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Effects of Oscillation on Impact Property of Weldments

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The present paper deals with the effects of oscillation on impact property of mild steel weldments. Mild steel plates were welded at different frequencies and amplitudes of longitudinal and transverse oscillation. Frequencies and amplitudes of oscillations were varied in the ranges of 0 to 400 Hz and 0 to 40 μm respectively. Impact test specimens were made out of the stationary and oscillatory welded workpieces and were tested on Izod testing machine.

The absorbed energy of the welds prepared under oscillatory (longitudinal and transverse) conditions show significant increase in comparison to absorbed energy of stationary prepared welds. It was observed that 80 Hz–40 μm and 400 Hz–5 μm oscillatory condition gave best results, at 80 Hz and 400 Hz frequencies respectively. At lower frequency higher amplitude and at higher frequency lower amplitude produce maximum percentage increase. However, best results are obtained at 400 Hz–5 μm oscillatory condition where the percentage increase in absorbed energy may be attributed to grain refinement which is caused by the initiation of dendrite fragmentation and grain detachment mechanisms in the weld pool because of its oscillation.

KEY WORDS: mild steel; stationary; longitudinal oscillation; transverse oscillation; frequency; amplitude; absorbed energy.

1. Introduction

Seal and Banerjee[1] studied the effect of vibration on grey cast iron solidification. They observed reduction in eutectic cell size and increase in tensile strength due to vibration. Shukla *et al.*[2] studied the literature concerning with the effect of vibration on solidification of castings. They concluded metallographic refinement in grain structure and enhanced mechanical properties apart from other things due to vibration. Watanabe *et al.*[3] investigated the effect of electromagnetic stirring on microstructure of SVS 310 s.

In order to obtain grain refinement they examined the parameters like magnetic field intensity, the frequency of alternating stirring and the relative distance from the electrode to magnetic field centre. Bead on plate TIG weld were made under the condition that welding current was 60 A and travel speed was 3 cm/min. A significant reduction in the grain size of weld metal was obtained when electrode was located 1–2 cm apart from the magnetic centre in welding direction and the stirring frequency was 0.5–1 Hz. They suggested fragmentation and increased constitutional super cooling of molten metal due to stirring as the mechanisms for grain refinement. Yamamoto *et al.*[4] vibrated molten puddle with low frequency (10–30 Hz) during pulsed MIG welding process. They observed remarkable grain refinement of weld structure of commercially available AI-MG alloy base metal. Grain refinement has beneficial effect in improving solidification crack susceptibility of AI-MG alloy weld metal.

Ganaha *et al.*[5] observed grain structure in gas tungsten arc welds of many alloys solidified under vibration. They found columnar and equiaxed grains in different ranges of intensity of vibration. Kou and Le[6] experimentally found the effect of transverse arc oscillation on structure and properties of aluminium welds. They concluded significant increase in ductility and strength due to arc oscillation. Researchers[6] noticed grain refinement in magnetically stirred gas tungsten arc welds of several aluminium alloys. Tewari and Shanker[7–10] carried out experiments to find the effect of vibration on structure and mechanical properties of mild steel welds prepared under vibration. They were of the view that yield strength, ultimate tensile strength, breaking strength and hardness improve due to oscillation. This paper presents the effect of oscillation on absorbed energy of stationary and oscillatory prepared welds.

2. Experimental Programme

Mild steel workpieces of 8, 10 and 12 mm thickness were machined on hydraulic shaper and FN2 universal milling machine. These workpieces were straightened in fitting shop. Two straightened workpieces were clamped on oscillatory table of set-up with the help of c-clamps and angle iron pieces.

Oscillatory table was rigidly coupled to the vibration exciter and moved freely over the two shafts mounted on bearings on the base plate of the set-up. Oscillator/power amplifier excited the electro dynamic vibrator at various frequencies and amplitudes of oscillation.

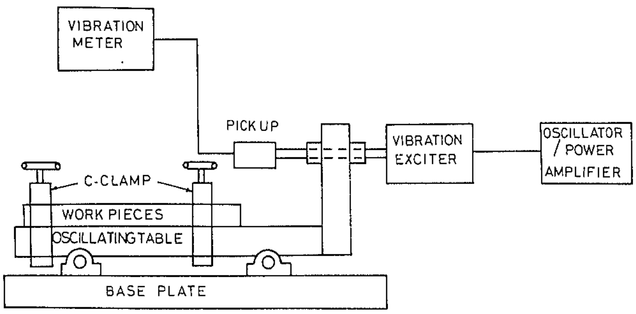

Fig. 1. Schematic diagram of the experimental programme.

