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Investigation of Strength of Butt Welded Joint In Ship Structure with Nanoparticles as Filler Material Using FEA

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Abstract: One of the most pivotal factor during construction of modern ships is to utilize high strength steels in order to obtain substantial weight reduction. The genuine joint capability, easy process, lowering fabrication price, as well as effective metal joining method is crucial in order to the production of engineering and structural components. Nowadays, there is great demand concerning lightweight but strong material joints which assists in ship construction. The weldment joint properties mainly depend on the filler composite of material. This paper studies about the strength of welded joints which utilizes different nanoparticles as filler material and judged with respect to different loading conditions through the conventional butt welding joint in ship structure. The AH36 steel is one of the standard high strength steels used for shipbuilding. The investigation of nanoparticle as filler material was carried out through finite element method, whereas conventional welding filler material grade 308LER was tested experimentally. Finite element method is utilized for analyzing mechanical properties of AH36 Butt joint by using nanoparticle (TiO2, ZrO2 etc.) as filler material.

***Index Terms* - Ship structure, welding strength, Nanoparticle (TiO2, ZrO2), FEM, UTM, TIG.**

I. INTRODUCTION

The AH36 is one of the most endorsed material in structural application such as shipbuilding, pressure vessel, nuclear reactor also aviation structure part due to excellent mechanical properties and good weldability. Adoption of welding techniques depends on based on the application of finalizing a product. The shipping industry is one of the oldest industries and still plays a vital role in our modern society [1-5]. Within a year ship had travelled approximately about seventy-five percent of the path to the moon and back towards earth. Structural failure in the ship is about 29.8 % [1]. Welding joints are an essential element in ship structure life. This process extensively utilizes hot-works method inside the shipbuilding industry. This joint strength depends on welding current, voltage, gas flow including method of joining, filler material used in the welding joint. Literature survey scrutinizes welding joints considering welding current, welding voltage, welding speed, material, a microstructure of welding joints, etc. [4-9]. In recent years focus has been on the microstructure of welded joints in ship construction application. For shipping corporations there is tremendous need for lightweight but strong welding joints inside marine construction which will reduce waste power as well as a structural failure. Therefore composite structures that are manufactured from different lightweight materials were introduced as using nanoparticles as filler material. It is necessary to investigate joint in ship structure with nanoparticles as filler material within weld to enhance ship structure life.

Welding system is joined by thermal process which operates by conducting electric current between welding zones to generate concentrated heat reservoir which welds or burns away steel and other metals. The residual stresses in welding depend on material property, a flow of heat source. The welding joint plays most important role in ship structure. The best strength of weldability and effective toughness of weld metals has been accomplished through intragranular acicular ferrite because of the increased thickness of high-edge limits [3]. Welding method works on two types: Fusion welding and Pressure Welding Processes, they include all variety of welding joints worked under the industrial sector. Fusion welding is more reliable as well as effective than it's counterpart. Structural welding joints consists of 80 percentage of Butt weld joint. The development of grain structure to a significant capacity in creating mechanical attributes (malleability and toughness) just as weldability [4].

Nanoparticle analysis is an intensified sensible research because of a wide assortment of potential applications in biomedical, optical and electronic field. Nanoparticles are of incredible logical precision as they are adequately a continuation between bulk materials also molecular structures. Those nanoparticles will have increasingly renewed interfaces so grain limit and density increase. The ZrO2 nanoparticles were altogether scattered in a water-solvent transition with energetic shaking and blended in the ideal extents with steady mixing in order to frame a slurry The welding joint strength increase due to strong pattern strengthening through the addition of titanium carbonitrides that would affirm to grain refinement [2].The particle size of nanomaterial is of nano-scale range as well as super-paramagnetic properties may be manifested by spinel ferrite nanoparticles. There are several approaches for attaining strengthening mechanisms but utilizing material matrix composites via nano-particle is optimum. . The titanium based material offers high quality, great consumption, and oxidation obstruction [7]. This research proves that by improving quantity of titanium oxide nanoparticles under terminal layer, tensile characteristics including influence toughness about welded sections is improved [3-7]. Residence regarding Al_2O_3 nanoparticles affects through an enhancement mechanical characteristics about Al/Al_2O_3 composite. The average size of nanoparticles is 50 nm inside A356 aluminum metal led toward significant enhancement within mechanical characteristics about composite [4]. For the development of welding strength generally, increase austenite content infusion zone.

