Effects of Longitudinal Vibration on Tensile Properties of Weldments

Improvements in tensile strength were realized in welds vibrated at amplitudes of 5 to 30 µm, but elongation suffered under the same conditions

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ABSTRACT. This paper presents the effect of longitudinal vibration, frequency and amplitude on yield strength, ultimate tensile strength, breaking strength and percentage of elongation on weldments prepared by the shielded metal arc process. The frequency range selected was 0 to 400 Hz, and the amplitude range was 0 to 40 µm. It was found that the tensile properties of the weldments improved when compared with the static welded test specimens, but there was a reduction in the percentage of elongation for specimens prepared under vibratory conditions. Increased frequency resulted in better tensile properties, but the percentage of elongation was reduced with an increase in frequency. Frequency in the range of 0 to 400 Hz and amplitude from 5 to 30 µm gave good results.

Introduction

The basis for arc welding is an electric arc (Ref. 1) between an electrode and the workpiece or between two electrodes. The arc is basically an electrical discharge through a path of ionized particles called plasma. The effect of vibrational energy on aluminum and its alloys showed grain refinement during solidification and a reduction in the extent and distribution of shrinkage, gas porosity and total solidification time (Ref. 2). The castings solidified under vibration resulted in grain refinement, pipe suppression, porosity reduction, metallographic refinement and improvement in the mechanical properties (Refs. 3–5). The nature and extent of these effects varied from metal to metal and the method of introduction of energy into the solidification. The effect of vibration on gray cast iron solidification was to vary the microstructure and increase tensile strength (Ref. 6).

The effect of low-frequency (35 Hz) arc oscillation (Ref. 7) on aluminum weld quality was improvements in structure and mechanical properties. Improvements in the tensile strength and hardness, and reductions in porosity and percentage of elongation of weldments were obtained by welding in the frequency range of 40 to 80 Hz (Ref. 8).

The present paper deals with the effect of frequency and amplitude of longitudinal vibrations on yield strength, ultimate tensile strength, breaking strength and percentage of elongation in the weldments prepared under vibratory and static conditions. During the range of experimentation, an appreciable improvement in the tensile properties of weldments was obtained with an increase in intensity of vibration, up to a certain level.

Experimental Procedure

The vibrating table was coupled to an electrodynamic vibrator, which was excited with an oscillator/power amplifier. The frequency and amplitude of vibrations were measured with the help of a vibration pickup in conjunction with a vibration meter — Fig. 1.

Workpieces of 250 x 250 mm (9.8 x 9.8 in.) were cut with a power hacksaw from mild steel plate 8 mm thick (0.31 in.), having 0.3% carbon. The material was selected because of its wide applications. A single bevel was prepared on the workpieces by using a shaper. These machined workpieces were thoroughly cleaned of dirt, dust, oil and grease. Two such machined workpieces were clamped onto the vibrating table abutting each other to form a single V-groove — Fig. 2A.

The vibrating table was mounted on shafts, which were supported on bearings. The desired frequency and amplitude of vibration were obtained by changing the position of the frequency and amplitude knobs of the oscillator/power amplifier unit.

The mild steel workpieces were welded at different frequencies (0 – 400 Hz) and amplitudes of vibration (0–40 µm) with a three-phase AC welding transformer and a 4 mm (%2 in.) diameter, all-position, rutile-type covered electrode designated as per Indian Standard IS-E316412 (AWS E6013). During welding, the voltage, current, arc length, travel speed and other electrode parameters were kept almost the same.

Transverse tensile test specimens (Fig. 2B — Indian Standard IS 3600, 1973) and microstructure examination specimens were prepared from these static and vibratory welded workpieces. Every test specimen was measured before testing for its gauge length, fillet radius and cross-section. These specimens were checked for surface finish, as poor surface finish may give rise to stress concentration and notches, which would affect the results. The tension test specimens were mounted on a universal testing ma-
Experimental setup consisting of a vibrating table mounted on the base plate through shafts and bearings and coupled to an electrodynamic vibration exciter (frequency range: 1 to 10 kHz), vibration pick up (displacement: 0 to 1000 μm; velocity: 0 to 1000 mm/s; frequency: 0 to 10 kHz; accuracy: ± 2%), oscillator/power amplifier (frequency range: 1 to 10 Hz; waveform: sinusoidal accuracy ± 2%), and vibration meter (displacement: 0 to 1000 microns pp, velocity: 0 to 1000 mm/s; frequency: 0 to 10 kHz; accuracy ± 2%).

