

Effect of weld geometric profile on fatigue life of cruciform welds made by laser/GMAW processes

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Abstract

The effect of weld geometric profile on fatigue life of laser-welded HSLA-65 steel is evaluated. Presented are results of cruciform-shaped fatigue specimens with varying weld profiles loaded cyclically in axial tension–compression. Specimens with a nearly circular-weld profile were created at 133 cm/min, as part of this effort, with a hybrid laser gas-metal-arc welding GMAW (L/GMAW) process. The ability of the laser-welding process to produce desirable weld profiles resulted in fatigue life superior to that of conventional welds. Comparison of finite-element analyses, used to estimate stress-concentration factors, to the hot spot and mesh insensitive approaches for convergent cases with smooth weld transitions is presented in relation to the experimental results. When a geometry-based stress concentration factor is used, the fatigue tests show much less variability and can be lumped into one master curve.

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1. Introduction

Fatigue life of a weldment is influenced by the material, environment, welding techniques, weld quality, connection details and the geometric profile of the weld. Welded

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joints are regions of stress concentration where fatigue cracks are likely to initiate. Geometry is one of the primary factors that control the fatigue life. Accordingly, procedures that improve weld geometric profile by reducing stress concentrations will have a beneficial impact on fatigue life. Most fatigue-life improvement methods implemented to date are post-weld operations. Kirkhope et al. [1,2] discusses methods of improving fatigue life in welded steel structures by operations such as grinding, peening, water-jet eroding and remelting. They stated that use of special welding techniques applied as part of the welding process in lieu of post-weld operations are attractive because the associated costs are lower and the quality control is simpler. Demonstrated in this paper is the use of a combined laser and gas-metal-arc welding (GMAW) weld procedure that results in a substantially improved geometric profile of a longitudinal fillet weld. The improved weld profile results in lower stress concentrations without the need of post-weld operations.

Laser welding is a relatively new technique that has potential to achieve excellent fatigue resistance, especially when used in combination with other more traditional welding methods such as GMAW. Good control over weld profile is demonstrated when a laser and GMAW processes (L/GMAW) are used together. Laser welding is a high-energy density process that can be used on a wide variety of metals and alloys. The automotive industry has used laser welding in production since the 1980s. Recently, the ship-building industry has looked toward laser welding to provide fabricated components in ship production. Original laser welding for ship structures utilized CO₂ lasers with up to 25 KW power. Current manufacturing systems are looking toward use of state-of-the-art ytterbium fiber lasers with power rating up to 10 KW. Also, much hope is placed in laser techniques to economically weld other structural components such as sandwich panels. The work presented in this paper is part of an ongoing effort to quantify the fatigue life of laser-fabricated shapes for use in naval vessels.

Some of the advantages that can be achieved through laser welding are ease of process automation, high welding speed, high productivity, increased process reliability, low distortion of the finished part and no requirement for filler metal. With current laser-welding techniques it is possible, as described by Duhamel [3], to achieve full-penetration welds in one pass on materials up to 1-in thick, depending on laser power and weld speed, with no filler and preparation as simple as precision cutting of the edges. In addition, distortion of the finished component is significantly less than distortions measured in conventionally welded or hot-rolled shapes. Even though filler material is not required in all cases to achieve a sound full-penetration weldment, lack of filler may cause undue stress concentrations due to the geometry of the joint, especially if a sharp radius or reentrant corner exists. These stress concentrations can substantially reduce fatigue life of a high-quality full-penetration weld, solely due to the geometry of the weld profile. The combination of laser welding with other processes such as GMAW, which is used to add filler material, can dramatically improve the weld geometric profile. Accordingly, the improved weld geometry results in lower stress concentrations and hence improved fatigue life.

Fatigue strength of laser-welded joints can be markedly different than that of conventional welds. Therefore, an experimental program was undertaken to assess the fatigue resistance of laser-welded joints to be used in beam fabrication. Tests were used to quantify the actual fatigue life of welds that were laser fabricated with various weld geometric profiles, using differing process parameters. Another objective of this effort is to compare the current results to existing methods used in analyzing fatigue life. The current

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