In presence of small particles like nanoparticles there will be increase in the number of grain boundaries and that will in turn have an influence on the mechanical properties. This in turn will increase the hardness and yield strength of the elastic modulus as well as toughness. When there is decrease in the size of the particles, the nanoparticles will be more brittle. The hardening impacts that was introduced by incorporations with the increasing of nanoparticles filler element has straightly improved the durability of a structure because of inflexible filler [12].

II. MATERIAL SELECTION

Every metal and alloy filler consumables are to be utilized toward structural fragments to be recognized through classification society as per authorized structure designs as well as satisfy particular IACS associated terms. The welding quality improved because those possessed austenite essence developed. The addition of TiO_2 nanoparticles is useful in refining the ferrite grain size of the reheated microstructures metals will also improve a bending strength of the weld [3]. Grade AH36 high strength structural shipbuilding steel is optimum according to ASTM A131. Edge planning does conditional as per URW28 either another perceived standard acknowledged via classification society. TIG welding method implemented operated to provide high-quality performance during an excellent standard polish is obliged, without creating use of unnecessary clean up by sanding also grinding.

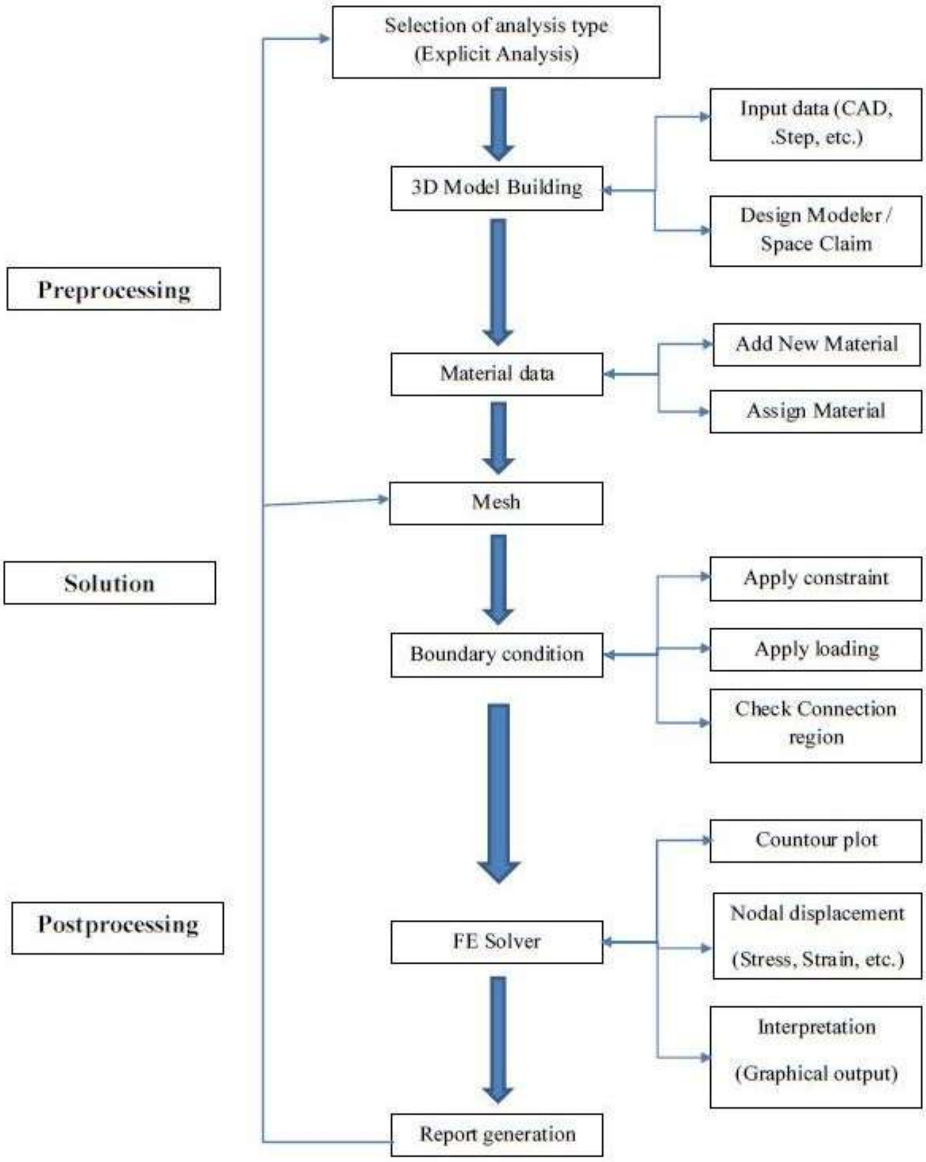


Fig. 1 Flow Diagram of FEM in ANSYS

