L.13 Micro-structural engineering during laser surfacing melting through laser beam shaping

A novel laser surface melting treatment has been developed to produce improved microstructure for enhanced centerline solidification cracking resistance. Laser surface melting (LSM) is often employed to enhance corrosion resistance of austenitic stainless steel (SS) components. However, microstructure and solidification cracking resistance of laser melted SS specimens is strongly influenced by the shape of the associated melt pool as well as by cooling rate. A tear-drop melt pool, a characteristic feature of LSM at high processing speed, gives rise to steeply oriented columnar grains, meeting head-on at track centerline. Evolution of this kind of microstructure makes laser surface melted region highly susceptible to centerline solidification cracking due to large degree of solute segregation at track centerline. Rapid cooling rate imposed by LSM makes the material to solidify with crack-prone primary austenite mode, thus compounding the problem.

Laser beam (LB) shaping offers an effective means to engineer surface microstructure of laser melted region by modifying the shape of associated melt pool. The results of present investigation, involving numerical thermal simulation (with ANSYS 7.0 software) and experiments, demonstrated that by using square LB, in place of a circular one, the shape of resultant melt pool can be effectively modified to yield flatter and more steeply oriented profile of the associated solidification front with respect to the direction of laser scanning (fig. L.13.1). The experimental results also demonstrated that in contrast to largely elliptical solidification front associated with the melt pool produced during LSM with circular LB, square LB generated melt pool with largely flat and steeply oriented solidification fronts with respect to the direction of laser scanning (fig. L.13.2). Development of flat and steeply oriented solidification front, produced with square LB, resulted in the evolution of smoothly curved columnar grains with broader region of axial grains at the centerline of laser surface melted track (fig. L.13.3). The results of numerical simulation also predicted that LSM with square LB should result in about 5-fold drop in the cooling rate (at solidification temperature) at the centerline of surface melted track under similar conditions of laser power density and processing speed. Surface microstructure and cooling rate conditions evolved during LSM treatment with square LB should result in enhanced resistance against centerline solidification cracking over that obtained with circular LB. The implication of the results is - LSM with square LB should facilitate processing at higher speed with reduced risk of centerline solidification cracking.

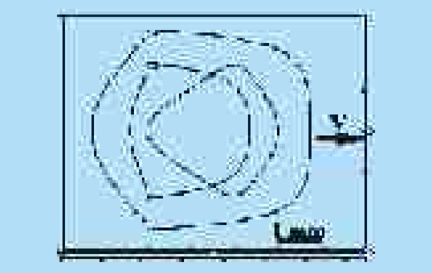

Fig. L.13.1 *Predicted surface profiles of melt pools 1Circular LB (5mm dia); 2- Square LB (5x5mm^2); 3-Square LB (3.6x3.6mm^2).*

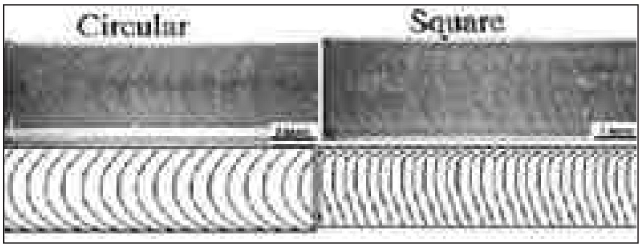

Fig. L.13.2 *Solidification fronts produced during LSM with circular and square laser beams.*

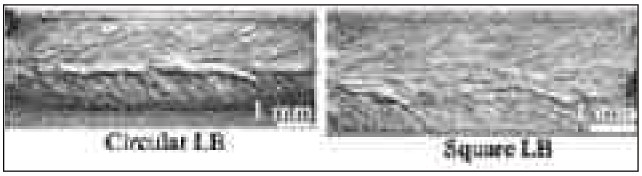

Fig. L.13.3 *Surface microstructures produced during LSM with circular and square laser beams.*

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L.14 Power modulation improves quality of laser cutting in steel, mild steel & stainless steel sheets

A novel laser piercing process has been developed for high quality laser profile cutting. In oxygen-assisted laser cutting, with blast mode initiation, the quality of the pierced hole at the cut-initiation region is very poor (fig. L.14.1). Due to this reason, close spaced profile cutting is not possible with this method. Besides, repetitive blast mode piercing also damages the cutting nozzle. Laser cutting with power modulation in pulsed mode (PM) and power ramp pulsed mode (PRPM) (shown schematically in fig. L.14.2), brought about significant improvement in the quality of pierced hole. Laser power modulation was achieved with SMPS control of input current in the indigenously developed 3.5kW CO_2 laser. Fig. L.14.3 compares shapes of pierced holes obtained in PM and PRPM modes of laser operation while Fig. L.14.4 presents a low magnification view of PRPM-initiated laser cut.

