Effects of Transverse Oscillation on Tensile Properties of Mild Steel Weldments

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In this paper an attempt has been made to study the effects of frequency and amplitude of transverse oscillation on yield strength, ultimate tensile strength, breaking strength and percentage of elongation of weldments. The weldments were prepared under different oscillatory conditions. The frequency and amplitude of transverse oscillations during experimentation were varied from 0 to 400 Hz and 0 to 40 μm respectively.

The tensile properties of the weldments prepared under oscillatory conditions are improved whereas the percentage of elongation reduced when compared with the stationary welded test specimens. It has been observed that increase in frequency of transverse oscillation results in the improved tensile properties of the weldments except the percentage of elongation which decreases with increase in frequency of oscillation. At 80 Hz frequency higher amplitude show greater value of tensile strength than lower amplitude. But at higher frequencies (300 Hz and 400 Hz) lower amplitudes show a significant increase in tensile strength value than higher amplitudes. The increase in tensile strength under oscillatory conditon is due to the grain refinement which is caused by dendrite fragmentation and grain detachment mechanism.

KEY WORDS: mild steel; weld; tensile strength; transverse oscillation; micrograph; frequency; amplitude.

1. Introduction

Recent development and advances have given the arc welding art a dominant place to shape and prepare the metal parts to produce engineering structures in metal industries. In arc welding a molten pool forms on the work at the arc location. By manipulation of electrode the molten pool is made to travel along the joint as desired. The physical and mechanical properties of fusion welds depend of course on relative freedom of weld metal from such defects as porosity, entrapped slag, cracks and incomplete fusion *etc.* These defects may be serious enough to result in the rejection of fabricated parts. Attempts[1–6] have been made to reduce defects like porosity, segregation *etc.* and improve the mechanical properties by solidifying metal under vibration. Kamath and Murthy[5] reported that columnar grain growth was suppressed and equiaxed grains were promoted under low frequency vibration solidification. Kou and Le observed grain refinement and reduction in hot cracking by high frequency arc oscillation welding on aluminium alloys whereas the structure and mechanical properties of aluminium alloys were found to improve significantly by low frequency arc oscillation. The author[7–11] observed a reduction in the porosity and percentage of elongation of weldments prepared under longitudinal vibration condition. The improvement in tensile strength and hardness of the weldments were significant due to transverse vibration.

The present paper describes the influence of frequency and amplitude of transverse oscillation on yield strength, ultimate tensile strength, breaking strength and percentage of elongation of weldments prepared under static and oscillatory conditions of welding. The weldments were prepared by welding mild steel plates in frequency range of 80 to 400 Hz and amplitude range of 0 to 40 μm.

2. Experimental Method

Two plates of mild steel were clamped on oscillating table (**Fig. 1**). These plates were welded under stationary and oscillating conditions. Oscillating table mounted on shafts supported on bearings was coupled to an electrodynamic vibrator. Welding of mild steel workpieces was done with a three phase welding transformer using 4 mm diameter mild steel electrode designated as IS-E316412 (AWS-E6013). The current and voltage ranges were 130–140 A and 25–30 V respectively.

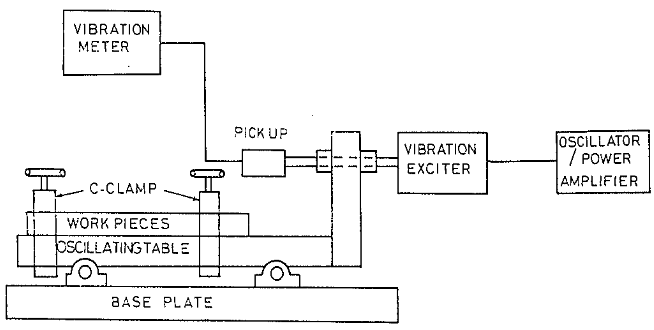

Fig. 1. Schematic diagram of the experimental programme.

