E. Hybrid Laser + GMAW Process for Fatigue-Resistant Welding

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Introduction

A primary issue of concern in fabrication of some steel structures is reliability under fatigue loading conditions. Welds with a sharp toe angle are undesirable under dynamic loading due to high stress concentration in this region, a factor which often determines weld fatigue strength. Therefore, a shallower wetting angle in the toe region is required to achieve reliability. If more heat input could be shifted to the edge of the weld pool, it would be expected that the toe angle would become shallow and not act as a stress riser. Therefore, the hybrid welding process was configured by applying the additional laser heat a substrate onto the substrate at the edge of the weld pool to improve wetting and spreading characteristics. With such a hybrid GMAW process, heat input can be tailored for a wide-shallow thermal field that will promote the widest possible weld deposit with minimal heat input.

Procedure

A preliminary hybrid process study was carried out for stationary welding, simultaneously applying the laser heat adjacent to the arc weld deposit so as to spread the molten metal over to the laser heated spot. The second phase of the work was undertaken to develop the traveling hybrid process for producing tee-joint fillet welds for fatigue test specimens of ½ inch-thick A572 Gr50 high-strength low-alloy columbium-vanadium structural steel. Two welding positions, 2F and 1F, were used. As shown in Figure 1, the laser beam was applied to only one toe of the weld, although weld toe angle improvements were noted for both sides of the weld. The fatigue test specimen, optimized VP-GMA arc heat input, wire feed rate, and travel speed were designed to provide comparison with prior fatigue data. Laser heat input and the location of the laser spot were determined based on the first phase results in order to improve the toe angle for the fatigue test specimen for both weld positions (1F and 2F). These cruciform fatigue test specimens were tested under the longitudinal dynamic loading.

Results and Discussion

The power supply VP waveform was tuned for 65% polarity balance for welding the tee joint specimens. The arc heat input efficiency of the 65% polarity balance waveform was about 78%, which is close to that of a conventional CV GMA welding process. This relatively high heat input condition was necessary to produce fillet welds with had adequate root penetration.

First, the 2F position was used with the hybrid process to produce the fatigue test weld specimens. The toe angles of each specimen were between 130 and 150 degrees. However, these toe angles are generally smaller than those known from prior work to produce the best fatigue results (close to 180 deg.). Thus, fatigue life of the 2F position hybrid welds were about equal to the mean fatigue life contained in BS 7608 Class F as shown in Figure 2. Since the fatigue tests of the 2F weld position samples didn't produce the desired results, it was necessary to change welding position from 2F position to 1F position to obtain better toe angles. The wetting angle in the hybrid weld toes made in this position were almost 180 deg. and the fatigue test results were considerably improved over the previous 2F-position welds as shown in the Figure 2. Here, the current test results are compared to previous weld data and to the British Standard BS 7608 Class F weld fatigue design and mean curves.

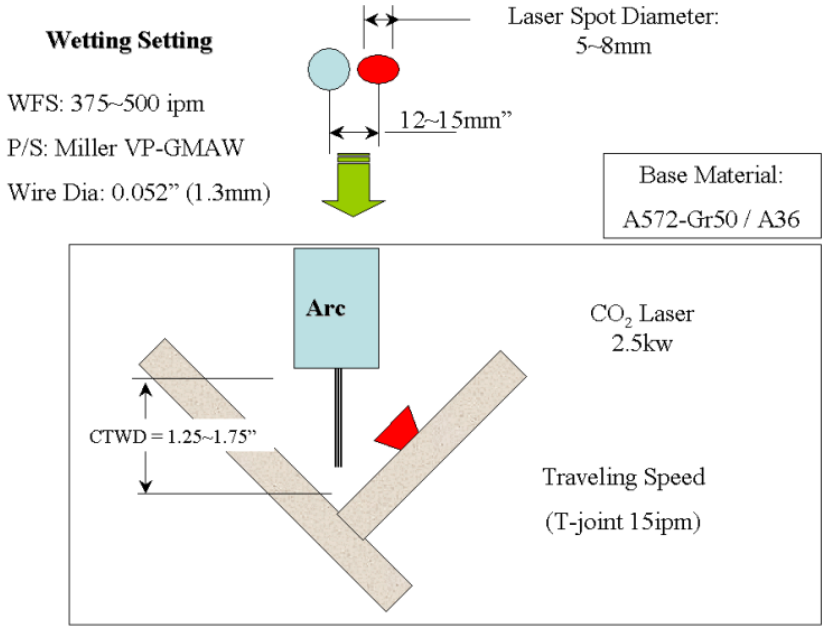

Figure 1. GMAW Torch and Laser Setup Window for 1F Position welding

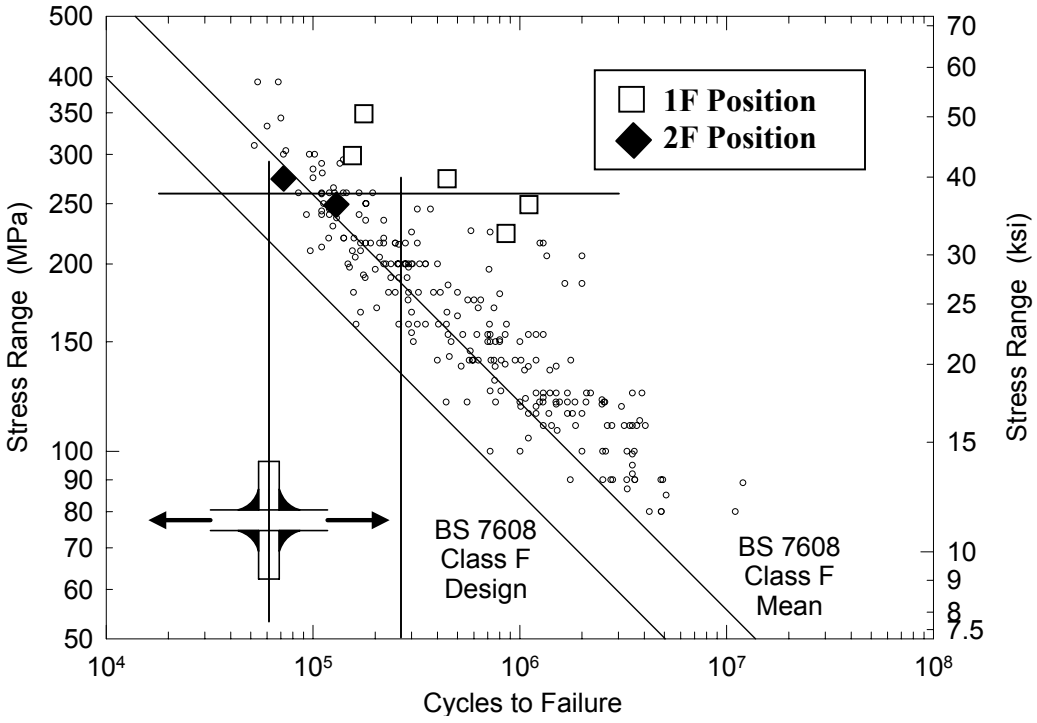

Figure 2. Fatigue Life Comparison between Hybrid Weld and BS7608

Conclusions

A hybrid (Laser + VP-GMAW) welding process was developed to produce high fatigue strength welds. Stationary hybrid weld tests and simulations helped to provide the insight into welding parameters 1F position welding was utilized to produce the fatigue test specimens with almost 180 deg. toe angle. The fatigue results were in the desired range.