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MICROSTRUCTURE ANALYSES OF MAGNETIC IMPALED ARC BEAM (MIAB) WELDING SPECIMEN

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Abstract – *Magnetic impaled arc beam welding is solid state welding process, which uses high speed rotating arc to produce sufficient heat for joining. This MIAB welding technique can be used for hollow i.e. pipe to pipe or pipe to solid plate/rod joining. This paper describes the results of the research on welding of 22mm diameter and 2mm wall thickness tube to tenon, which represents the core of this investigation. Weld development work on this components was conducted for the purpose of getting a knowledge base for MIAB welding's weld quality. Discussion and analysis of these results are presented in this paper.*

Keywords – *MIAB welding, Weld quality of MIAB, Tube to Tube joining.*

I. INTRODUCTION

The MIAB fastening/welding method was at first investigated by the Paton electrical fastening Institute throughout the 1950's and 1960's. It had been later industrialised for industrial applications by Kuka fastening systems, WHO named it the Magnet arc method. Today, MIAB fastening/welding is meant for a range of applications throughout Europe and therefore the state, and Paton continues its MIAB analysis and development efforts. MIAB fastening/welding may be a forge fastening method that depends on an electrical arc to supply the required heating to soften the surfaces being welded. The arc heating additionally drops the yield strength of adjacent solid material to permit for adequate shaping action, a crucial side of the method. A basic illustration of MIAB attachment is shown in Figure 1 and 2 that illustrates the attachment of two tubes.

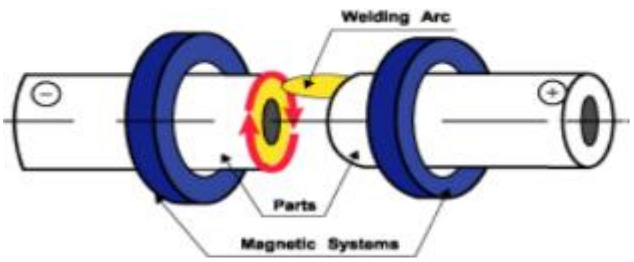

Figure 2 - Basic Schematic of the MIAB Welding Process [1]

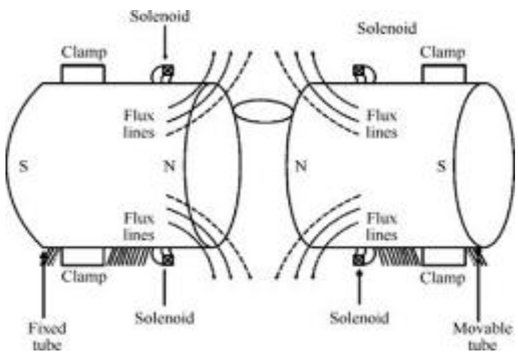

Figure 2 – Detailed Schematic of the MIAB Welding Process [1]

As the figure indicates, associate arc is formed to whirl/spin around the tubes because of the presence of a flux generated with either permanent or electromagnets. The speed of the arc is considerable, reaching speeds as high as 200 m/s. The quickly rotating arc, together with the thermal physical phenomenon i.e. conductivity of the metal being welded, with success creates very even heating at the joint. Upon completion of the heating section, the elements ar fleetly brought along harassed/under pressure. This upset step squeezes the liquified material out of the joint, and creates a shaping/forging action on the remaining plasticized metal. The shaping/forging action produces the ultimate solid-state joint. The method doesn't use filler metal. Shielding gas, though generally used, is typically not needed. Once shielding gas isn't used, as within the case of this

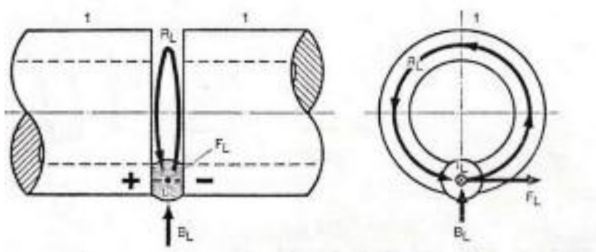

Figure 3 - Interaction between Current and an Applied Magnetic Field [2]

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analysis, a brief pulse of high current is extra that expels contaminated liquified metal before upset. Upon initiation of a drawn arc, an electromagnetic force FL is created on the arc. The force is thanks to the axial part of current flow within the arc, IL, crossing the radial part of the applied force field, BL. This magnetism force on the flowing current is spoken as a Lorentz force, and given by: f = J x B, wherever f = magnetism force density, J = current density, and B = magnetic flux. The magnitude of the force, F, is proportional to the magnetic flux, B, the arc current I, and therefore the arc length L and such as by: F = B*I*L.