FEA ensure automaton statistical framework toward discovering quality including the execution about creating structures which likewise foretells over item reacts to actuality situation, vibration, aqueous flow including environmental influences. They will reveal product failure, wear out conversely performance about an environmental situation it is called analysis. FEM includes conformity regarding point called “nodes” which create a specific geometrical pattern. Attached node do calculable ingredients themselves which form mesh which carries material also structural characteristics about CAD model within change establishes will act to explicit conditions. The mesh density can vary over the material and depend upon the predictable stress regarding the critical region.

Table 1: Material Properties

Material Properties	AH36	ZrO_2 Nanoparticles	TiO_2 Nanoparticles	Al 5028	308 LER
Density (Kg/m3)	7800	5680	4230	2660	7750
Young Modulus (MPa)	$2e^4$	$2e^5$	$288e^3$	$71e^3$	$2e^4$
Poisson ratio	0.26	0.3	0.29	0.35	0.3
Yield Strength (MPa)	350	2000	680	228	450
Melting Point (°c)	-	2715	2123	-	-
Boiling Point (°c)	-	4300	2972	-	-

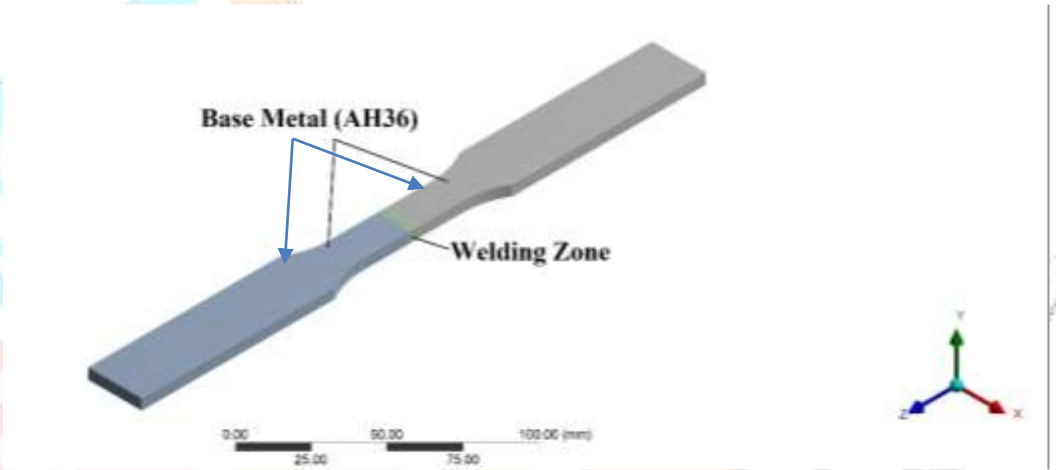


Fig. 2 CAD Model of Welded Tensile Specimen

ANSYS software allows to determine complicated structural engineering problems while also making excellent, faster design conclusions. Mesh density varies over the material and physical properties depending upon forecasted variation into stress levels concerning specific area. Areas of expertise important variations under stress normally demand to dense mesh quality since small either none stress variety.