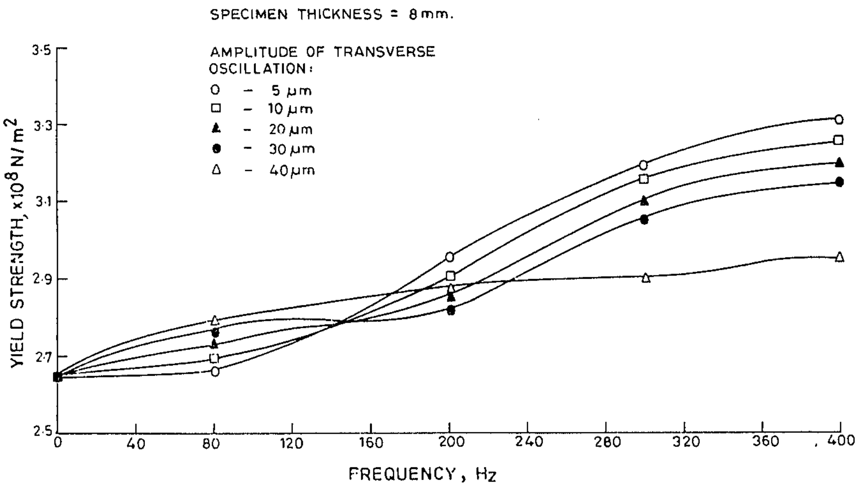

Fig. 2. Effect of frequency on yield strength (transverse oscillation).

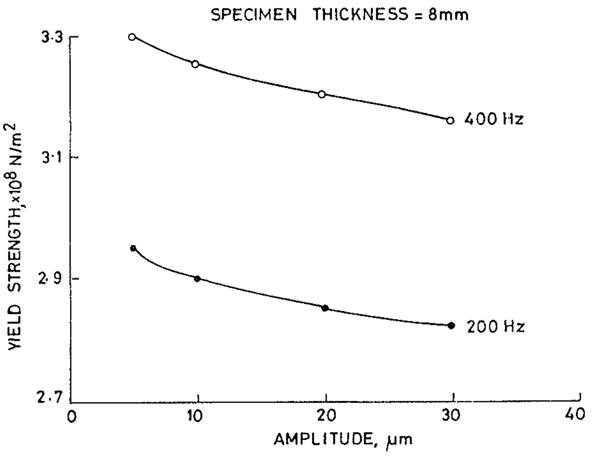

Fig. 3. Effect of amplitude on yield strength (transverse oscillation).

Experiments were conducted at almost same input energy, length of the arc and speed of electrode travel. The frequency and amplitude of transverse oscillations of the workpieces were 0 to 400 Hz and 0 to 40 μm respectively. Frequency and amplitude of transverse oscillation were monitered and measured by oscillator/power amplifier and vibration meter.

Tensile specimens were cut from stationary and oscillatory (transverse oscillations) welded workpieces. All weld tensile specimens were made as per widely used standard methods. Test specimens were cut from welded workpieces. Then the test specimens were machined on shaper and milling machines to remove all surface irregularities. Sharp corners were filleted to avoid any stress concentration.

Microstructure studies samples (10 mm × 10 mm cross section) were cut from welds of 8 mm thick welded workpieces with a hacksaw. On a belt sander these specimens were rough ground and they were kept cool by frequently dipping them in water while the grinding operation was continuing. Specimen movement was kept perpendicular to the existing scratches during grinding. Specimen was rough ground till the surface became flat and free from nicks, burrs and hacksaw marks. Finally, final polishing was performed with a wet rotating wheel covered with a special cloth which was charged with aluminium oxide abrasive particles. Final polishing made the surface bright and scratch free. In order to perform microstructural studies of these polished specimens, the structural characteristics were made visible by dipping the specimens in an etchant 2% nital solution for about 10 sec and later washed with methanol. Microstructure studies of these etched specimens were carried out.

Tension test of the welded test specimens under stationary and transverse oscillation condition was performed on a 30 ton universal testing machine. Yield strength, ultimate tensile strength, breaking strength and percentage of elongation of tension test specimens perpared under stationary and transverse oscillation were calculated. Leitz metallurgical microscope was used for metallographic examination. Specimens' surfaces were viewed at the center of the welds and at extreme ends. Microstructure photographs were taken at 200 magnification. Linear intercept technique was used for grain size calculation from micrographs. Length parameter is the mean intercept length, $L = L_T/(P \cdot M)$ where L is grain size in μm, T = total test line length in mm, M is magnification and P is the number of grain boundaries intersections. In the present case test line length was taken as 50 mm. A line of 50 mm was drawn on a transparent sheet which was kept over the micrograph and the number of grain boundary intersections was actually counted. Six times this process was repeated in different directions on the same micrograph to have an exact picture of the grain size. The average of the six values of L gave the grain size of the specimen.

