iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 6 **Issue:** V **Month of publication:** May 2018

DOI: http://doi.org/10.22214/ijraset.2018.5429

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International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 6.887
Volume 6 Issue V, May 2018- Available at www.ijraset.com

Microstructural Analysis of Friction Welding of 430F Stainless Steel and MS Rod

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Abstract: ***The welding of unique materials finds a wide assortment of utilizations in the fields of modern development and assembling, where the trademark highlights of the distinctive materials are enhanced for the coveted application to bring about cost adequacy and esteem expansion. Non-combination welding strategies, for example, strong state welding and high vitality shaft welding are more prominent for welding unique metal mixes, because of less entanglements, than combination welding, which dissolves the base metal and structures weak intermetallic mixes (IMCs) that may prompt disappointment. Different variables must be considered while evaluating the plausibility of welding unique metals and creating a sound weld joint. This paper displays an expansive grouping of the most ordinarily utilized welding forms for unique materials, examines a portion of the regularly utilized welding forms with cases of some normal material blends, basic factors for good welding, and down to earth troubles emerging from the physical and concoction properties of materials. From the discoveries, it can be gathered that ceaseless change and research is as yet required in the field of different metal welding, especially in the light of expanding interest for custom fitted material for present day designing and mechanical applications.***

I. INTRODUCTION

The need for joining dissimilar metals arises from the complex functionality of many modern industrial applications. As manufacturers focus on reducing production and operational costs, search for enhanced mechanical and thermal properties, and lightweight solutions for sectors like the shipping, aviation, and automobile industries, multiple material combinations are increasingly being used for many products [1-10]. An emerging field of joining dissimilar metals is transportation, where multi-material solutions consisting of steel, aluminum, magnesium, and composites are replacing monolithic steel structures, thus reducing the weight of vehicles and improving fuel efficiency [8-15]. In the case of friction welding of dissimilar materials, alloying between the base metals and filler metal is a major consideration that has to be taken into account. The weld metal formed can exhibit entirely different characteristics from one or both of the base metals. The main factors that contribute to the failure of joints between dissimilar metals by arc welding are alloying problems (formation of the brittle phase and limited mutual solubility), improper joint design, great differences in the melting temperature or the coefficient of thermal expansion (CTE) of the materials involved, thermal conductivity differences, and corrosion problems including galvanic corrosion, oxidation, hydrogen-induced cracking, and sensitization [14-22]. Conflicts may arise when the optimum heat control of the metals differs, and compromises are thus required. In light of the complexity of the process and the compromises required, dissimilar metal welding (DMW) requires more careful study than conventional, similar-metal welding procedures. [3]

II. OBJECTIVES

To establish a Friction welding process in place of MIG welding and to develop indigenized friction welded parts which are imported.

A. Friction welding

Friction stir welding (FSW) is a solid-state joining process that uses a non-consumable tool to join two facing workpieces without melting the workpiece material.[1] Heat is generated by friction between the rotating tool and the workpiece material, which leads to a softened region near the FSW tool. While the tool is traversed along the joint line, it mechanically intermixes the two pieces of metal, and forges the hot and softened metal by the mechanical pressure, which is applied by the tool, much like joining clay, or dough. It is primarily used on wrought or extruded aluminium and particularly for structures which need very high weld strength. FSW is also found in modern shipbuilding, trains, and aerospace applications[20-25].