III. DESIGN AND DEVELOPMENT TENSILE SPECIMENSELECTION

The designed tensile specimen is in accords to ISO 1604:2008. The tensile specimen is conceptualized with dimensions of 263×25×5 mm. Welding zone is selected based on the parameter of material thickness according to AWS (American welding Society). The edge preparation regarding welding joint is crucial element which depends upon thickness of sheet, length of the weld, welding technique and application of the product. The edge preparation of weldment lead to good quality of joint as well as several passes utilized to fabrication.

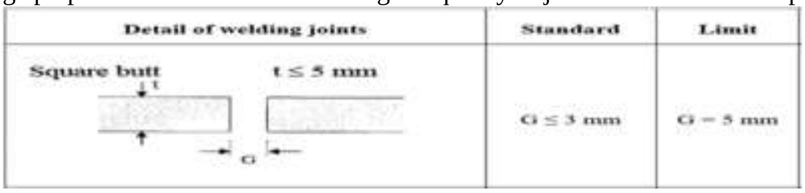


Fig. 3 Edge planing of Butt-welding joint

The edge planning regarding a butt-welded joint is as designated by URW28. It is accepted by an organization and exhibited in fig. 3.Tensile model compromises of hexa element for meshing. The 3576 node and 2105 element within mesh model. The Specimen is fabricated by using laser cutting due to its higher precise dimensional necessity. The AH36 material is used as base metal and filler material is 308LER. TIG welding procedure is one of the demanding and quickest methods utilized within aviation as well as marine organization. The dilution in mild steel is more in TIG welding as compared to MIG welding. The presence of oxygen and nitrogen within heat influenced zone will result in increases in TiO_2 nanoparticle content in the electrode coat [3]. During fabrication of welded tensile specimen by TIG welding technique is exercised via a welding current of 240 amps, the gas flow 7 Lt/min also speed of welding 98 mm/min. All welding is completed in a single pass as directed by AWS standard. The function of a direct current energy reservoir implies to convey 70 % concerning the intensity about heat toward the anode. Welds all in all demonstrated low ductility contrasted with that of the base metal [11].

Fig. 4 Physical Model of Tensile Specimen

Fig. 4 presents the fabrication design of a tensile specimen. Fabrication of 6 units of base material AH36 and 308LER filler material is done.

IV. RESULTS AND DISCUSSION

The weldment attributes are modified by welding technique also parameters utilized for its creation. The hardness created by utilizing a number of the welding pass. The addition of TiO_2 nanoparticles credited decline grain microstructure The most beneficial outcomes in welded analyses is due to four-pass sample in which the acquired strength differentiated with a conventional aluminum joint of without TiO_2 nanoparticles has developed around 40 MPa [7].

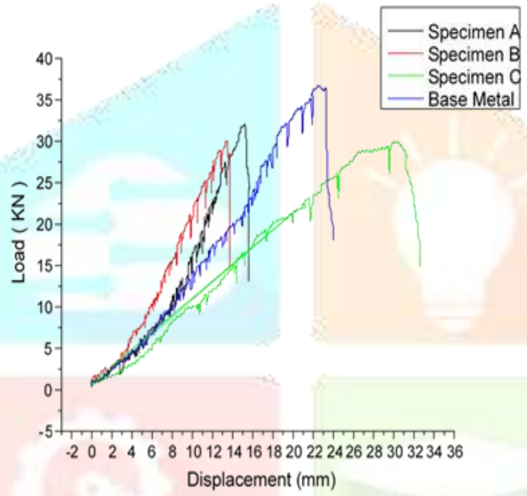


Fig. 5 Load (KN) Vs Displacement (mm)

Fig. 6 Weldment failure within the HAZ region

The graph indicates that if welded tensile strength is less in comparison to base metal tensile specimen. The tensile specimen examination loadings applied 0, 2, 4, and 6% of total filler material weight. The researcher remarked to optimize the strength of joint at 4% material of SiCNP and MWCNTs mixture with conventional filler material. Composite among SiCNP filler accomplished the most elevated estimation of strength and Young's modulus at concerning 11% and 4%, individually when contrasted with conventional filler material [12].