II. DESCRIPTION OF COMPONENTS AND WELD SETUP

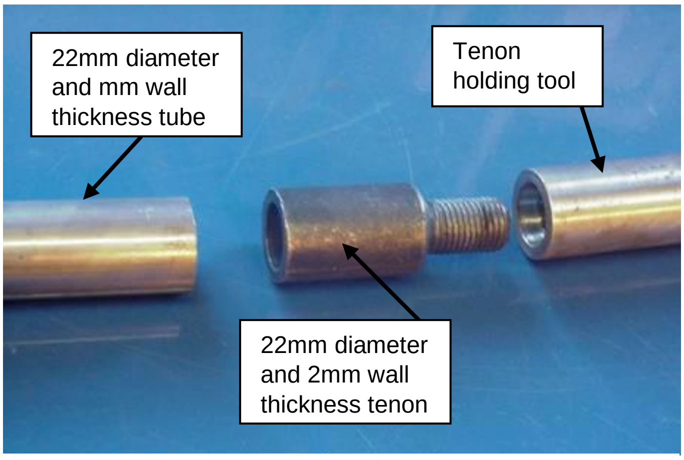

Figure 4 – Test Component

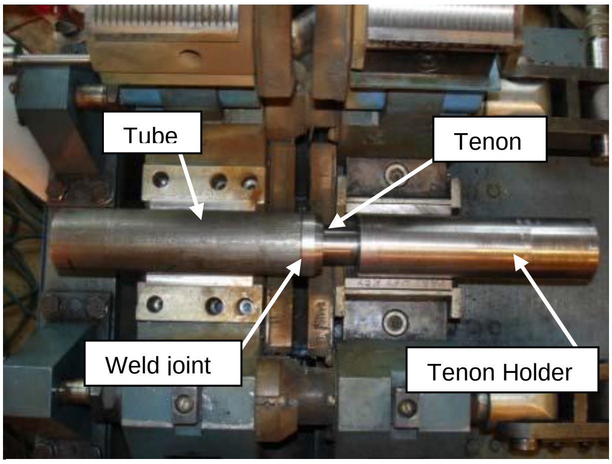

Figure 5 – Part Loading

The MIAB welding is conducted for the 22mm OD and 2mm wall thickness Tube to Tenon joint of mild steel. Aim of this research was to check the feasibility for Tube to Tenon joint and to study the effect of various parameters on joint by carrying out different tests on weld joint. Figure 4 shows component i.e. hollow rod and Tenon with Tenon holding tool during the process. In following figure 5 shows experimental setup is show where pneumatically operated MIAB welding machine and loaded parts are shown. Welding is carried out for 250A arcing current for 10s and 400A upset current for 1s at 2mm air gap, 50V arc voltage and 3000 gauss magnetic field.

III. MECHANICAL TEST METHODS

Two kind of destructive testing methods were used, one is tulip bend test and second is tensile test. In the case of tulip bend test the hollow pipe i.e. welded part is cut longitudinal through weld joint as shown in the figure 6. This kind of test is used to check the weld penetration in inner side of the tube via naked eye. When slots are bended comment looks like tulip flowers that is why this test is known as the tulip bend test.

A. TULIP BAND TEST

Result shows that weld is penetrating throughout the outer as well as inner periphery of the joint. Joint is homogenous without any visual crack or discontinuity. Uniaxial tensile testing was the other mechanical test technique used to evaluate the respectability of the welds. Extreme loads at failure were observed, however the essential marker of a satisfactory weld was regardless of whether failure happened along the weld interface. Figure 6 is a photo of a run of the mill satisfactory elastic test which failed in the Tenon and not in the weld joint. These tensile disappointments ordinarily surpassed 30,000 pounds of load, which implies the weight on the welds was typically in the vicinity of 365 Mpa at Tenon failure.

Figure 6 – Tulip test on tube to tenon weld

B. TENSILE TEST As shown in the fiure 7 tube which is connect to anode side, exhibits over burning due to upset current. High speed video camera whichhas capacity of 1200 frames per second was to check this behaviour. It was

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observed, in high speed video camera whch has 1200 frames per second capturing ability, during the upset current arc was shifted towards anode side which is sown in the figure 8. This is currently known behaviours but random testing gives at idea that this has some connection ith duration of upset current, higher the duration more burning and vice versa.