Fig. 2 — A — Butt joint specification; B — transverse tension test specimen (IS 3600, 1973).

All dimensions are in mm.

Fig. 3 — Effect of frequency of vibration on yield strength of welds prepared under longitudinal vibration at different vibration amplitudes. Voltage: 25 V; current: 130 A.
machine and loaded up to the breaking point. The test specimen dimensions after fracture were also taken. The experimental data were used to determine the yield strength, ultimate tensile strength, breaking strength and percentage of elongation.

The specimens for metallographic examinations were prepared as per Indian Standard IS 7739, 1973, Part V. Normally, specimens were cut to 10 x 10 x 8 mm size (0.4 x 0.4 x 0.3 in.) with a hack saw. However, smaller specimens were mounted on a bakelite moulding powder. Initially, specimens were coarse ground on a belt sander in a direction perpendicular to scratches to make them flat and free of nicks and burrs. Coarse grinding was followed by intermediate polishing with emery papers having successively finer abrasives. Final polishing was done with a wet rotating wheel covered with a special cloth charged with aluminum oxide abrasive particles. All these operations resulted in a bright and scratch-free surface. These specimens were etched with 2% Nital solution for about 10 s, and were later washed with methanol solution. The specimens were then ready for metallographic examination on metallurgical microscope. The specimens' surfaces were viewed at three places, including the center surface, and the microstructure at all three places were found to be almost the same. Therefore, the microstructure photographs were taken in the middle of the specimens.

Results and Discussions

Figures 3 and 4 show the effects of vibration frequency and amplitude on weld strength. It can be observed from these figures that with the increase in frequency of vibration, an increase in weld strength is more pronounced in the amplitude range of 5 to 30 μm, and as the amplitude increased, yield strength decreased at 200 and 400 Hz. However, when the intensity of vibration (frequency x amplitude) was more, the rate of increase in yield strength was adversely affected. The improvement in the yield strength is the result of microstructural changes due to welding and solidification of the weldments under vibration.

The effects of frequency and amplitude of vibration on the ultimate tensile strength of the longitudinally vibrated test specimens are given in Figs. 5 and 6, respectively. These figures show that with the increase in frequency the ultimate tensile strength increases. This increase is more pronounced in the amplitude range of 5 to 30 μm. Figure 6 also shows that with the increase in amplitude the ultimate tensile strength of the test speci-
mens decreases at 200 and 400 Hz.

Effect of frequency and amplitude of vibration on breaking strength, which is defined as the strength of the material at which the tensile specimen fails (breaking load/original area of cross-section), are shown in Figs. 7 and 8, respectively. Figure 7 shows that with an increase in frequency, breaking strength increases, which is more perceptible in the amplitude range of 5 to 30 μm. Figure 8 shows that with an increase in amplitude, the breaking strength of the test specimens decreases at 400 and 200 Hz. This occurs up to 20 μm, then it reduces.

The effects of frequency and amplitude of vibration on the percentage of elongation are shown in Figs. 9 and 10, respectively. Figures 9 and 10 indicate that with the increase in frequency and amplitude of vibration the percentage of elongation decreases.

Figures 11 and 12 show the microstructure of the specimens welded under static and vibratory conditions. Comparison of these figures reveals that under vibratory conditions there is a change in grain structure from coarse to fine grains. Grain size varied between 38 and 11.7 μm in the static and vibrated welds with a variation in frequency of 0 to 400 Hz and amplitude of 0 to 40 μm. This may be due to the increased mobility of metal atoms due to vibration treatment of the weld metal. Thus, chances of spontaneous formation of stable nuclei are increased, which result in a reduced grain size. Frequency increase has a positive effect on grain size reduction (Fig. 12A–D); whereas, an increase in amplitude adversely affects grain size reduction (Fig. 12E, F). Improved yield strength, ultimate tensile strength, breaking strength and reduced percentage of elongation.
elongation are due to the reduction in grain size of the weld metal with vibration.

Conclusions

On the basis of the above experimental results, the following conclusions may be derived:

1) The welded test specimens under longitudinal vibratory conditions exhibited improvements in yield strength, ultimate tensile strength and breaking strength.

2) The improvement in the yield strength, ultimate tensile strength and breaking strength is significant in the frequency range of 80 to 400 Hz and an amplitude range of 5 to 10 μm.

3) Percentage of elongation decreases with an increase in the ranges of frequency and amplitude.

References