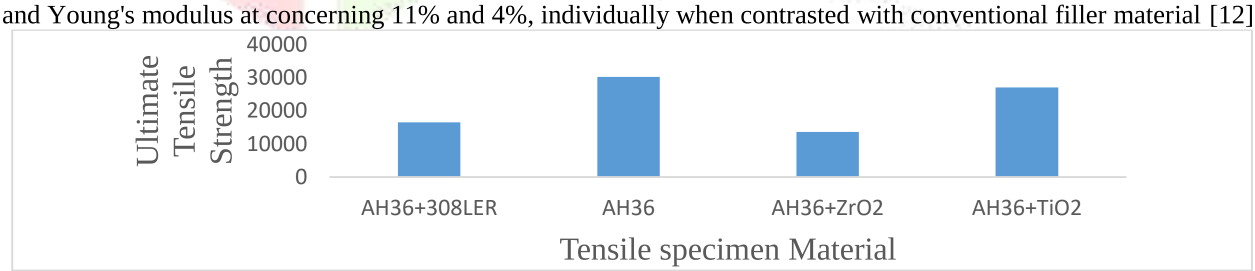
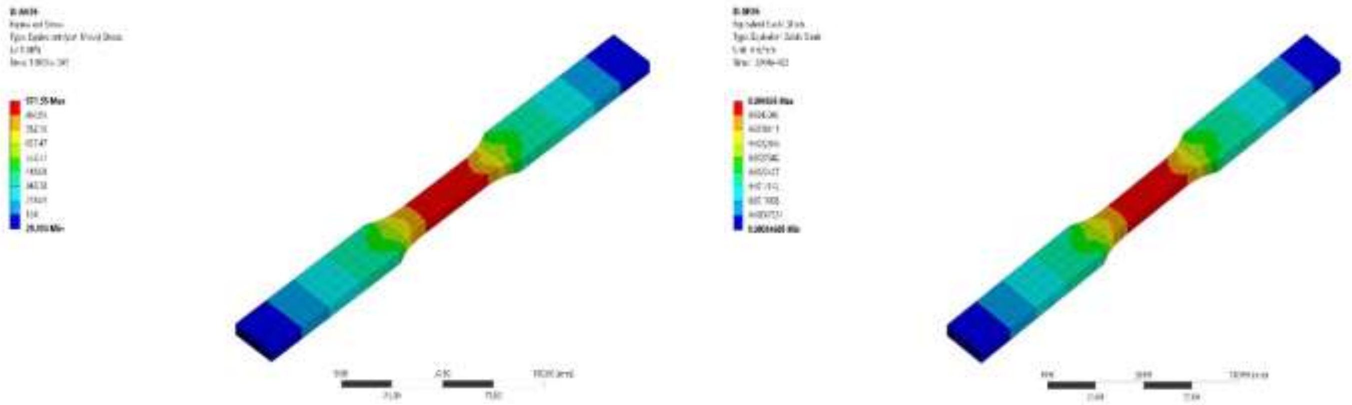


