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EXPERIMENTAL FOR THE EXPLOSIVE WELDING IN DIFFERENT TYPE STAINLESS STEEL MATERIAL

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ABSTRACT

Explosive welding is a process used for large surface area joining of dissimilar material with metallurgical bonding. Over the last few decades, a lot of work has been done in this field. This paper briefly presents the basic mechanism and detailed for weld different material and shows the cladding of these tow material and show the microstructure between them. Finally, the paper points out components with complex structure are the important development direction of explosive welding.

Keywords: explosive welding, micro-hardness test, impact test, microstructure test.

1. INTRODUCTION

The aggregate term welding can be characterized as the way toward joining two or more materials by limited combination or consideration over the interface. Amid this century enormous advances have been made and numerous new procedures presented from that point forward this joining procedure appeared to assume a vital part in industry. Be that as it may, selecting the proper welding procedure is a vital choice to be made.

From the innovation found in the mid-sixties was dangerous welding created as a generation device in industry, this technique has developed and has assume fundamental part in the compound, nuclear vitality, flying machine, space, cryogenic, power, power producing industry. This cladding moderately shabby, yet basically solid material, e.g. carbon steels with non-destructive, heat resistance and utilizing to bond structure of any material.
Besides, the capacity to join either comparative or disparate metal blends with high respectability security is viewed as the fundamental attractions of the dangerous welding.

Touchy welding, additionally called hazardous cladding, is a high-vitality process, in which strong surfaces of two metal segments of disparate or comparable materials are cladded by explosion vitality from angled high speed sway. The flyer plate hits the base plate immediately determined by the effect power, and the fast stream cleans the oxide film and adsorption layer on the metal surfaces, then the two clean metal surfaces contact with each other close under high weight, so the metallurgical holding is shaped [1].

Explosive welding includes materials science, blast mechanics, fluid mechanics, and some different subjects. Since American L.R. Carl was the principal who set forward the possibility of unstable welding, a considerable measure of hypothetical and test examines on hazardous welding have been done both home and abroad and numerous advancement and results have been made in system investigation [2].

It is the strong state welding process in which controlled explosion of a touchy is utilized to create a weld surface. This procedure is equipped for joining the huge surface range as because of the disseminating capacity of high vitality thickness accessible in the touchy over the welding territory. The metal plates are joined at an inward point bringing on significant neighborhood plastic twisting at the interface in which metallurgical holding happens in nature and much more grounded than the guardian metals [3]. The bond is framed because of the high-speed diagonal effect, and this effect helps in streaming activity. Streaming is the procedure which assumes an extremely indispensable part in joining of the metals plate, in flying activity the top surface of both the metals which contain non-metallic movies, for example, oxide which make snag for the development of the metallurgical bond are tidy up and help in smooth welding process. Protection of force is utilized to portray the holding component [4]. The weight must be adequate high and for an adequate period of time to accomplish between nuclear bonds.

The speed of the crash point administer the time accessible for holding, the nature of the bond relies on upon watchful control of the procedure parameters. These incorporate material surface planning, plate detachment, the hazardous burden, and explosion vitality and explosion speed [5]. Amid the hazardous welding the impact happen for a brief timeframe i.e. with in miniaturized scale sec, because of which dispersion process can't happen with in such a brief timeframe, which is the reason this strategy is generally connected in the creation of metal overlaid composite materials made out of different material [6].The first distribution to perceive the potential for producing metallic welding by utilizing violently determined plates showed up as a part of 1944 [7]. The main unstable holding patent connected with the business utilization of the system was issued in 1962 [8]. More than 260 different comparative and dis-comparable metal and composite blends can be welded by utilizing touchy welding strategies [9]. The two parameters i.e. plate speed Vp and crash speed Vc ought to be not as much as that of the speed of sound in either material to be welded [10]. It is for the most part perceived that for the flyer plate choice

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material with least thickness and ductile yield quality ought to be brought [11]. The touchy with explosion speeds more prominent than 120% of the sonic speed of the metal ought not to be utilized [12]. The weight sway at the crash point is commonly somewhere around 0.5 and 6 GPA [13]. The thickness of the unstable had a little impact on the bond quality while that of the stand-off separation was more persuasive despite the fact that the impact is little [14].