Vibration meter along with a vibration pick up was used to measure, the frequency and amplitude of oscillation (**Fig. 1**). Workpieces were welded with mild steel electrodes IS-E 316412 (AWS-E 6013) under stationary and oscillatory conditions with the help of a three phase welding transformer at 0 Hz, 80 Hz, 200 Hz, 300 Hz and 400 Hz frequency. Amplitudes of oscillation during welding were 5 μm, 10 μm, 20 μm, 30 μm and 40 μm. 8 mm, 10 mm and 12 mm thick workpieces were welded with three number of passes. Welds are cleaned well after each pass to avoid any inclusion of slag in them. This process is repeated after each pass. In subsequent passes more weld metal is deposited in order to complete the weld. The voltage was in the range of 25–30 V and current in the range of 130–140 A. During experimentation input energy, length of arc, speed of electrode travel and other electrode parameters were kept almost same. During the course of investigations the frequency and amplitude of oscillation were increased from 400 Hz to 600 Hz and 40 μm to 70 μm but the deterioration of mechanical properties were obtained, therefore all the experiments were done upto 400 Hz frequency and 40 μm amplitude of oscillations. Standard procedure was adopted to fabricate Izod impact test specimens. The Izod test specimen was first cut of 70 mm length from the welded workpieces and then final machining was carried out on shaper and milling machine to make the specimen of 55 mm length. 2 mm deep v-notch was cut at the centre of the weld. After fabrication Izod test specimens were tested on Izod testing machine. The specimens were loaded as cantilever on a Izod impact testing machine. A weighted pendulum strikes the test specimen as it swung its path along the arc. The energy that is required to fracture the test specimen is recorded in joules on the scale. The average value of three such readings were taken for one oscillatory condition of the test specimen. Absorbed energy of test specimen were recorded at 20°C. Samples for the microstructure studies of 10 mm × 10 mm cross section were cut from the welded workpieces with the help of a hacksaw. Belt sander was used for rough grinding of these specimens. In order to keep the specimen cool, they were frequently dipped in water while they were ground. Specimen movement was kept perpendicular to the scratches during grinding. Rough grinding was done till the surface became flat and free from nicks, burrs and hacksaw marks. Small specimens were mounted on a bakelite piece with bakelite moulding powder after rough grinding and were polished with emery papers containing successively finer abrasives. Finally fine polishing was done with wet rotating wheel covered with a special cloth which was charged with aluminium oxide abrasive particles. The surface became bright and scratch free after fine polishing. These polished specimens were dipped in an etchant (2% nital solution) for about 10 sec and later washed with methanol in order to make their structural characteristics visible. These etched specimens were used for microstructure studies. For metallographic examinations Leitz metallurgical microscope was used. The specimens' surfaces were viewed at the centre of the welds and at extreme ends and microstructure photographs were taken at 200 magnification. Linear intercept technique was used for grain size determination from photo micrographs. The length parameter is the mean intercept length.

$$L=\frac{L_T}{P\cdot M}$$

Where, L = grain size, microns

L_T = Total test line length in mm

M = Magnification

P = The number of grain boundaries intersection.

In this case the test line length selected was 50 mm. 50 mm line was drawn on a transparent sheet which was kept over the microstructure photograph and number of grain boundary intersections was actually counted. This process was done 6 times in different directions on the same photograph to get an exact picture of the grain size. The average of the 6 values, gave the grain size of the weld.

(Grain sizes of stationary condition - 38 μm, oscillatory condition - 400 Hz–5 μm and 80 Hz–40 μm, longitudinal - 6.2 μm and 23.2 μm, transverse - 6.7 μm and 12.8 μm at 400 Hz–5 μm and 400 Hz–40 μm respectively.)

3. Results and Discussions

Figs. 2 to **7** depict the effect of frequency and amplitude of longitudinal and transverse oscillations on absorbed energy of 8 mm, 10 mm, and 12 mm thick specimens in the frequency and amplitude ranges of 0 to 400 Hz and 0 to 40 μm respectively. Figures 2 and 4 indicate an increasing trend of absorbed energy with increasing frequency of longitudinal and transverse oscillations and a decreasing trend with increasing amplitude of oscillations (Figs. 3 and 5). These figures further show that percentage increase in absorbed energy for welded specimens prepared under longitudinal and transverse oscillations at 400 Hz frequency and 5 μm amplitude of oscillation is about 29%. Figures 6 and 7 are showing the effect of plate thickness on absorbed energy for welds prepared under longitudinal and transverse oscillation at frequencies 80, 200, 300 and 400 Hz and amplitudes 5 and 10 μm. The plots show that absorbed energy varies little with increase in specimen thickness. Figures 2 and 4 reveal that at 5 μm, 10 μm and 20 μm amplitude of oscillation the absorbed energy increases with increase in frequency of oscillations and is highest at 400 Hz–5 μm