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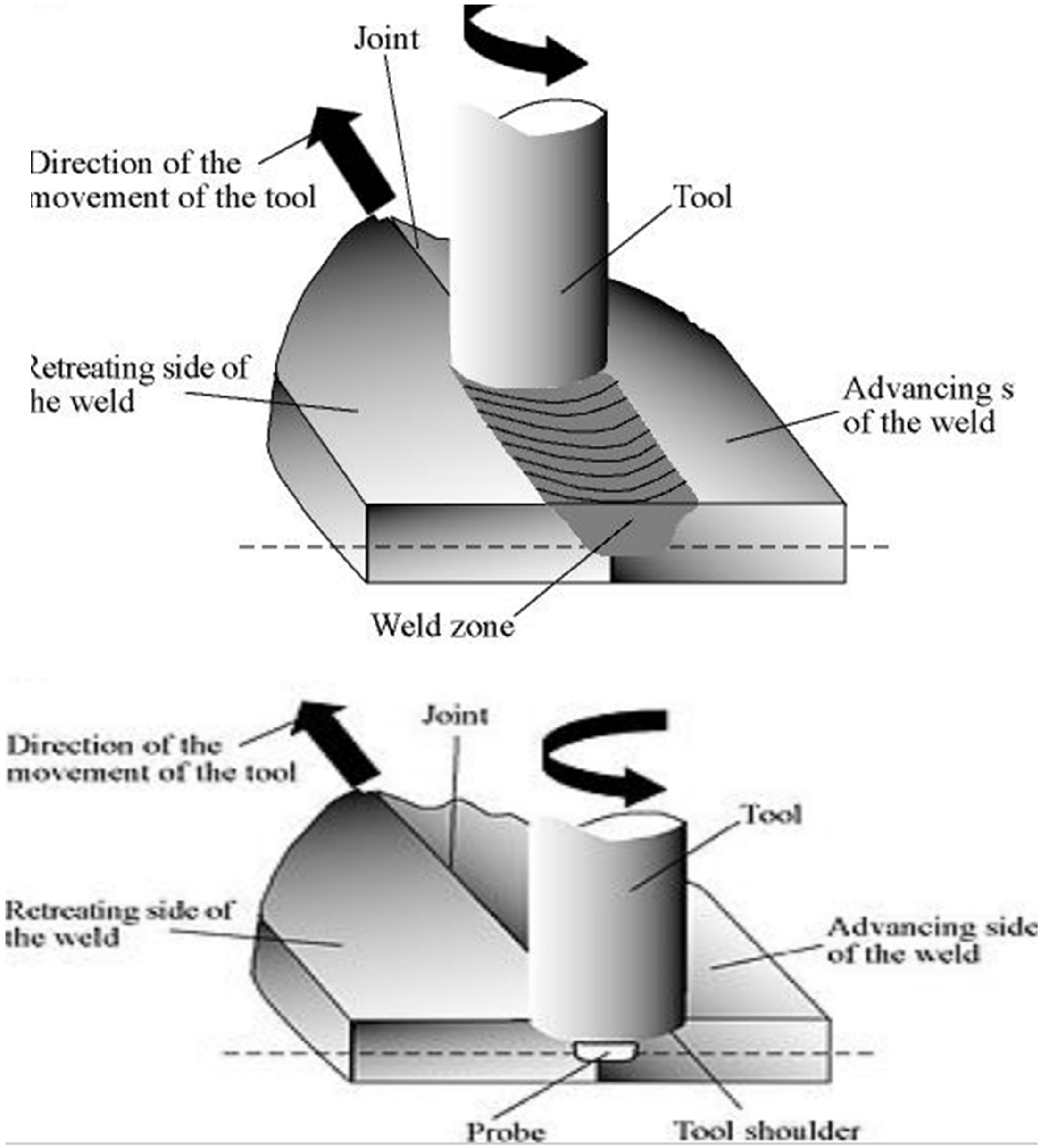

Figure 1 Process of friction welding

B. Principle of operation

A rotating cylindrical tool with a profiled probe is fed into a butt joint between two clamped workpieces, until the shoulder, which has a larger diameter than the pin, touches the surface of the workpieces. The probe is slightly shorter than the weld depth required, with the tool shoulder riding atop the work surface. After a short dwell time, the tool is moved forward along the joint line at the pre-set welding speed. Frictional heat is generated between the wear-resistant tool and the work pieces. This heat, along with that generated by the mechanical mixing process and the adiabatic heat within the material, cause the stirred materials to soften without melting. As the tool is moved forward, a special profile on the probe forces plasticised material from the leading face to the rear, where the high forces assist in a forged consolidation of the weld. This process of the tool traversing along the weld line in a plasticised tubular shaft of metal results in severe solid state deformation involving dynamic recrystallization of the base material.

