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Investigation on the Weldability of High-Strength Steels Used for Low-Temperature Environment

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1. INTRODUCTION

With the development of oil and gas exploitation and auxiliary building rising, the pipeline construction and the corresponding station construction are gradually transferred to the deep sea and polar regions. The temperature of the steel material service environment can reach -40°C, or even lower. Thus, the low temperature performance of steel materials has been put forward higher requirements. For example, in Russia, the longitudinally submerged arc welded (LSAW) pipeline in the Bovanenkovo–Ukhta project [1] was recently constructed with K65 steel (the highest grade of the Russian natural gas pipeline), which is similar in specifications and yield strength requirement (550 MPa grade) to API X80 but has a stricter low temperature toughness value of 60 J at -40°C (compared to -20°C for API X80 grade [2,3]) due to the extreme Arctic environment. The requirement for low temperature toughness of weld joint has been a great challenge, especially the weld metal of bending pipe. Thus, the low temperature toughness of the weld metal (WM) has been asked a governing parameter in the overall toughness performance of the pipeline optimal.

Previous studies [4-6] suggested that there are two major approaches to improve the low temperature toughness of weld metal. One is to use different types of fluxes and the other is to change WM composition either through the use of newer filler materials or by metal power additions in WM. Therefore, it is very significant to improve the low temperature toughness of weld joint through reasonable design of the alloy composition for welding wires. Moreover, welding parameter's setting and post-weld heat treatment (PWHT) are also very important. Preheating temperature and interpass temperature, welding heat input and plate thickness, can influence the welding thermal cycle so that the microstructure and mechanical properties of weld metal will be changed [7-9]. Once the brittle microstructure formed in weld metal, it seems that a significant improvement in toughness cannot be achieved through optimization of the conventional heat treatment (tempering treatment) process [10]. In order to elucidate the above problem in the present studies, welding wires preparation was first completed and the effect of alloy composition on the low temperature toughness of weld metal was studied. Second, the effect of welding parameter (i.e., interpass temperature) on the microstructure and toughness of multi-pass weld metal was investigated and the mapping of multi-pass weld metal microstructure evolution was shown. Last but not the least, a new PWHT that could significantly improve the low temperature toughness of multi-pass weld metal was successfully designed.

