World Academy of Science, Engineering and Technology
International Journal of Economics and Management Engineering
Vol:9, No:10, 2015

Enhancement of Fracture Toughness for Low-Temperature Applications in Mild Steel Weldments

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Abstract : Existing theories of Titanic/Liberty ship, Sydney bridge accidents and practical experience generated an interest in developing weldments those has high toughness under sub-zero temperature conditions. The purpose was to protect the joint from undergoing DBT (Ductile to brittle transition), when ambient temperature reach sub-zero levels. Metallurgical improvement such as low carbonization or addition of deoxidization elements like Mn and Si was effective to prevent fracture in weldments (crack) at low temperature. In the present research, an attempt has been made to investigate the reason behind ductile to brittle transition of mild steel weldments when subjected to sub-zero temperatures and method of its mitigation. Nickel is added to weldments using manual metal arc welding (MMAW) preventing the DBT, but progressive reduction in charpy impact values as temperature is lowered. The variation in toughness with respect to nickel content being added to the weld pool is analyzed quantitatively to evaluate the rise in toughness value with increasing nickel amount. The impact performance of welded specimens was evaluated by Charpy V-notch impact tests at various temperatures (20 °C, 0 °C, -20 °C, -40 °C, -60 °C). Notch is made in the weldments, as notch sensitive failure is particularly likely to occur at zones of high stress concentration caused by a notch. Then the effect of nickel to weldments is investigated at various temperatures was studied by mechanical and metallurgical tests. It was noted that a large gain in impact toughness could be achieved by adding nickel content. The highest yield strength (462J) in combination with good impact toughness (over 220J at – 60 °C) was achieved with an alloying content of 16 wt. %nickel. Based on metallurgical behavior it was concluded that the weld metals solidify as austenite with increase in nickel. The microstructure was characterized using optical and high resolution SEM (scanning electron microscopy). At inter-dendritic regions mainly martensite was found. In dendrite core regions of the low carbon weld metals a mixture of upper bainite, lower bainite and a novel constituent coalesced bainite formed. Coalesced bainite was characterized by large bainitic ferrite grains with cementite precipitates and is believed to form when the bainite and martensite start temperatures are close to each other. Mechanical properties could be rationalized in terms of micro structural constituents as a function of nickel content.

Keywords : MMAW, Toughness, DBT, Notch, SEM, Coalesced bainite
Conference Title : ICEM 2015 : International Conference on Engineering Management
Conference Location : Chicago, United States
Conference Dates : October 08-09, 2015