The work pieces to be joined are prepared to have a smooth square cut surfaces. Under an axial force stationary work piece is slowly brought in contact with rotating work piece and friction is generated at the contact surfaces. The axial pressure to the stationary work piece is increased until the friction between the surfaces raises the heat to the welding temperature. At this moment, the rotation of the work piece is stopped, but the pressure is maintained or, in some cases increased to complete the weld. The weld joint obtained will be bulged due to the squeezing action of the softened metal. The excess metal can be removed by machining.

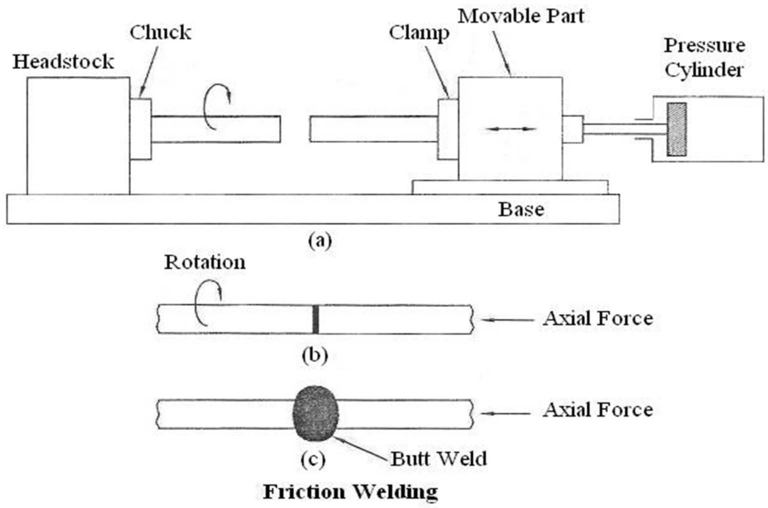

Figure 2 Friction welding

1) Advantages of Friction Welding

a) Easily joins dissimilar metals.
b) Friction welds are higher strength than other means of joining.
c) Concave shape of weld penetration
d) Friction welds minimize the Heat Affected Zone (HAZ).
e) High penetration is obtained
f) The weld may not have to be heat treated

2) Advantages of Friction Welding Over MIG Welding

1) Frictional welding is a controlled process components are frictionally bonded. The bond is strong and free from voids and porosity.
2) No Torch angle problem occurred in friction welding
3) No Filler metal is used
4) Moreover the weld cycle is extremely short, so that productivity is very attractive. Once set up the Friction-welding process is carried out by unskilled workers and could be automated.
5) The Friction Welding process is suitable for mass production

3) Disadvantages of Friction Welding

1) Plate to plate welding cannot be done
2) Only axle symmetry parts can be welded

C. Problems Encountered in Welding Dissimilar Materials

Major factors to be taken into consideration before selecting a suitable welding method for joining dissimilar materials include aspects such as the composition of the dissimilar base materials and filler material (if used), service conditions, and the geometry of the joint. The service conditions may make particular processes unsuitable: for example, soldering and adhesive bonding are not applicable for high temperature applications, and mechanical joints are not suitable for leak-proof joints. The geometry of the joint makes some welding methods difficult to apply, e.g. friction welding. The main causes of difficulties and complexities in the welding of dissimilar metal joints, are:

1) Compositional gradients and microstructural incompatibility between the dissimilar base metals which lead to a large variation in chemical, physical, and mechanical properties in the joint, resulting in the formation of brittle IMC.
2) Problems associated with welding individual similar base metals.
3) Increased complexity of the joint as a result of adding filler or insert materials.
4) Incompatibility due to great differences in physical properties like melting temperature, density, thermal conductivity, and the thermal expansion coefficient