Explosive welding is of two sorts. The diagonal and parallel design, the slanted setup is appeared in Figure-1, this technique become an integral factor when the span of plate is dainty and little, yet when the plate is huge then parallel strategy is taken as appeared in Figure-2.

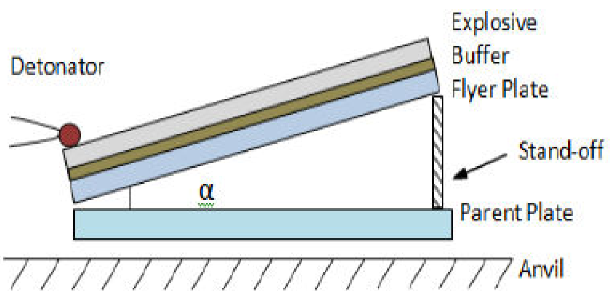

Figure-1. Oblique configuration [15].

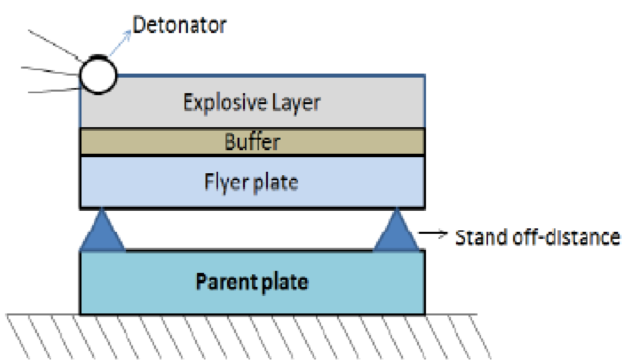

Figure-2. Parallel configuration [15].

In parallel method the plates to be welded are clean and polish very gently so as to form the good welding, in this process the base plate are keep at the ground in which the flyer plate is placed at top of it by the predefine distance called stand-off distance, the design of the stand-off should be able to bear and handle the load of flyer plate and explosive, above this buffer sheet is kept at the surface of flyer plate ,so as to protect the top surface from damage due to the shock impact of the explosive. Now the prepared explosive placed in a box structure design at the perimeter of the flyer plate is placed at the top of the flyer plate.

Then we can call that the explosive welding is cold pressure welding process, in this reported works show comprehensive information on small scale cladded combination in which an explosive welding windows are given and has successful results were obtained.

These clads are performed with different dimensions areas by using constant thickness for flyer and base plate, the material of the flyer plate is 304L austenitic stainless steel while that of the base plate is of carbon steel A516GR60.

2. EXPERIMENTAL WORKS

We used some equipment in this experimental work during and after the explosive cladding welding then we uses the following material are used during performing this work:

a) The flyer plate used are of the type austenitic stainless steel 304L, thickness 3mm with four dimensions in areas as (550x550, 650x650, 1000x1000, 2000x1000) mm^2
b) The base plates used are of the type C.SA 516GR60, thickness 14mm, with four dimension as (500x500, 600x600, 950x950, 1950x950) mm^2.
c) The anvil plates are of C.S. type A517Gr70, thickness 115mm with two dimensions (710x710, 2100x1100) mm2, however, beside the metal anvils, sand ground anvil is also used with lower cost as it can be leveled easily after each operation.
d) The Teflon spacers of 8mm outer diameter are used for separating the flyer and base plates by a specified stand-off distance.
e) The steel bolts of (M8x30) mm2 are used for an initial clamping of the base plates with the anvil steel block by using wire ties.
f) The wall packing of steel sheet (0.28) mm thicknesses are used for holding the flyer plate, the buffer sheets and the explosive materials. The height of the wall varied depending on the selected explosive layer thickness for each experiment.
g) The high pressure gasket (buffer sheet), of thickness 3mm with four dimensions and base plates during welding.
h) The electrical detonators type EK-40-69, are used for initiation the detonation processes.
i) The booster charges of high detonation velocities explosive are used in some tests for quick ignition and traveling the detonation waves at shorter time.

The mechanical, chemical and physical properties of the clad plates as shown in the table, where the material specified in different dimensions for explosive welding type.

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Table-1. Properties of the glad plates.