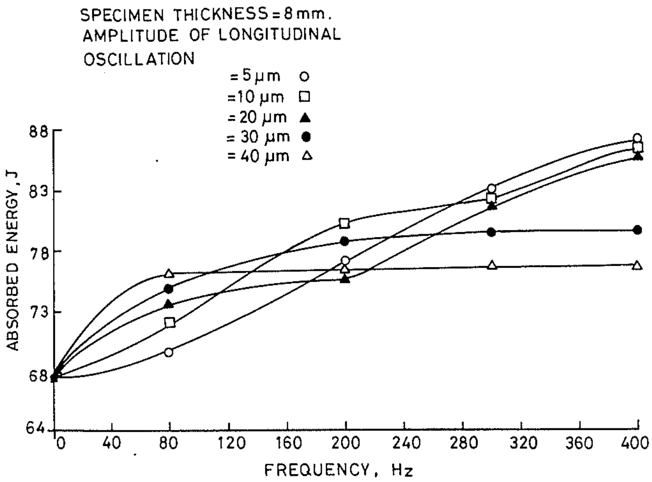

Fig. 2. Effect of frequency on absorbed energy (longitudinal oscillation).

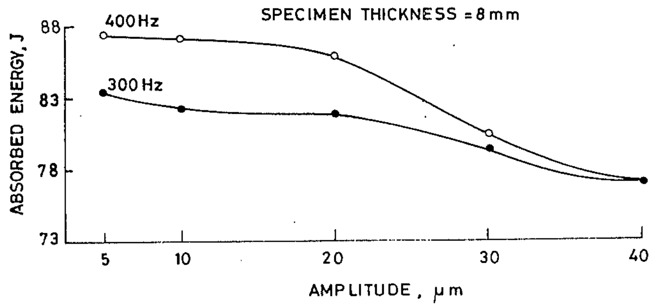

Fig. 3. Effect of amplitude on absorbed energy (longitudinal oscillation).

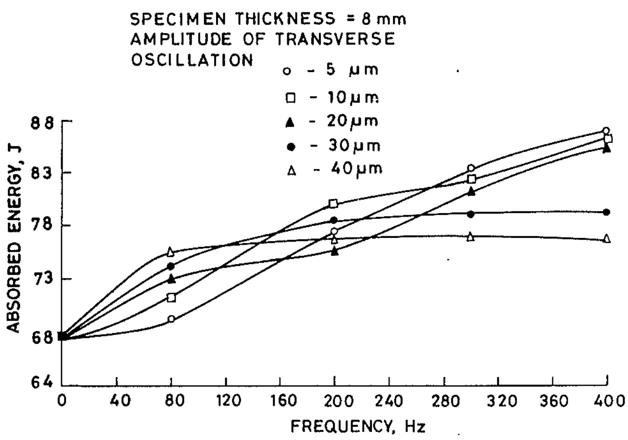

Fig. 4. Effect of frequency on absorbed energy (transverse oscillation).

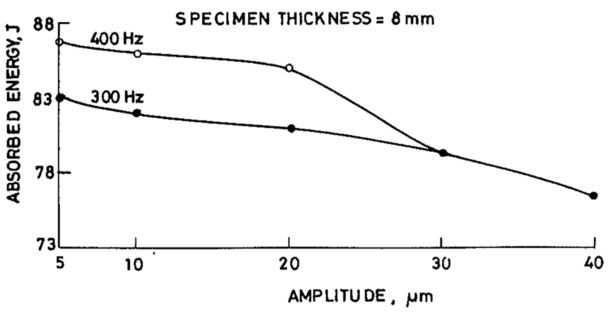

Fig. 5. Effect of amplitude on absorbed energy (transverse oscillation).

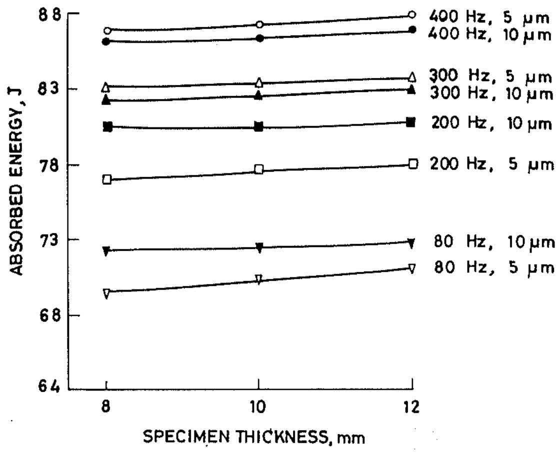

Fig. 6. Effect of specimen thickness on absorbed energy (longitudinal oscillation).