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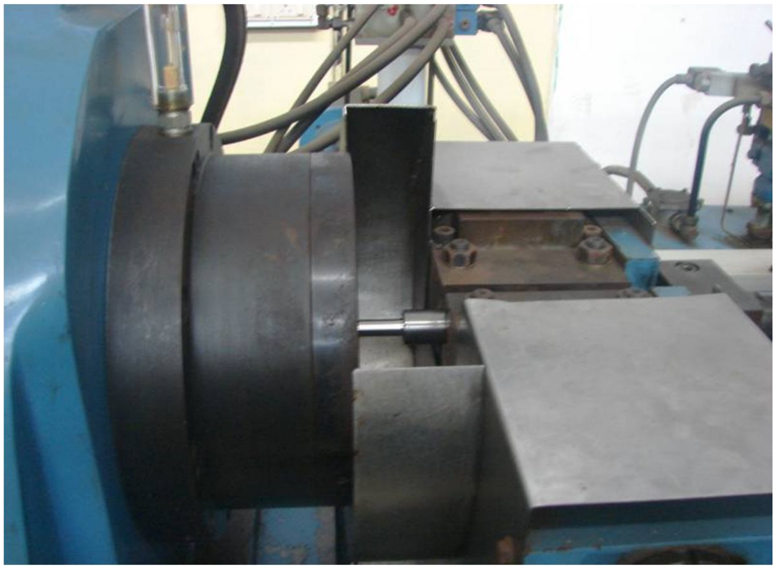
D. Description and Operation of Friction Welding

Friction welding machine consists of chuck to holds one of the work pieces and rotates it at high speeds (around 2500 rpm).One work piece will held stationary and another will be movable and brought in contact with rotating work piece. The maximum temperature will reaches to 0.8Tm of recrystalisation temperature.



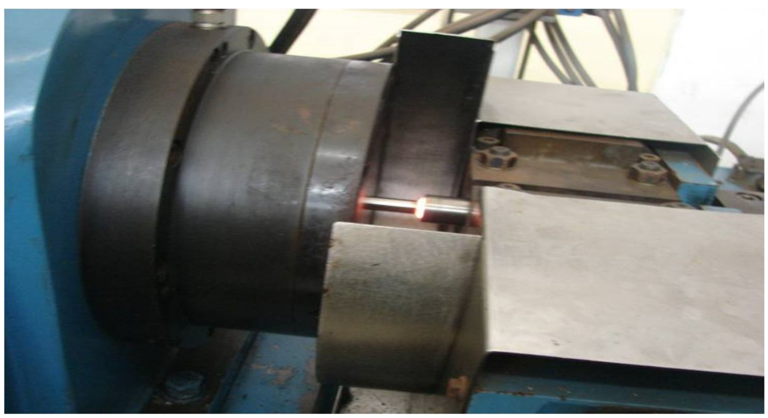


Figure 4 Experimental process of friction welding

E. Cost of MIG Welding Vs Friction Welding

MIG Welding	Friction Welding
1. 300 Rs/piece of imported friction welded push rod assembly	1. 100 Rs/piece instead of importing
2. 2 Rs per push rod assembly of local components	2. 4 Rs per push rod assembly of local components

Main Parameters of Friction Welding

1) Friction Force / Pressure
2) Burn off length
3) Rotation Speed
4) Upset Force

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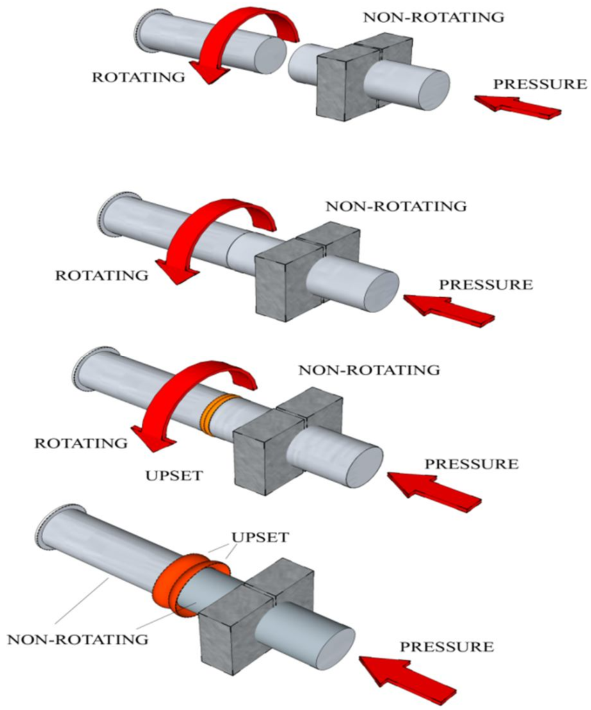