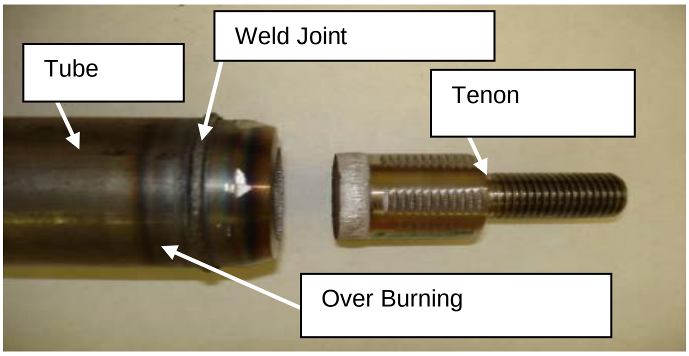


Figure 7 – Tensile test on tube to tenon weld

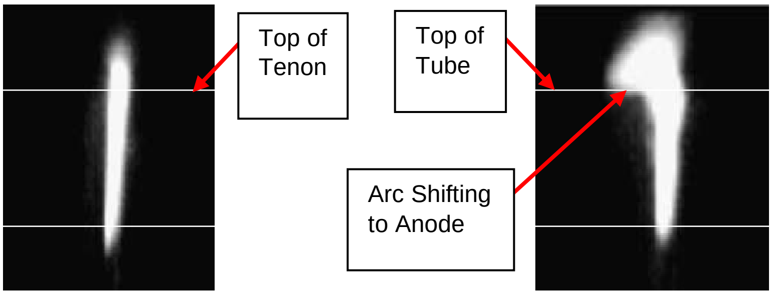


Figure 8 – Arc Monitoring

IV. MICROSTRUCTURE ANALYSIS

Scanning electron microscopy and Optical techniques revealed the weld behaviours like plastic flow lines, transformation from weld metal to base metal. Our base material has microstructure of ferrite and pearlite. Four various thermo mechanically affected zone/sections (THERMO MECHANICALLY AFFECTED ZONE) were analysed as shown in the fig 9. Table no. 4 shows the microstructure of various zone form weld to base metal. Results of SEM and optical microscopy are shown in figure 10.

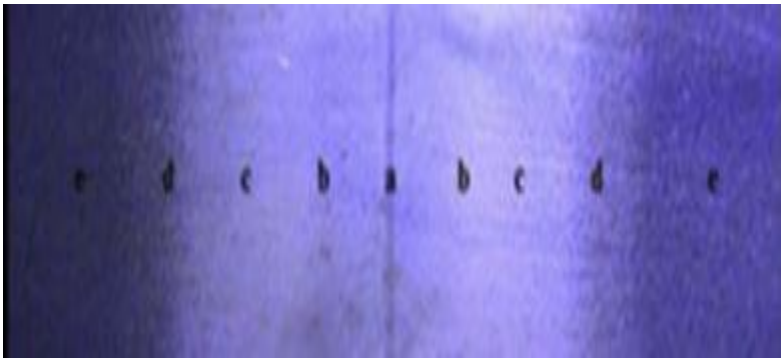
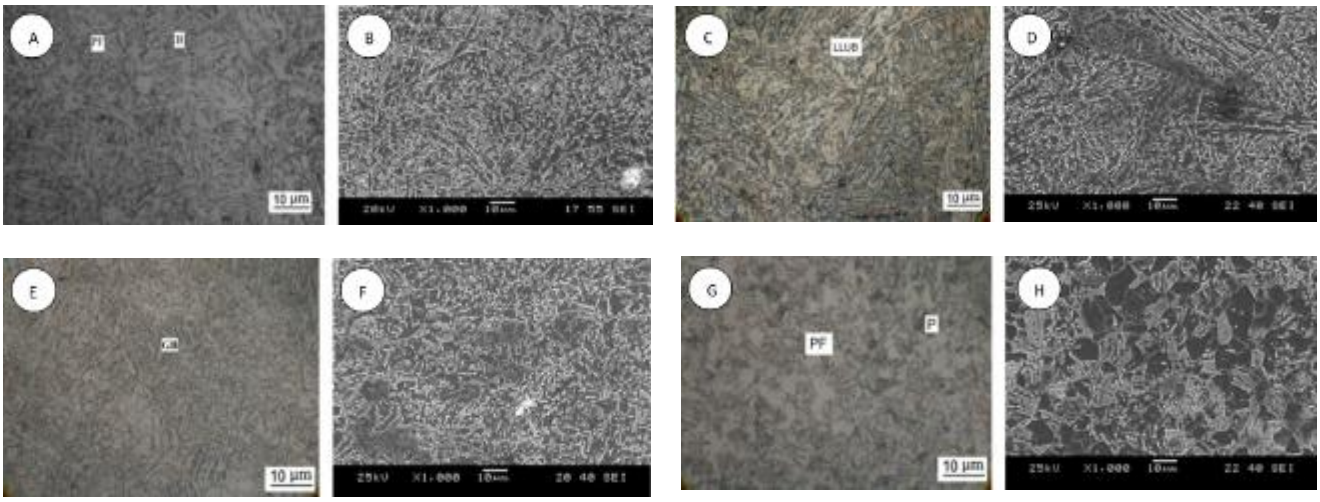