Material plates	**Dimension**(mm)	**Chemical composition**
Flyer plates	550x550x3 650x650x3 1000x1000x3 2000x1000x3	**Standard analysis**
ASTM-A240-304L austenitic heat resistance Chromium-Nickel Stainless Steel		0.03C, 2.0Mn, 0.04Pb, 0.03S, 18-20Cr, 8.0-12.0Ni, 0.1(max)N
		Experimental Analysis
		0.0153C, 1.654Mn, 0.0443Pb, 0.0131S, 0.7080Si, 18.53Cr, 9.462Ni, 0.2605Mo, 0.5492Cu, 0.0894V
Base Plates	500x500x14 600x600x14 950x950x14 1950x950x14	Standard Analysis
ASTM-A516GR60		0.18C, 0.6-0.9Mn, 0.035Pb, 0.04S(max), 0.15-0.4Si
		Experimental Analysis
		0.1679C, 0.7289Mn, 0.0194Pb, 0.0231S, 0.2020Si, 0.0030V, 0.0152Cu, 0.0457Ni

Table-2. Material properties with heat treatment.

Material properties	**Heat treatment**
Flyer Plates	Solution-annealed by heating to 1040 ^{o}C for an appropriate time followed by water or rapidly quenching.
Tensile Strength 485Mpa (min), Yield Strength 170Mpa (min), Elongation in 50mm 40% (min), Hardness Brinell 183(max).	
Base Plates	Tempering at 595 to 705 ^{o}C and Cooling in rates faster than in air.
Tensile Strength 380-515 Mpa(min), Yield Strength205Mpa (min), Elongation in 50mm 27% (min), Bending properties (similar to flyer material).	

2.1 Experimental welding arrangement

Parallel explosive welding arrangements are designed and used during the experimental work as shown in the diagram in Figure-1. The flyer plate is separated from the base plate by a specified stand -off distance which is controlled by using the Teflon spacers as mentioned before, with specified height for each experiment.

Furthermore, each flyer and base plates are prepared to high surface finish characteristics, however, along the time was spent to prepare the base plate's surface by using the sand blast and chemical treatments to obtain the required clean surface finish.

2.2 The MICRO-hardness tester

The automatic micro-hardness tester type METALLOX-2 survived for testing (Vickers and knop) using a diamond pyramid at 400 X or 500 X final magnifications at a preselected time of load. The specimens for the micro-hardness of a welded joint was prepared by machining (cutting, milling, grinding and high polished) to the finest (50X25) mm, with full clad thickness are examined for micro-hardness in a line perpendicular to interface layer of cladding plates as shown in Figure-3, Where 18 measuring points in one layer and multilayer (double, triple) clad plate thickness for each specimen with special care taken for interface zones. The distances between each two points are (0.2) mm at the interface and (0.5 to 1) mm for the nearest zones and (2-3) mm away of them.

The Vickers micro-hardness number HV in N/microm^2 is calculated from this equation:

$$HV = 185 \text{ X } 10^3 \frac{F}{D^2} \tag{1}$$

Where: F= is the loading force, D= is the diagonal of indentation

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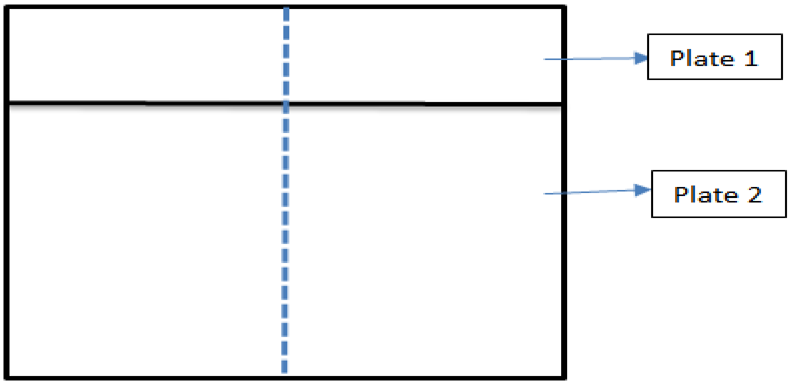

Figure-3. The micro-hardness measuring points for each explosive cladding specimen.

The test were carried out for each welding specimen as before and after stress relieving by using an electric furnace at 400 ^{o}C for 45 min and slow cooling inside the furnaces to remove any sort of residual stresses.