Figure 5 Main parameters of friction welding

Figure 6 Characterisation of friction welding

F. Characterisation
1) Study between 430F S.S and MS rods friction welding
2) Study between 430F S.S and EN3b friction welding

G. Characterisation

1) Study of profile
2) Study of heat effected zone
3) Macro and micro
4) Hardness traverse of weld, parent metal and heat effected zone
5) Microstructure at each stage

H. After Friction Welding

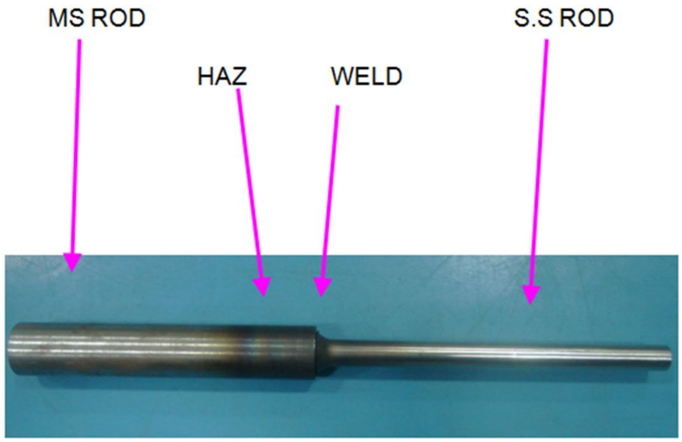

Figure 7 Material after friction welding

I. Chemical Composition of 430F S.S

Table 1 Chemical composition of 430F S.S

Specified Chemical Composition in %	Observed Chemical Composition in %
C – 0.12 Max Mn – 1.25 Max Cr – 16 to 18 S – 0.15 Min Si – 1.0 Max	C – 0.09 Mn – 0.39 Cr – 16.53 S - 0.20 Si – 0.680
Hardness Specified	Hardness Observed
279 HV Max	252 HV, 253 HV

J. Chemical Composition of En3B

Table 2 Chemical Composition of En3B

Specified Chemical Composition in %	Observed Chemical Composition in %
C – 0.25 max Mn – 1.00 max P – 0.06 max S – 0.06 max Si - 0.35 max	C – 0.20 Mn – 0.80 P – 0.013 S - 0.02 Si – 0.223
Hardness Specified	Hardness Observed
120 – 140 HV	135 HV

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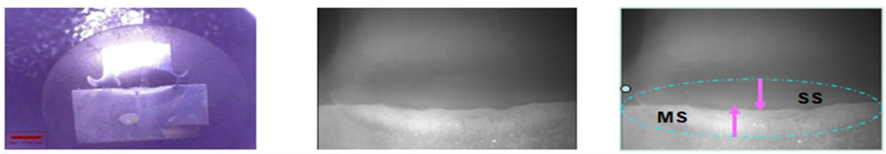
K. Chemical Composition of MS

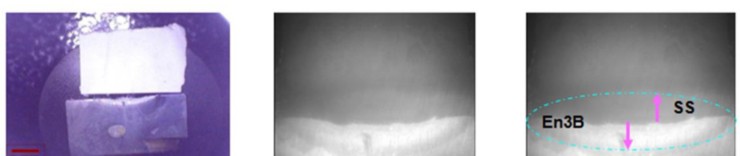
Table 3 Chemical Composition of MS

Specified Chemical Composition in %	Observed Chemical Composition in %
C – 0.20 max Mn – 1.5 max P – 0.045 max S – 0.045 max Si - 0.40 max	C – 0.18 Mn – 0.82 P – 0.014 S - 0.03 Si – 0.22
Hardness Specified	**Hardness Observed**
136 HV	130 HV