Figure 9 – Microstructure of joint A – TMAZ I , B – TMAZ II, C – TMAZ III, D – TMAZ IV, E – BASE MATEL



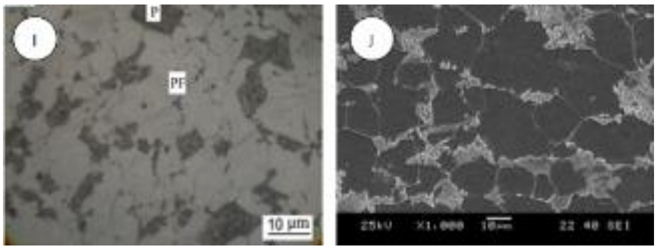


Figure 10 – A, C, E, G, I are the results of optical microscopy and B, D, F, H, J are results of SEM X1000, where A,B – TMAZ I , C,D – TMAZ II, E,F – TMAZ III, G,H – TMAZ IV, I,J – BASE MATEL.

PF: polygonal ferrite, P: pearlite, B: bainite, LLUB: lath like upper bainite, GB: granular bainite

Thermo Mechanically Affected Zone I shows fine bainite with two-dimensional figure polygon primary solid solution ferrite. Bainitic needles shaped during this zone ar comparatively shorter. Upset force applied for weld development plays a great role in microstructural part modification at the weld boundary. Deformation attributable to upset pressure will increase the dislocation density and therefore the dislocation acts because the nucleating sites for bainitic. Isasti rumored the result of plastic deformation in increasing the bainitic transformation. Plastic deformation forces bainitic transformation to happen at upper temperature and in smaller amount. But plastic deformation upsurges the nucleation sites for bainitic transformation, the transformation rate drops with deformation. This is often thanks to slow bainitic growth. As defect density will increase, they hinder the expansion of bainite, leading to shorter solid solution laths in bainite. Rule [3] rumored the reduced transformation fraction with magnified defect density thanks to deformation. Additional the deformation conjointly favours two-dimensional figure solid solution transformation thanks to magnified grain boundary space [3] and ends up in the formation of two-dimensional figure solid solution and bainite.

Slat/Lath like higher bainite in TAMZ II contains comparatively long and parallel solid solution laths compared to Thermo Mechanically Affected Zone I. Thermo Mechanically Affected Zone II receives lighter deformation compared to Thermo Mechanically Affected Zone I, thus dislocation density is a smaller amount. Low dislocation density helps in nucleating the bainite while not obstructive the expansion of solid solution laths. Slat/Lath like higher bainite is chemical compound free bainite, and it contributes to smart weld toughness [4]. Granular bainite is discovered in zone III of Thermo Mechanically Affected Zone. Granular bainite is AN equiaxed bainitic solid solution structure with separate islands of MA constituent. Granular bainite is made thanks to slow cooling and high atomic number 14 Si content [5]. High Si prevents the rich carbon compound cementite forming, leading to formation of blocky primary solid solution i.e. ferrite with MA section. Like higher bainite, the granular bainite is rich carbon content cementite free bainite however exhibits lower toughness. Low toughness is thanks to coarse three dimensional/blocky structure [6].

Next to granular bainite, Thermo Mechanically Affected Zone IV has recrystallized fine grained primary solid solution and lamellar mixture. The microstructure of all welded samples show four distinct Thermo Mechanically Affected Zones, however the microstructure on the weld interface (Thermo Mechanically Affected Zone I) varies with heat input, that is mentioned in following section.

A. EFFECT OF ARC ROTATION CURRENT ON MICROSTRUCTURE

Arc rotation current controls melting of the faying surface [7], so the lower arc rotation current (170 A) chosen for fastening/welding doesn't cause comfortable melting leading to scientific discipline defects like voids at weld interface. Increase in arc rotation current will increase the magnitude Hendrik Antoon Lorentz forces, manufacturing quicker arc rotation [8]. Quicker arc rotation causes bigger force that forces the liquified metal and alternative impurities towards the outer diameter of the tube [9].