The calculated results are presented in the table before and after stress relief, to the stainless steel flyer plate and carbon steel for parent plate material as shown in the Table-3:

Table-3. Micro-hardness results from experiment.

Material	**Micro-hardness** (n/mm^2) **before stress relief**											
	Flyer plate					**Base plate**						
Tex=25mm D= 1.5mm	351	351	357	366	370	221	209	228	237	254	221	195
Tex=25mm D= 1.5mm	Micro-Hardness (N/mm^2) After Stress Relief											
	Flyer plate					Base plate						
	366	345	351	383	342	245	228	251	237	245	210	210

2.3 The impact (charpy) test

Impact tests indicate the behavior of material under conditions of sudden loading and to some extent measure its toughness. The impact specimen of (60X10) mm with full cladded thickness is shown in Figure-4 Where the two grooves are milled using a milling circular cutter of (1.6) mm thickness and the test was performed by using a 150J striking energy, the results from this test shown in the Table-4.

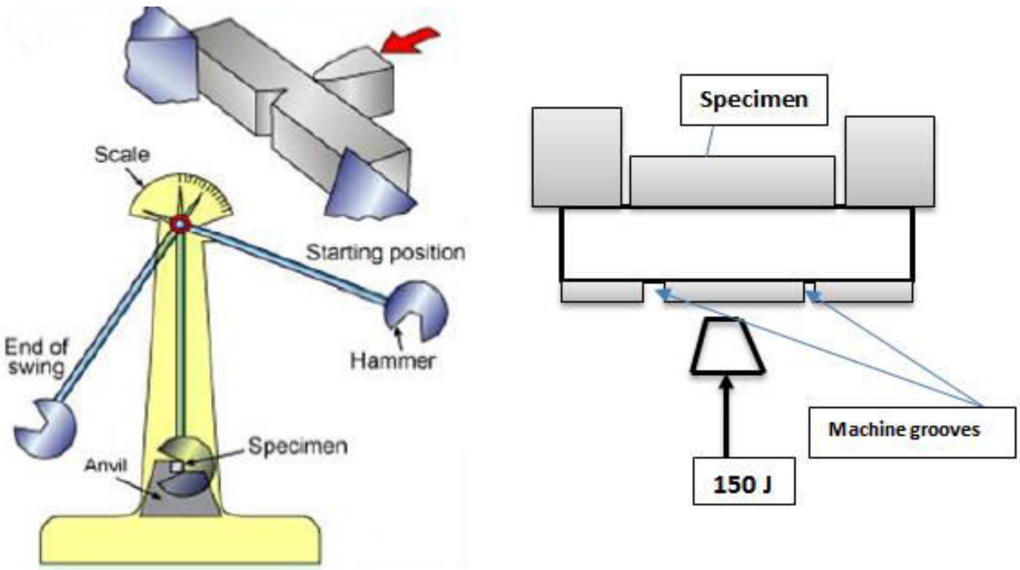

Figure-4. Impact test machine with specimen that it utilizes.

Table-4. Impact test results.

Experiment number	**Explosive thicknesstex** (mm)	**Stand-off distance d** (mm)	**Kinetic energy of** (150 J)	**Area under test** (mm^2)	**Impact test** (Kg /cm^2)
I	25	3	25	110	2.31
II	25	1.5	27	110	2.50

3. Results and work

The aim of this work is to investigate experimentally the effects of explosive welding parameters on the welded clads then we see from the experimental that the work is completed by successfully joined for constant flyer and parent plate thickness, And these schematic diagrams showing the results before and after welding tests.

These diagrams shows that the tensile strength are increasing when using sand anvil as the base plate acts as an anvil and reflects most of the tensile stress waves to interface region while the steel anvil shows lower amounts of ductilities due to high deformation process produced from the action of different direction of shock stress waves between all flyer, base, anvil plates surfaces.