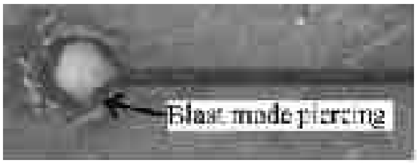

Fig. L.14.1 *Laser cut with blast piercing.*

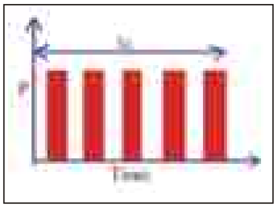

Fig. L.14.2(a) *PM power.*

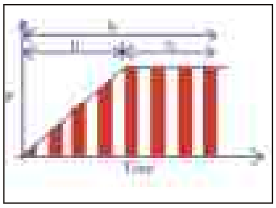

Fig.L.14.2(b) *PRPM power.*

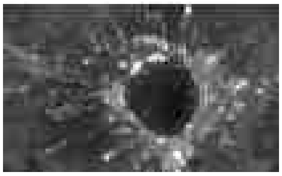

Fig. L.14.3(a) *PM (360m).*

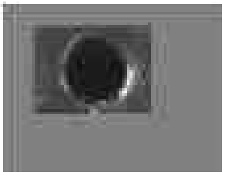

Fig. L.14.3(b) *PRPM (250m).*

Fig. L.14.4 *Laser cut with PRPM piercing.*

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L.15 Development of a 120kW programmable switch mode power supply for 10kW CO_2 laser

A 120kW programmable switch mode power supply (SMPS) has been developed for 10 kW transverse flow CW CO_2 laser. Laser power modulation is useful in many material-processing applications to control dynamic laser material interaction involved. The SMPS has been used to modulate discharge current in the laser, which in turn, modulates laser power. Output current of power supply can be programmed for three different modes viz. (i) Continuous mode (ii) Pulsed periodic mode (iii) Retriggerable single shot mode. Power supply is based on the modular concept i.e. two numbers of 60kW SMPS are connected in series to increase output rating. The individual modules are based on IGBT-switched, full bridge topology with a switching frequency of 25kHz and phase shift pulse width modulation (PSPWM) control strategy. A complex programmable logic device (CPLD) is used to shift the gate drives of the IGBTs of module-2 by 90° in phase with respect to module-1. An 8-bit micro-controller (μC) AT89C52 is used to generate reference signal for PSPWM controller. Each module delivers 1.5kV and 40amps, thus providing combined output rating of 3.0kV and 40amps. The prime advantage of the scheme is: the output ripple frequency is four times of the switching frequency of the individual module, therefore, requires low LC filter component values and yields higher modulation bandwidth of the SMPS. The SMPS has a modulation bandwidth of ~ 2.0kHz. The full load efficiency of 95% has been achieved. The μC not only performs supervisory functions such as error announcement, trip indication etc., but also detects fault conditions in the SMPS and promptly blocks gate drive to IGBTs, thus protecting them. Fig. L.15.1 and Fig. L.15.2 present block diagrams of SMPS and its operation in pulse periodic mode at 500Hz. The SMPS is housed in a standard 19inch x 6feet tall rack.

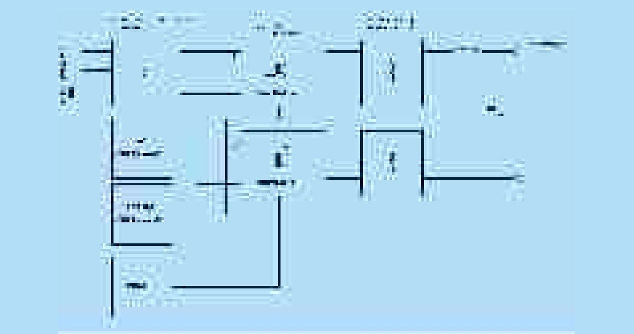

Fig. L.15.1 *Block diagram of 3.0 kV, 40 amps compact SMPS.*

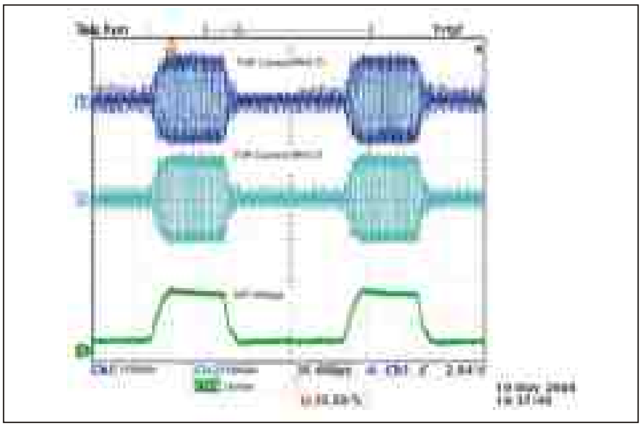

Fig. L.15.2 *Operation of SMPS in pulse periodic mode at 500 HZ.*

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