Weld geometry	Sample Observations	Remarks
1. Bead Shape	CONCAVE	OK
2. Bead width (mm)	3.95 mm	Ok
3. Penetration (mm) On SS On MS	 1.93mm 2.20mm	 Ok Ok
4. Throat Length (mm)	Nil	Ok
5. Leg length (mm)	-----	Ok
6. Micro defects in weldment	Nil	Ok
7.Excessive throat thickness(mm)	Nil	Ok
8. Hardness Survey	Carried out from the MS rod to SS rod through weldment	
Conclusion : The weld bead shape of the welded sample was concave and the penetration over the rod was 65% and the hardness survey from the rod to rod through was carried out and no abnormal variation was noticed		

Figure 8 Welding Inspection of MS Rod Vs SS Rod Assembly



Weld geometry	Improved sample observations	Remarks
1. Bead Shape	CONCAVE	OK
2. Bead width (mm)	3.83mm	Ok
3. Penetration (mm) On SS On En3B	 1.87mm 2.01mm	 Ok Ok
4. Throat Length (mm)	Nil	Ok
5. Leg length (mm)	Nil	Ok
6. Micro defects in weldment	Nil	Ok
7.Excessive throat thickness(mm)	Nil	Ok
8. Hardness Survey	Carried out from the En3B to SS rod through weldment	
Conclusion : The weld bead shape of the welded sample was concave and the penetration over the plate was 62% and the hardness survey from the plate to rod through was carried out and no abnormal variation was noticed		