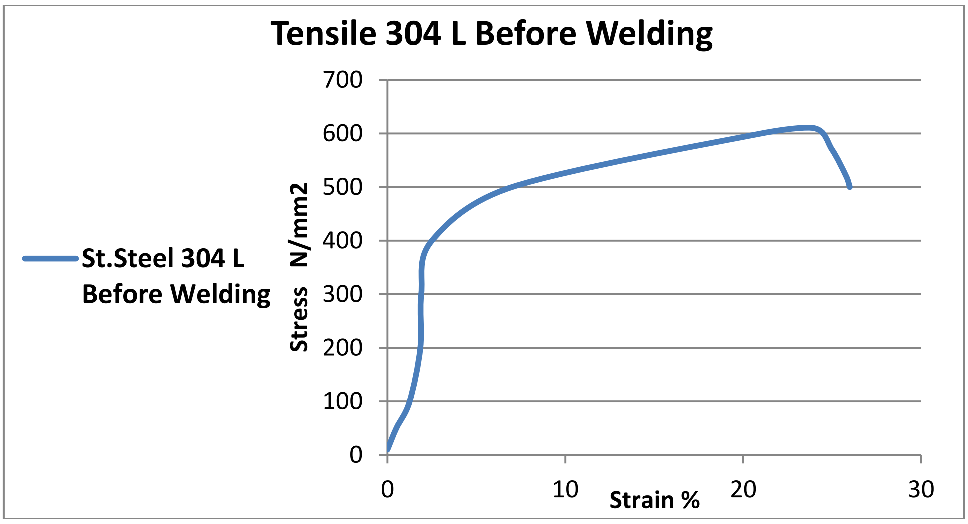

Figure-5. Tensile stress-strain curve for stainless steel 304 L material before welding.

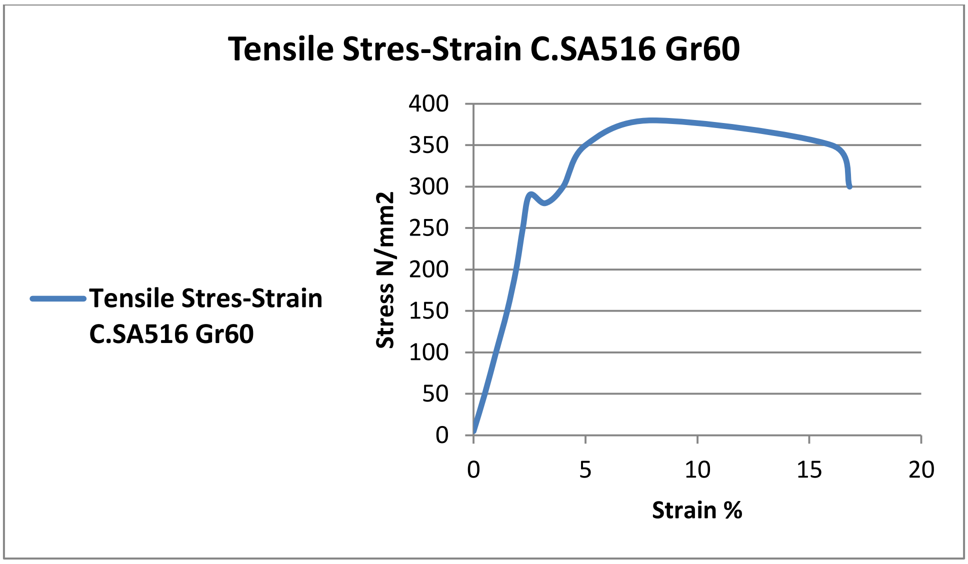

Figure-6. Tensile stress-strain curve for carbon steel A516 GR 60material before welding.