Fig. 7 Ultimate Tensile Strength of Filler Material

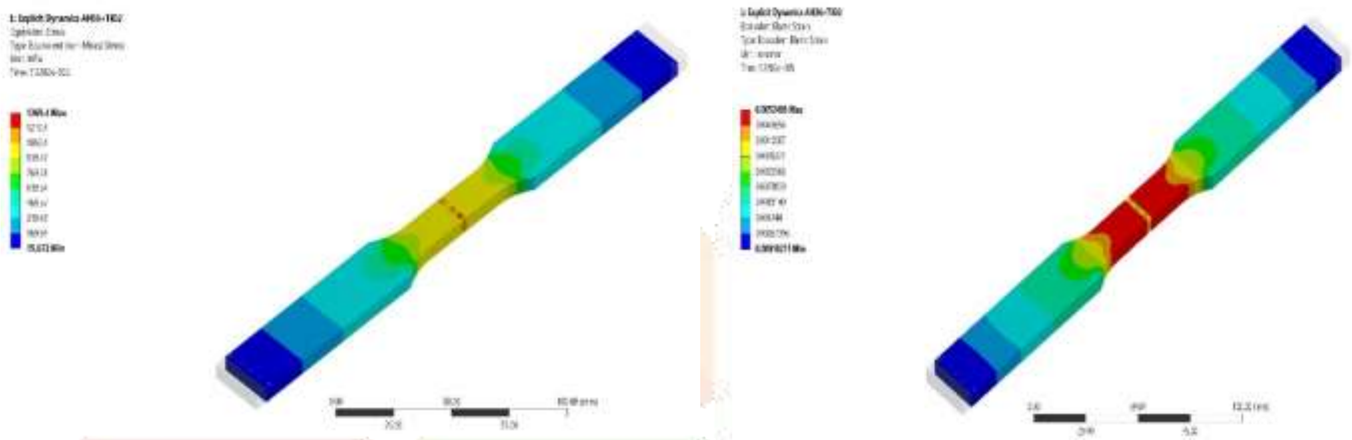
During strength examination, specimen alignment and gripping is most important. The gripping and misalignment of specimen influences on attribute of results. The perfect hold appearance ought to equivalent width as that strip surfaces of a specimen; except if identical order survives covering experience regarding critical master. From fig. 7 it is concluded that TiO_2 as a nanoparticles filler material exhibits higher ultimate tensile strength than its counterpart 308LER at the same operating conditions. The reason for this variation if because the grain structure of TiO_2 is fine.



(a) **(b)**

Fig. 8 Explicitly dynamic analysis of AH36 material in ANSYS

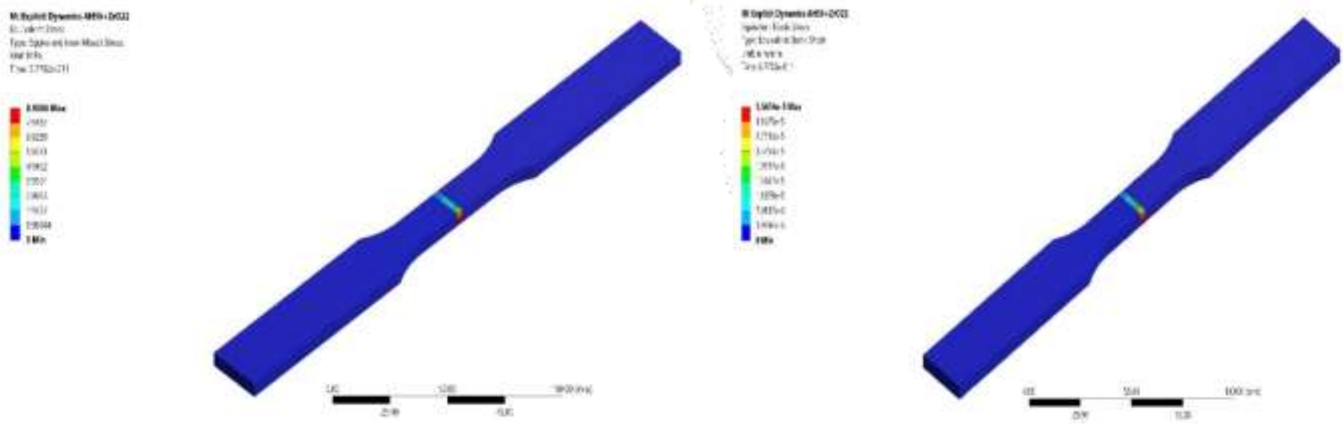
The Fig. 8 (a) indicate that equivalent (Von-Mises) stress of AH36 Base metal tensile specimen is 971.55 MPa and Fig. 8 (b) shows that maximum equivalent strain is 0.004858.