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The samples welded with lower arc rotation current (170A) fails at weld interface. This is often thanks to void formation with poor melting at faying surfaces. The voids at weld interface are prejudicial. Detrimental to weld durability, thus failure happens at the weld interface shown in figure 7. However, within the samples welded with higher arc rotation current (250 A) the failure occurred at base metal thanks to defect free weld interface with bainite. As arc rotation current plays a major role in formation of defect free interface, it shows a major individual result on weld UTS. Arc rotation current and upset current show vital interaction result on weld durability. Lower arc rotation current and lower upset current cause higher weld durability.

This is thanks to the variation in range of voids with upset current. As upset current will increase, the metal expulsion at interface will increase [10]. Therefore lower arc rotation current and better upset current increase the amount of voids at weld interface and degrade the mechanical properties of the weld, inflicting a failure below abundant lower load. Among the samples unsuccessful at the weld interface, the sample A has higher strength (390 MPa) compared to B sample.

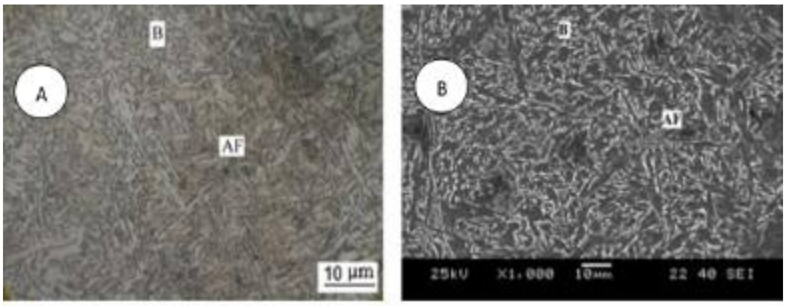

Figure 11 – A is the result of optical microscopy and B is result of SEM X1000, where A, B – TMAZ I for 175A current.

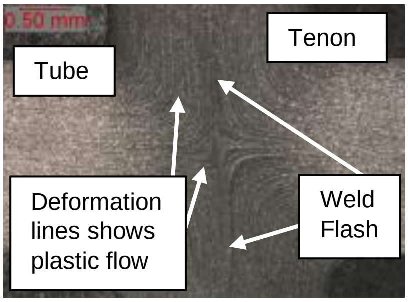

Figure 12 – Optical microscopy shows plastic flow in weld

SEM small graph figure 11a of the broken surface shows a mark structure thanks to micro void concretion bearing on ductile kind of fracture in Sample A. Figure 11b shows the fracture surface of sample welded with lower arc rotation current Sample B. Fracture surface contains compound impurities at the weld interface. These compound impurities ar probably thanks to atmospherical corrosion of void region. Therefore poor melting upon displeasing produces weld interface with defect, inflicting poor joint strength in MIAB attachment.

Joint of sample A exhibits excessive upset, it provides sturdy proof of the plastic flow that happens throughout the upset section of the MIAB attachment method. Tube to projection joints were then created and analyzed optically. Figure 12 shows a typical joint with a better read/view of the bond line.

V. CONSULTATION

MIAB welding technique is one of the undeveloped old technology which doesn't required edge preparation, filler material, and high level manual skill and after weld finishing process even though it will provide best in class weld quality. Ford motor has given testimony that, "MAIB welding will bring a revolutionary change in automotive industry", to European manufacturing company, which is the only one who successfully produces MIAB welding machine for FORD.

Figure 12 is a photo micrograph from the weld development of 22mm tube-to-tube joints, provides robust proof of the shaping/forging action of the MIAB weld method. As mentioned on top of, booming MIAB welds rely upon the right bodily function of the contaminated liquid metal from the joint followed by shaping of the plasticized region so as to make intimate metallurgic contact. This leads to the diffusion needed to realize a sound solid-state weld joint. Figure thirty seven shows the results of sensible diffusion, namely, no proof of a definite bond line. From the results of SEM and optical microscopy are prepared for short conclusion.

TMAZ I contains bainite and two-dimensional polygon primary solid solution ferrite/acicular ferrite. TMAZ II contains slat/lath like higher bainite. TMAZ III contains granular bainite. TMAZ IV contains fine primary solid solution ferrite and lamellar mixture pearlite. Deformation throughout disconcerting affects the transformation of microstructure in weld interface (TMAZ I). All four TMAZs show higher hardness and TMAZ II has peak hardness because of presence of slat/lath like higher bainite. Due to bainitic transformation in TMAZ the samples show higher weld durability and malleability. Arc rotation current plays a big role within the formation of defect free weld interface. Lower arc rotation current causes science defects like void in weld interface, leading to the degradation of weld properties. However, the optimized values of arc current are going to be a section of exploration for various materials and dimensions.

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