Figure 9 Welding Inspection of En3B Rod Vs SS Rod Assembly

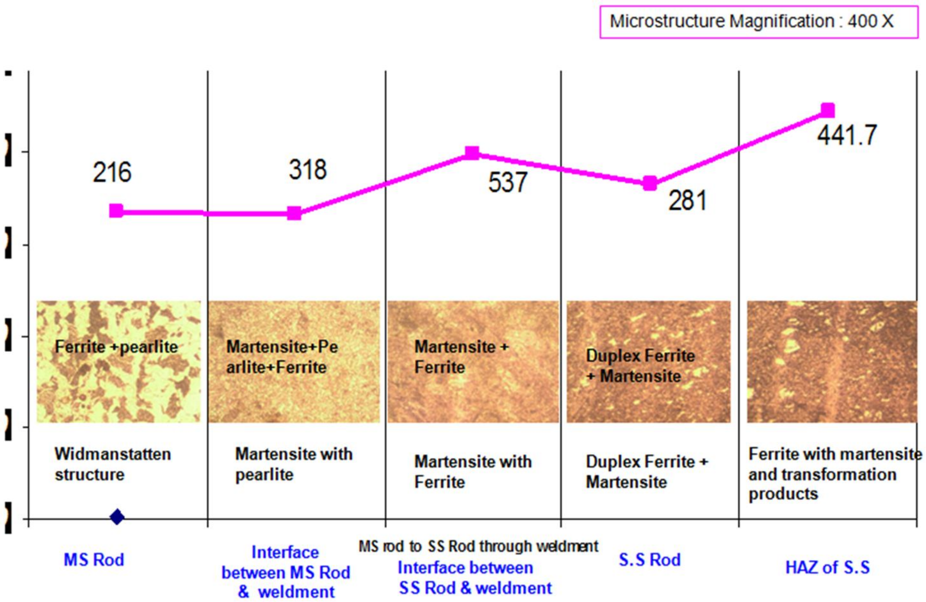


Figure 10 Hardness Traverse with microstructures of MS and SS Rod

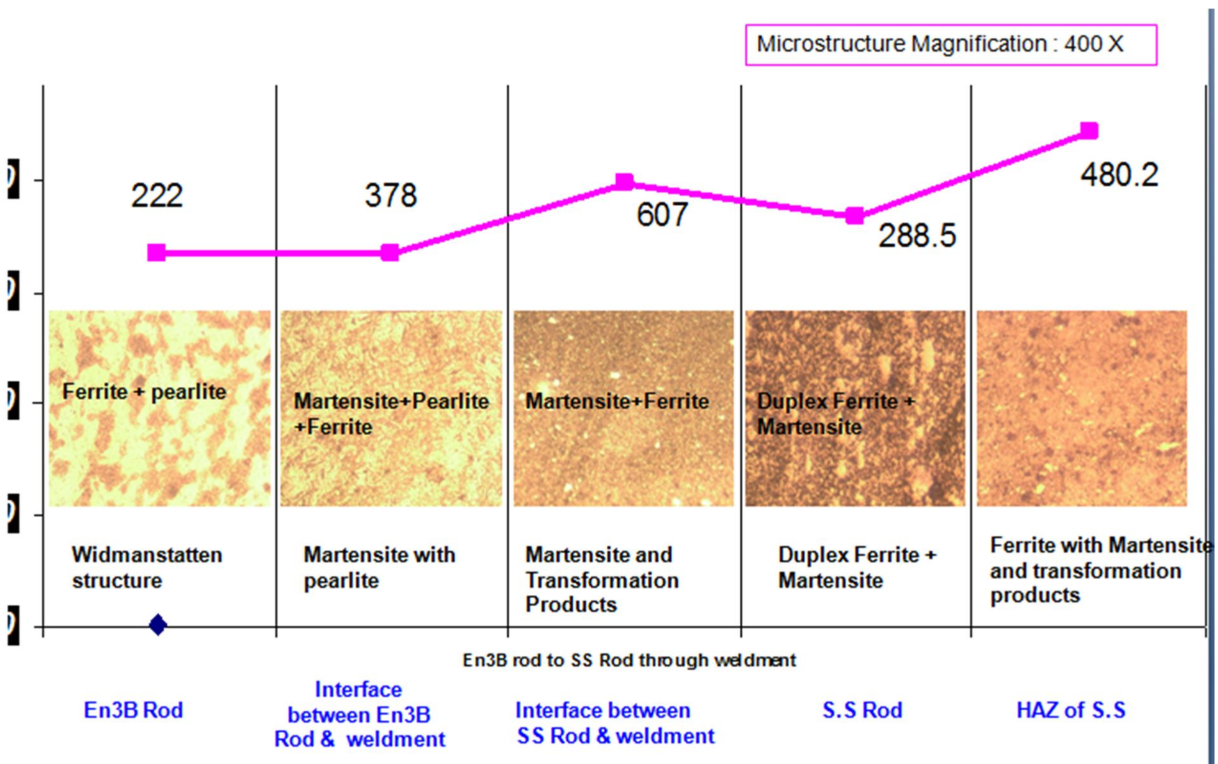


Figure 11 Hardness Traverse with microstructures of En3B and SS Rod

Table 4 Pullout test results

Specified	Observed
40KN	49.16, 67.54, 85.02KN

III. CONCLUSION

Friction welding has been successfully employed to weld dissimilar steels. Strength of the joints obtained were good and ductility was reasonable. Chemical composition of the steels used for welding play an important role in deciding the properties of the weld. Major conclusions are:

A. Microstructural evaluation of the friction welded joints revealed three distinct zones namely, Base metal stainless steel, plastically deformed welded zone and base metal mild steel.

B. Characterization and HAZ zone optimization of friction welding parameters done and it shows good microstructural changes with pearlite, ferrite and martensite phases.

C. During friction welding, the metal tends to decrease in length of steel by showing a flash formation.

D. Micro-hardness measurements in stainless steel to mild steel results with absence of hardness value in weld zone. Due to sticky layer at the interface of stainless steel as well as MS joint, the weld zone is negligible.

E. On a whole friction welding gives better results and high productivity with decreased cost with mass production.

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