(a) **(b)**

Fig. 9 Explicitly dynamic analysis welded tensile specimen of AH36 and TiO_2 Nanoparticles

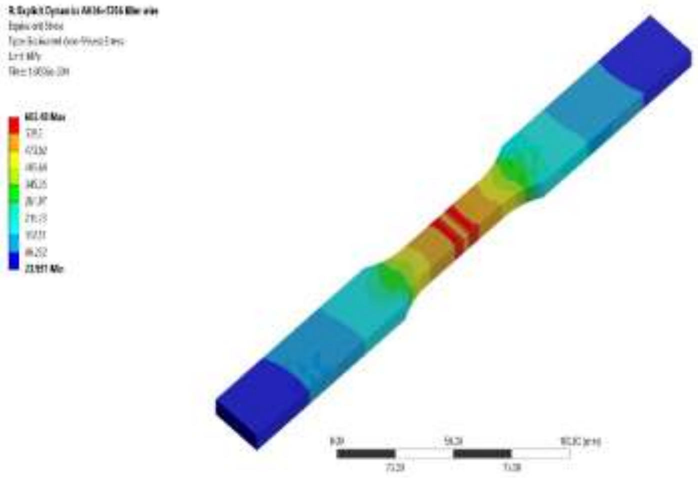
Fig. 9 (a) stipulates that maximum equivalent (Von-Mises) stress of TiO_2 nanoparticles as filler material with base metal AH36 is 1369.4 MPa and Fig.9 (b) indicates that maximum equivalent strain is 0.0052405



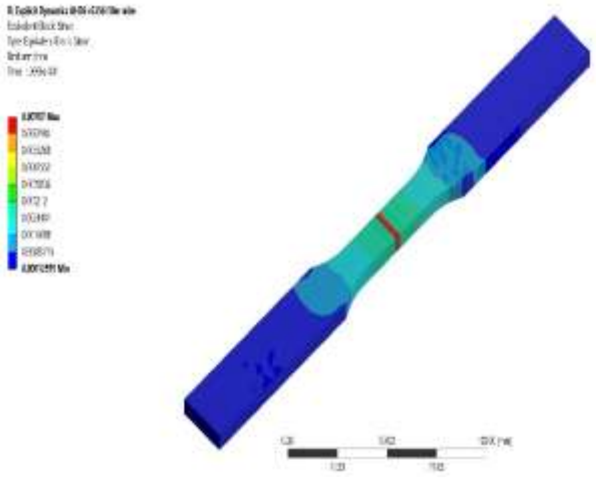
(a) **(b)**

Fig. 10 Explicitly dynamic analysis welded tensile specimen of AH36 and ZrO_2 Nanoparticles

Fig. 10. (a) show that equivalent (Von-Mises) stress of ZrO_2 nanoparticles as filler material is 8.9086 MPa and fig. 10. (b) depicts that maximum equivalent strain is 3.5634e-5



(a)



(b)

Fig. 11 Explicitly dynamic analysis welded tensile specimen of AH36 and 5356 Wire

Fig. 11 (a) stipulates that maximum equivalent (von-Mises) stress of 5356 Filler Wire as filler material with base metal AH36 is 602.48 Mpa and Fig. 11 (b) indicates that maximum equivalent strain is 0.00707. The literature survey indicates that increase in Ti will result in decrease of Mn and Si within weld pool. The above analysis shows higher stress concentration within the fusion zone that replicate the probability of the failure zone.

Brittleness is attained by breaking with low vitality under effect. Within heat affected region, material has brittle characteristics since the possibility of failure under this region rises [11]. As per FEA examination, stress convergence of nanoparticles as filler material was tremendously high when contrasted with regular filler material.

V. CONCLUSIONS

The purpose of this study is to analyze the strength of the welding joint using nano-particles. During this study, the different filler materials and mechanical properties are studied. In order to increase the strength of the weld, FEA of nanoparticles TiO_2 and ZrO_2 is carried out. The conventional filler material E308L is analyzed experimentally to check the strength of butt weldment. The comparative studies of FEA and experimental results are carried out. The following conclusions are drawn from the study,

- It has been observed that failure of the tensile specimen occurs at welding regions.
- As there is a decrease in the grain size of filler material, it leads to hampering the hardness of weld. To maintain the hardness the filler material optimized grain size should be selected.
- The obtained FEA and experimental results prove that the strength of TiO_2 nanoparticle as a filler material is more than conventional filler material.
- This evaluation provides the guidelines on the strength of the weld and states that the grain size, shape and size of nanoparticle and the volume of nanoparticle have a major impact on the strength of welding joints and its mechanical characteristics.

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