SPC1. Prevention of Fatigue Cracking in Structural Steel Welds

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Introduction

To stay competitive in today's industry, better and cheaper materials are needed. These materials also have to support more demanding conditions. In the design of cyclically loaded welded structures, it is the fatigue strength of the joints the one that will dictate the fatigue strength of the whole piece. The presented project addresses this problem by developing a weld metal that by means of phase transformations can induce a compressive residual stress. This residual stress state will make the nucleation of fatigue cracks more difficult effectively increasing the fatigue strength of the welded joint.

Technical Approach & Results

When a weld joint cools down to room temperature, there is a net change in its volume. This volumetric change has two main components: the thermal contraction due the lowering of the energy state and a component related to the phase transformations associated with the materials employed. During the austenite-martensite transformation in steels, there is a well known volumetric expansion. If the transformation occurs in the latter stages of cooling, this expansion can counteract the effects of the thermal contraction and as a result induce a compressive residual stress. This residual stress state reduces the possibility of fatigue cracks being nucleated at the weld toes effectively increasing the fatigue strength of the joints. Unfortunately, having the martensitic transformation is not enough to obtain a better performance. The geometry of the weld is also very important since any abrupt transition between the weld and base metals can produce a stress raiser that easily can override the effect of the compressive residual stress. To avoid that, silicon was employed to produce weld metals with improved fluidity that can result in welded joints with a smooth transition between the weld and base materials.

Conclusions

Manganese and Chromium additions were used to effectively modify the martensite start temperature to a point where the weld metal starts its transformation in the latter stages of cooling and finish over room temperature. Different Ms resulted in different residual stress states. A relatively low cost weld metal that maximizes the fraction of transformed martensite and avoids the formation of harmful phases was developed. Weld metal fluidity problems were solved by silicon additions. The proper selection of welding parameters allowed the production of welded joints with good morphology and penetration that induced compressive residual stresses at the weld toe.