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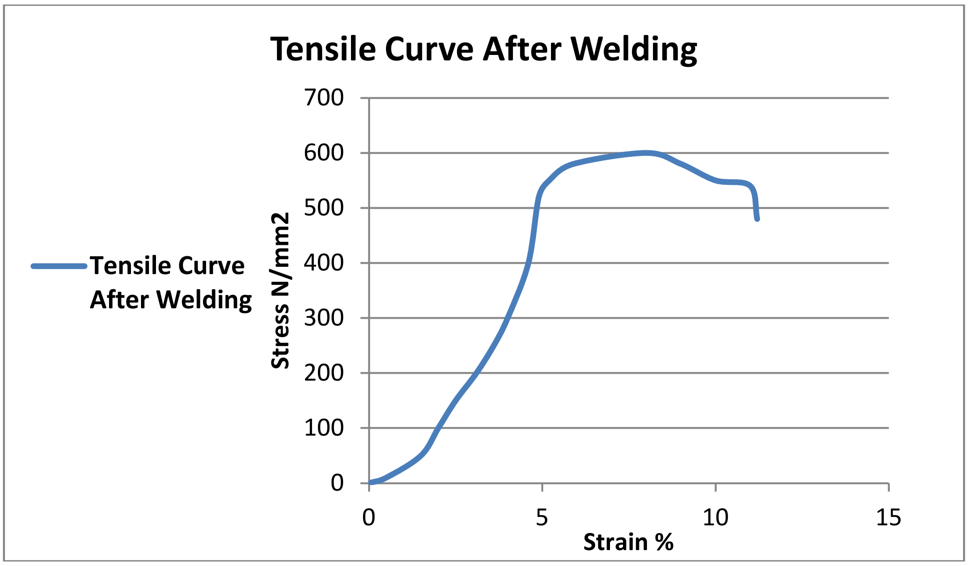

Figure-7. Tensile stress-strain for stainless steel 304 L material curve after welding.

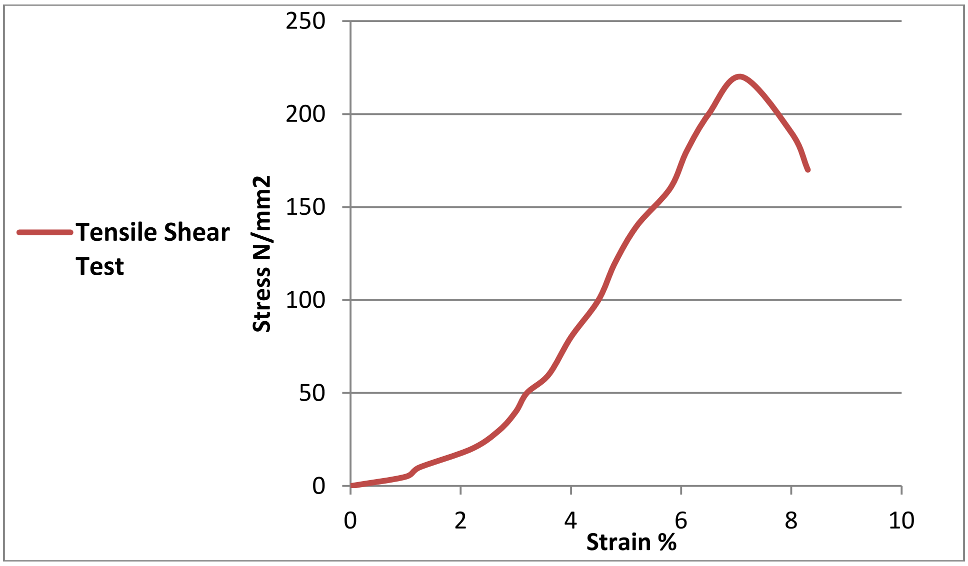

Figure-8. Tensile stress-strain curve for carbon steel A516 GR 60material after welding.

Then we can see the microstructure of the specimen before and after explosive welding shows the wave top in Figure-9 with higher magnification X200. Were a pocket of melting after the wave was produced containing a stainless steel material as its boundary, then Figure-10 Shows the wave dimension increase towards the base plate Figure-11 shows the original plate before welding.

Figure-9. The microstructure of the st.st. And carbon st.at its boundary after welding.

Figure-10. Wave dimension increase towards the base plate.

Figure-11. Original st.st. before welding.

CONCLUSIONS

The austenitic stainless steel is hardened adjacent to the weld interface by explosion welding, whereas the carbon steel is not hardened to a great extent impact strengths also can be reduced by the presence of the hardened zone at the interface, decrease hardness, and restored impact strength. It is clear from the results which were drawn on the above graphs that the micro-hardness increase in the level of hardness in the clad metal and backer steel and this clad section depend on the stress waves produced by the high intensive impact pressure.

A preliminary result indicate from the impact test a small decrease in impact resistance consistent and then shows the specimen was more brittle with increasing (d) and (tex).

We see from the picture of the microstructure for all welding propagation which are expected to be strong bond with amount of melting actions and the vortices is to be larger which may produce continuous melting layers and the wave boundaries consist of compressed elongated grains.

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