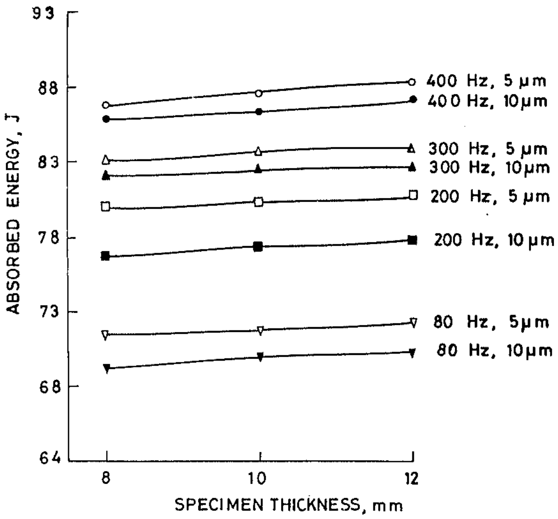

Fig. 7. Effect of specimen thickness on absorbed energy (transverse oscillation).

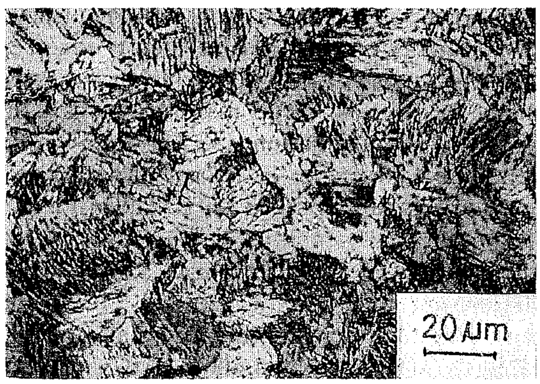

Fig. 8. Micrograph of stationary prepared weldment (grain size - 38 μm).

and lowest at 400 Hz–40 μm oscillatory conditions. Absorbed energy of the weld prepared under oscillatory conditions is more in comparison to weld prepared under stationary condition. This is due to refinement of weld metal microstructure. The grain size of stationary prepared weld (**Fig. 8**) is 38 μm. Grain sizes of welds prepared under longitudinal oscillation conditions are 6.2 μm (**Fig. 9a**) at 400 Hz–5 μm, 23.2 μm (Fig. **9b**) at