3. Results and Discussions

Figures 2 to **7** show the effects of frequency and amplitude of oscillation on the yield strength, ultimate tensile strength and breaking strength of transversely oscillated test specimens. These figures indicate that generally the yield strength, ultimate tensile strength and breaking strength of the test specimens improve with the increase in the frequency of transverse oscillation. The improement is more pronounced in the amplitude range

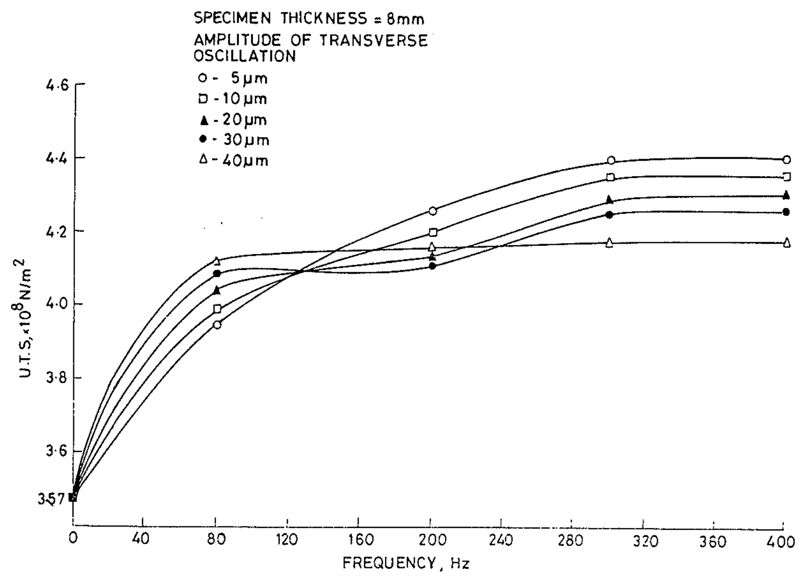

Fig. 4. Effect of frequency on ultimate tensile strength (transverse oscillation).

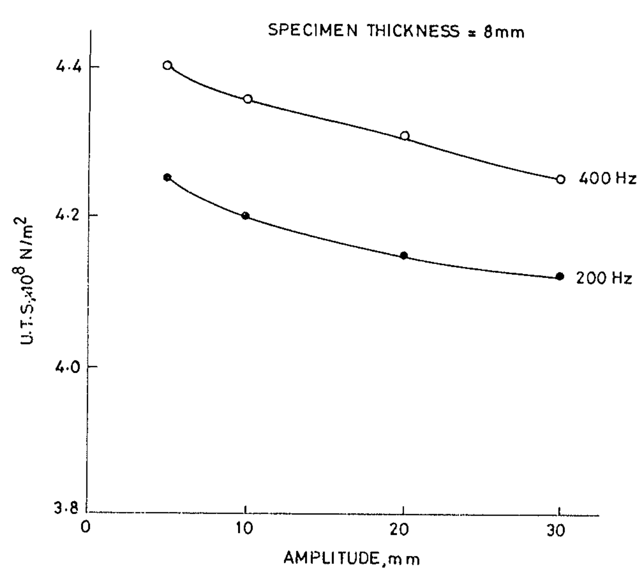

Fig. 5. Effect of amplitude on ultimate tensile strength (transverse oscillation).

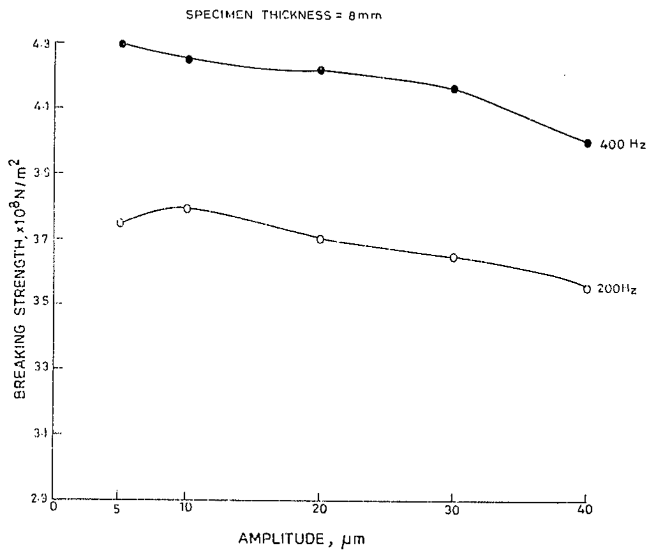

Fig. 7. Effect of amplitude on breaking strength (transverse oscillation).

