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New Process to Girth Weld Pipe With a Gasless Technology

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Abstract

A new process to girth weld pipe is presented. This semi-automatic gas-less process combines the innovations in controlling the power input through an inverter-type machine along with microstructure control of the weld metal deposited to achieve high strength (over matching 550 Mpa Yield Strength) and Charpy V-Notch toughness of over 60 Joules at -20 deg C.

With recent advances in development of high strength (>690 MPa yield strength) steels, there is a great impetus to build pipelines and off-shore structures with such steels. The trend toward stronger, tougher materials allows thinner sections to be used to reduce the costs associated with construction of oil and gas pipelines. Most off-shore structures require pipe joints to be girth welded in the 6G-R position, often in windy and hostile environments. The mechanical property requirements of the weld metal for off-shore applications are very stringent with superior fracture toughness requirement. These requirements become difficult to meet with traditional welding processes for welding high strength steels.

For these reasons a welding process that produces clean weld metal, with microstructure that provides superior toughness at service temperatures and without the costs and complexities associated with shielding gas is especially attractive for this application.

This paper will concentrate on the metallurgical aspects of the weld metal and the systematic steps taken to achieve high strength weld metal without sacrificing toughness. The results show that this is a practical and unique solution that minimizes the contamination from the environment by controlling the power input to the arc. The design of a slag system that maximizes the cleanliness of the weld metal to achieve acceptable toughness is also discussed. The results provide evidence to show that a 15% overmatch in yield strength of API Grade X-80 pipe without sacrificing productivity or toughness is possible.

Introduction

With recent advances in development of high strength (>690 MPa Yield Strength) steels, there is a great impetus to build pipelines and off-shore structures with such steels. This trend, going to stronger, tougher materials in thinner sections, is inevitable for pipelines, in particular with the increased emphasis on energy and the costs associated with transportation of oil and gas (1). All transmission pipelines are built under field conditions(off-shore and on-shore), often in remote locations, and girth welds joining two pieces of pipe require out-of position welding. For these reasons a welding process that does without the costs and complexities associated with shielding gas is especially attractive for this application.

BACKGROUND

Self-Shielded flux cored arc welding consumables (FCAW-S) have been used for welding pipelines, off-shore structures, bridges and general purpose fabrication for over 40 years (2). The Lincoln Electric Company pioneered this process where welding is accomplished semi-automatically without the necessity of flux or shielding gas (3). The FCAW-S process is not as "clean" as FCAW-G or SAW processes. Due to the absence of any external protection from the atmosphere, the nitrogen and oxygen levels in FCAW-S systems are functions of the nitride and oxide forming scavengers added to the electrode to prevent porosity and the level of exposure of the arc and the weld pool during welding. Long arc lengths in traditional FCAW-S designs have historically been the road block to achieving acceptable ductility and toughness. While gas shielded flux cored arc welding (FCAW-G) and Submerged arc welding (SAW) processes produce nitrogen levels of 40-80 ppm in the weld metal, nitrogen in welds produced with FCAW-S electrodes are an order of magnitude higher (200-300 ppm) in nitrogen. Such high nitrogen levels in ferritic steel weld metal have limited consumable manufacturers to shy away from developing FCAW-S electrodes for high strength applications. The intentional alloying for weld metal protection in FCAW-S designs involves addition of elements like aluminum, magnesium, titanium and zirconium which are much more reactive than iron in forming oxides and nitrides, thus protecting the weld metal in the arc and during solidification (4,5). While magnesium does not have any appreciable solubility in iron, titanium and zirconium drastically affect the hardenability of the weld metal. They are generally used in very small amounts. Aluminum's effect on the phase stabilities is dramatic. The effect of aluminum on weld metal properties has been studied by several authors (6-9).