT cable, bimetallic parts like bushes. In power plant turbine shafts and rotors.

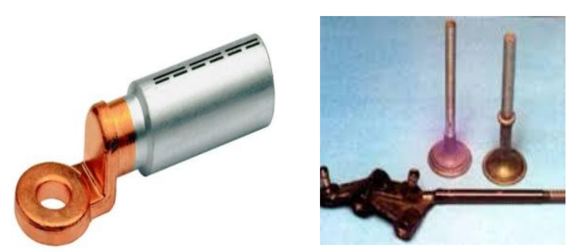

Fig.1 Friction welded joints of Bi metallic HT power-cable and Poppet valve.

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2. EXPERIMENTAL SETUP

2.1Experimental Details

In this experimental study, EN-24 steel and ETP-copper rods are used for friction welding process, which contains chemical composition of EN-24 (Cr 18, Ni 14, Mo 3.0, S 2.0, Si 0.75, C 0.08, P 0.045) in weight percentage and for ETP-copper (Cu 99.9, Pb 0.005, O_2 0.04, Bi 0.0005, remaining 0.03) in weight percentage. Cylindrical test specimens of 25mm diameter and 100mm length were prepared for friction welding. Before friction welding the surfaces of specimen, facing operation was performed in the centre lathe. Joining of Two similar materials are performed on a continuous drive friction welding machine (KUKA) at Welding Research Institute of BHEL, Trichy (Fig 2). Friction welding parameters are Friction pressure (20 bar, 30 bar, 40 bar), Forging pressure (30 bar, 40 bar, 50 bar) and Friction time (5sec,7sec, 9sec), Using DOE concepts the mean plot is drawn to evaluate the axial shortening of Joints (Fig 3).

Fig. 2 KUKA –Rotary Friction welding machine

Fig. 3 EN-24 and ETP copper friction welded joints

2.2 Taguchi's Design of Experiments

Taguchi method is a powerful tool in quality optimization makes use of a special design of orthogonal array (OA) to examine. Number of experiments used to design the orthogonal array for 3 parameters and 3 levels of welding parameters (Table 1.)

Minimum experiments = [(L-1) X p] +1
= [(3-1) X 3] +1
= 7 ≈ L9

3. Result and Discussion

Table. 1 Friction welding parameters of EN-24 & ETP-copper cylindrical rounds.

Friction pressure (bar)	Upset pressure (bar)	Friction time (sec)	Axial shortening (mm)	SNRA1
20	30	5	199	45.9771
20	40	7	190	45.5751
20	50	9	186.1	45.3949
30	30	7	194	45.7560
30	40	9	178	45.0084
30	50	5	185.4	45.3622
40	30	9	177	44.9595
40	40	5	186	44.9595
40	50	7	179	45.0571

Table 2: Response for Signal to Noise Ratios of Friction welding process (Larger is better).

Level	Friction Pressure (bar)	Upset Pressure (bar)	Friction Time (sec)
1	45.65	45.56	45.58
2	45.38	45.32	45.46
3	45.14	45.27	45.12
Delta	0.51	0.29	0.46
Rank	1	3	2

Rank -1: denotes that the dominating parameter of friction welded joints of EN-24 steel & ETP-copper is Friction pressure(Table 2).

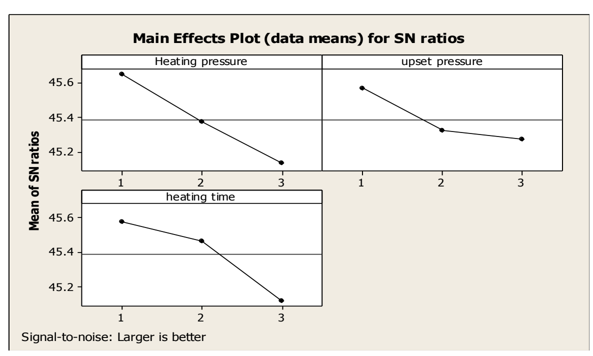

Fig. 4 Main effects plot for SN ratios of friction welding

From above figure 4 shows that the optimum parameter of friction welding process of dissimilar material like EN-24 and ETP copper cylindrical rods.The diagram illustrate the larger is the better concept of axial shortening of welded joints with out any defects which derived by Signal to noise ratio values.

Table 3. ANOVA values of dissimilar friction welded joints

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Friction pressure	2	182.90	182.90	91.45	5.44	0.155
upset pressure	2	72.06	72.06	36.03	2.14	0.318
Friction time	2	154.76	154.76	77.38	4.60	0.179
Error	2	33.63	33.63	16.81		
Total	8	443.34				

S = 4.10054 R-Sq = 92.41% R-Sq (adj) = 69.66%. The above ANOVA (table 3) that the higher value of F-test denotes that the influencing parameter of friction welded joints of dissimilar materials such as En-24& ETP copper rods of Friction pressure of weld parameter.

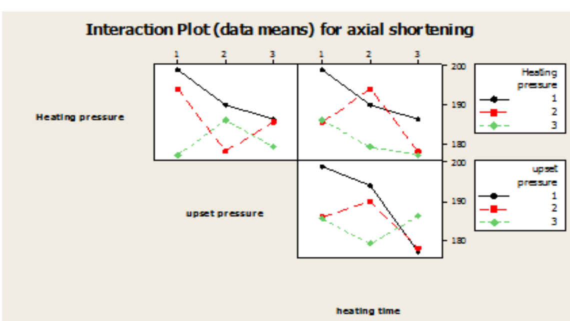

Fig. 5 Interaction plot for axial shortening

Figure 5 shows the interaction between friction welding parameter for achieving larger axial shortening of length. It also represent level 2&3 of friction pressure, Level 1,2&3 of upset pressure and level 1,2&3 of friction time of dependant parameters of friction welded joints of Dissimilar materials.

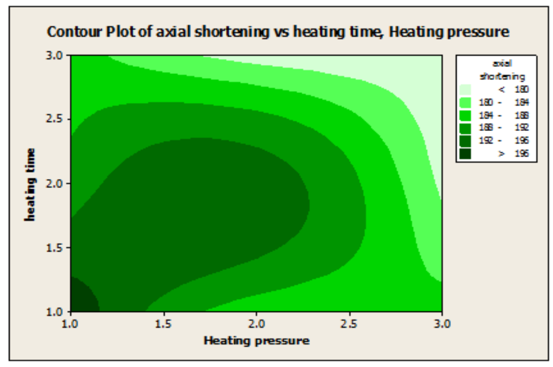

Fig. 6 contour plot axial shortening versus heating time, for friction welding process.

Contour plot is a graphical representation of influencing parameters of friction welding process with jointing of EN-24 and ETP-copper cylindrical rod with maximum area denotes the optimum parameters of friction welding process (fig 6).

It indicates level the first level of heating pressure and first level of heating time is optimum level of friction welding.

4. Conclusions

In this experiment, we conclude that the axial shortening, joining of dissimilar materials and optimum parameter were evaluated. The main conclusions are summarized as follows:

- Optimum parameter for the friction welded joints of EN24 steel and ETP-copper rods is heating pressure (20bar), upset pressure (30bar), heating time (5sec), axial shortening (199mm), S-N ratio (45.9771).
- EN-24 alloy steel and ETP-copper cylindrical rounds provided good weldability property.
- The axial shortening exponentially increased by increasing friction pressure and friction time and plays an important role in Hardness and Ultimate strength of EN-24 steel and ETP-copper rods.
- This method may be adopted in manufacturing of dissimilar material automotive components using friction welding process.

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