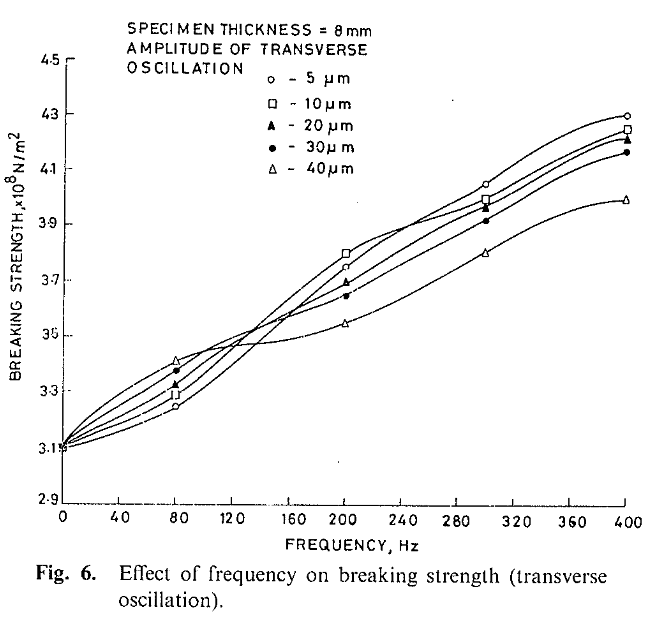

Fig. 6. Effect of frequency on breaking strength (transverse oscillation).

of 5 to 30 μm. Maximum increase in yield strength is 23 %, ultimate tensile strength 24 % and breaking strength 38 %. This increase is at 400 Hz frequency and 5 μm amplitude of oscillation.

In oscillatory welds reduced grain size 29.2 μm, 15.3 μm, 7.6 μm and 6.8 μm at 80 Hz–5 μm, 200 Hz–10 μm, 300 Hz–5 μm and 400 Hz–10 μm oscillatory (transverse oscillation) conditions respectively, are obtained compared to stationary prepared welds which produces 38 μm grain size of weld microstructure. It is observed that as the frequency increases with low amplitudes of oscillations (5 μm/10 μm) the grain size reduction is more and more which brings about the increase in yield strength, ultimate tensile strength and breaking strength of the oscillatory (transverse oscillation) prepared welds. The grain refinement in microstructure due to transverse oscillation is caused because of dendrite fragmentation. Due to transverse oscillation dendrites' fragments are carried into the bulk of the weld pool where they work

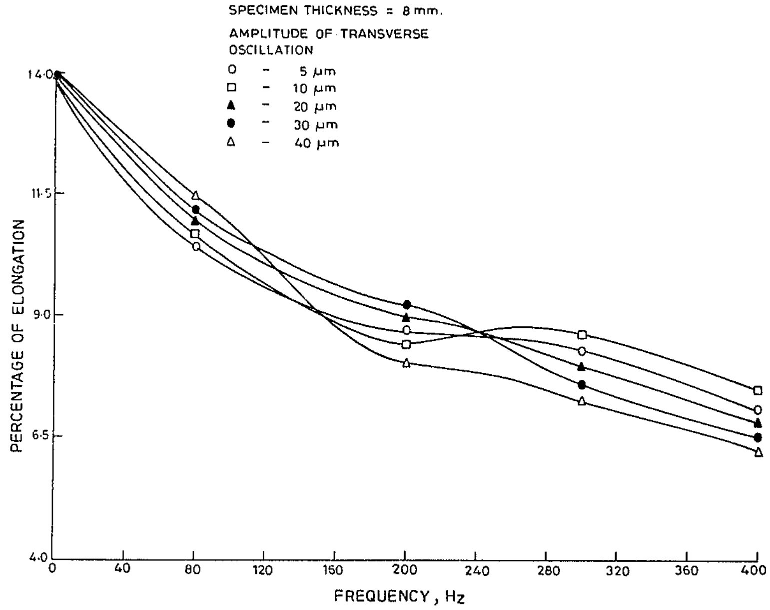

Fig. 8. Effect of frequency on percentage of elongation (transverse oscillation).

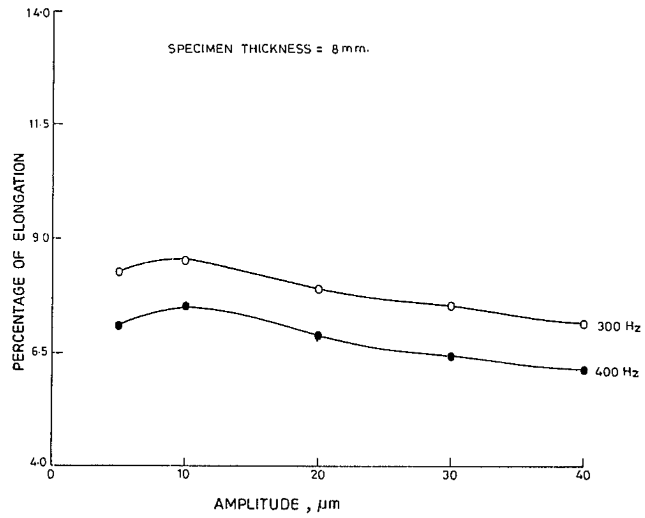

Fig. 9. Effect of amplitude on percentage of elongation (transverse oscillation).