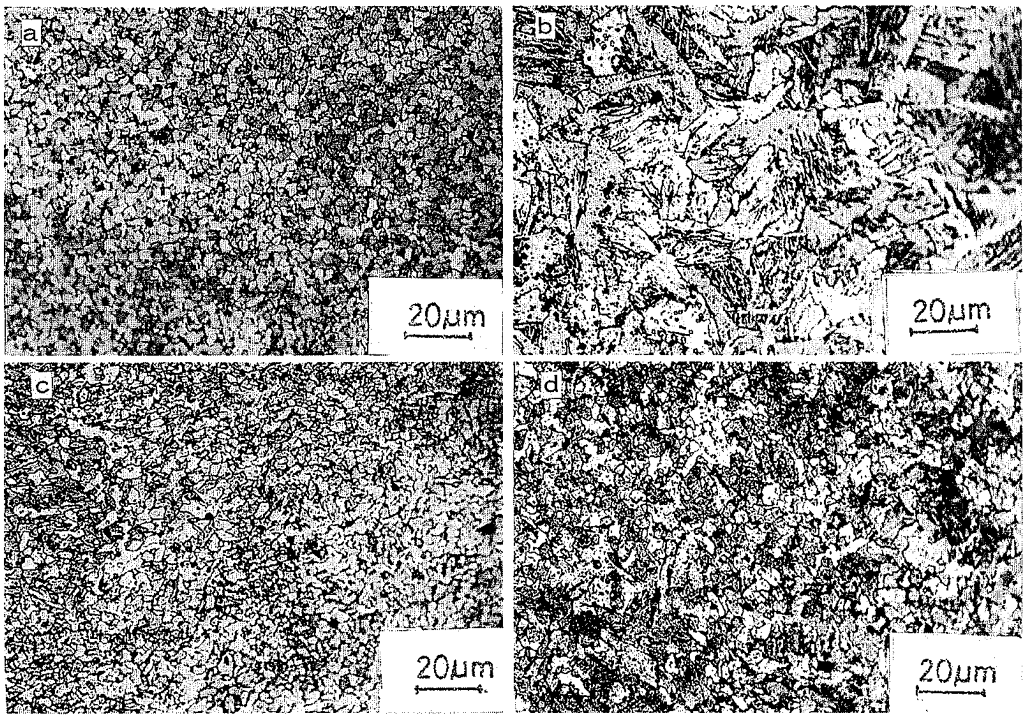

Fig. 9. Micrograph of oscillatory prepared weldment.
a. Grain size = 6.2 μm at 400 Hz–5 μm (longitudinal oscillation).
b. Grain size = 23.2 μm at 80 Hz–40 μm (longitudinal oscillation).
c. Grain size = 6.7 μm at 400 Hz–5 μm (transverse oscillation).
d. Grain size = 12.8 μm at 400 Hz–40 μm (transverse oscillation).

80 Hz–40 μm and under transverse oscillation conditions are 6.7 μm (Fig. **9c**) at 400 Hz–5 μm, 12.8 μm (Fig. **9d**) at 400 Hz–40 μm. At 400 Hz–5 μm oscillatory conditions (longitudinal and transverse oscillation) grain sizes of weld metal were having maximum refinement in microstructure. This is due to high frequency and low amplitude (400 Hz–5 μm) of oscillation *i.e.* high intensity of oscillation which is product of frequency and amplitude, is more beneficial for the microstructure grain refining mechanisms in comparison to low frequency and high amplitude (80 Hz–40 μm) and high frequency and high amplitude (400 Hz–40 μm) as they produce either slow or rapid stirring of weld pool which give rise to less refinement in the weld metal microstructures. Due to high intensity of oscillation (400 Hz–5 μm) dendrite fragmentation takes place at a faster rate unlike low frequency and high amplitude (80 Hz–40 μm) and high frequency and high amplitude (400 Hz–40 μm) where dendrite fragmentation takes place at slower pace. Also at 400 Hz–5 μm weld pool convection occurs during welding owing to various driving forces at a faster rate compared to 80 Hz–5 μm and 400 Hz–40 μm oscillation condition. Weld pool convection causes fragmentation of dendrite tips in mushy zone. These dendrite fragments are carried into the bulk weld pool and they act as nuclei for new grains. Second mechanism which is also responsible for grain size refinement of weld metal is the grain detachment mechanism. Due to high intensity of oscillation at 400 Hz–5 μm oscillatory condition weld pool convection causes partially melted grains to detach themselves from base metal immediately adjacent to the weld pool. These partially melted grains then act as nuclei for the formation of new grains. Thus grains' refinement occurs under oscillatory conditions of welding. Apart from these two mechanisms rapid cooling due to oscillation further help in grain refinement.

4. Conclusions

On the basis of experimental results the following conclusions may be derived.

(1) Absorbed energy of welds prepared under Oscillatory (longitudinal and transverse) conditions improve significantly. The increase is maximum at 400 Hz–5 μm condition and minimum at 80 Hz–5 μm.

(2) The oscillations bring about refinement in grain size. In stationary condition the grain size was 38 μm where as for longitudinal oscillation and transverse oscillation condition of 400 Hz–5 μm the grain sizes were minimum (6.2 μm and 6.7 μm respectively).

REFERENCES

1) A. K. Seal and M. K. Banerjee: *Indian Foundry J.*, **3** (1984), 15.
2) D. P. Shukla, R. Agarwal, D. B. Goel and P. C. Pandey: *Indian Foundry J.*, **22** (1976), No. 6, 13.
3) T. Watanabe and H. Nakamura: *Trans. Jpn. Weld. Soc.*, **21** (1990), No. 2, 37.
4) H. Yamamoto, S. Harada, T. Ueyama, S. Ogawa, F. Matsuda, K. Nakata and K. K. Yosetsu: *J. Light Met. Weld. Constr.*, **31** (1993), No. 2, 12.
5) T. Ganaha, B. P. Pearce and H. W. Kerr: *Metall. Trans.*, **11A** (1980), 1351.
6) S. Kou and Y. Le: *Welding J.*, **64** (1985), No. 3, 51.
7) S. P. Tewari: *Indian Weld. J.*, **18** (1986), No. 1, 21.
8) S. P. Tewari and A. Shanker: *Weld. J.*, **73** (1994), No. 11, 272-S.
9) S. P. Tewari and A. Shanker: *ISIJ Int.*, **33** (1993), No. 12, 1265.
10) S. P. Tewari and A. Shanker: *J. of Eng. Manufacture*, **207** (1993), 173.