Fig. 10. Microstructure photograph of stationary prepared weldment (grain size = 38 μm).

as nuclei for new grains to form and also partially melted grains which are loosely held at the base metal weld metal interface detach themselves from the base metal and are carried in the weld pool where they work as nuclei for new grains to form. Thus dendrite fragmentation, grain detachment and higher cooling rate due to transverse oscillation cause microstructure grain refinement–29.2 μm (**Fig. 11(a)**), 15.3 μm (Fig. **11(b)**), 7.6 μm (Fig. **11(c)**) and 6.8 μm (Fig. **11(d)**) compared to stationary prepared weld where grain size is 38 μm (**Fig. 10**). The above described mechanisms of microstructure grain refinement are accelerated at higher frequencies and lower amplitudes (400 Hz–10 μm, 300 Hz–5 μm, 200 Hz–10 μm) due to higher intensity of oscillations which is a product of frequency and amplitude. Therefore due to accelerated mechanisms of dendrite fragmentation, grain detachment and cooling because of transverse oscillation brings about more refined microstructure of welds which in turn produces higher increase in yield strength, ultimate tensile strength and breaking strength. Grain refinement also increases hardness of welds and because of increase in hardness, percentage of elongation of weld decreases (**Figs. 8** and **9**) under oscillatory condition.

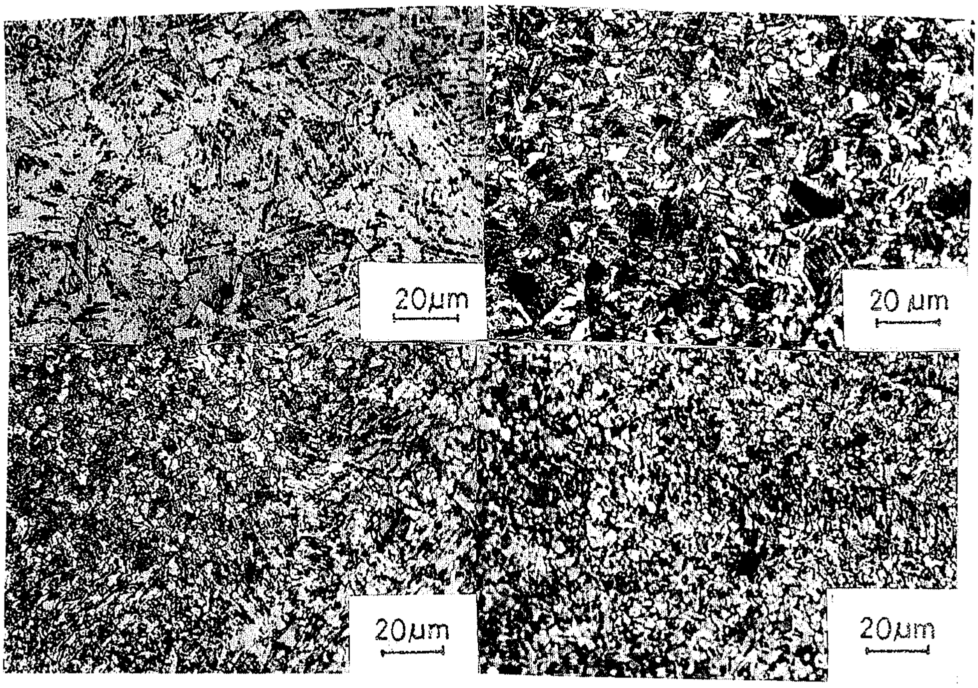

Fig. 11. Microstructure photograph of oscillatory (transverse oscillation) prepared weldment.
(a) Grain size = 29.2 μm at 80 Hz–5 μm. (b) Grain size = 15.3 μm at 200 Hz–10 μm. (c) Grain size = 7.6 μm at 300 Hz–5 μm. (d) Grain size = 6.8 μm at 400 Hz–10 μm.

4. Conclusions

(1) Yield strength, ultimate tensile strength and breaking strength of the welded test specimens prepared under transverse oscillation conditions improve by 23 %, 24 % and 38 % respectively.

(2) Improvement in the yield strength, ultimate tensile strength and breaking strength is significant in the frequency range of 80 to 400 Hz and amplitude range of 5 to 30 μm.

(3) Increase in frequency and amplitude range reduces percentage of elongation of transverse oscillated test specimens by 60 %.

(4) Grain refinement occurs due to transverse oscillation as is evident from the micrograph of oscillatory prepared welds.

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