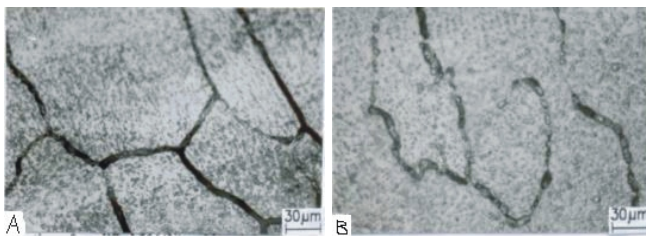


E316-15 electrodes. Welded components are often subjected to heat treatment at various stages of manufacturing cycle for providing dimensional stability, stress relieving and for restoring desired mechanical properties and corrosion resistance. Due to higher carbon content of indigenously developed welding electrode, critical cooling rates for avoiding sensitization of the welded components after solution annealing is higher than that of the base metal. It has been established earlier that a cooling rate of 65 K/h resulted in sensitization while cooling with a higher rate of 75 K/h did not cause sensitization. Slow cooling from solution annealing temperature is preferred to reduce reintroduction of residual stresses and distortion. Laser surface resolidification with modulated laser power generated a microstructure that was resistant to sensitization even when cooled at the rate of 65 K/h.



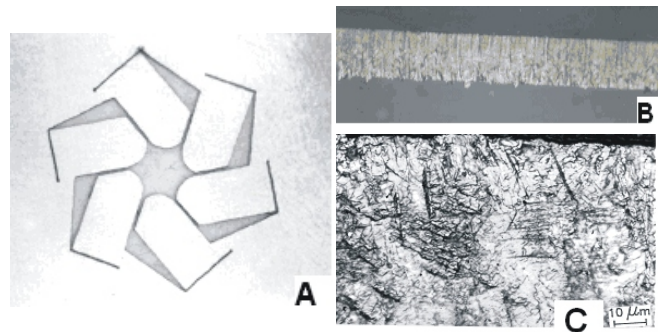
**Fig. L.5.1** Microstructures of 316 (N) weld metal after solution annealing treatment (A). Untreated base metal and (B) Laser Treated Zone.

Laser surface treatment of modified type 316(N) weld metal were carried out with a high power CO<sub>2</sub> laser in CW and pulsed modes as well as with a 150 W average power pulsed Nd-YAG laser. Laser treatment conditions had a profound effect on the integrity and sensitization resistance of the treated specimen after a solution annealing treatment involving cooling at the rate of 65 K/h. Surface treated specimens with pulsed Nd-YAG laser with high peak power density and low repetition rate (3 Hz) produced numerous solidification cracks. On the other hand, surface melting with CW laser eliminated cracking but the specimens failed in intergranular corrosion (IGC) tests. However, specimens, treated with pulsed CO<sub>2</sub> laser at higher repetition rate (100-200 Hz) and 50% duty cycle superimposed on CW laser power (2.4kW pulses riddled over ~800W CW), not only avoided solidification cracking but also passed IGC test. In contrast to continuous grain boundary network of chromium carbide in solution-annealed base metal, fig.L.5 (A), laser surface treated region exhibited frequent discontinuities in the grain boundary network of chromium carbides, fig.L.5 (B).

(Contributed by: A K Nath, aknath@cat.ernet.in)

## L.6 Improved cut quality in titanium with modulated CO<sub>2</sub> laser beam

Titanium finds extensive use in aerospace, medical and vacuum applications. Cutting of Titanium sheets is one of the primary requirements in the fabrication of most of the components. Non-contact laser cutting, because of its low heat input characteristics, has the capability to cut with narrow kerf width; straight cut edges, low roughness, and minimum heat affected zone (HAZ). However, initial piercing required for initiating laser cutting within the sheet and ejection of viscous molten metal for dross-free cutting usually pose problem.



**Fig. L.6.1** A) Profile-cut Titanium sheet, B) Dross-free cut surface and C) No noticeable HAZ below cut edge. (Peak power = 600 W; frequency = 500 Hz; duty cycle = 30%, speed = 60 mm/min).

With extensive experimental study of the dynamic behavior of melt ejection in the 1 mm thick Titanium sheet using a 3.5 kW CO<sub>2</sub> laser operated in continuous wave (CW) and pulsed modes and different gases e.g. Ar, He and N<sub>2</sub> for melt ejection, optimum laser and process parameters were established for piercing holes and dross-free profile cutting. Laser pierced holes with optimum combination of low tapering and narrow heat affected zone were created with modulated laser beam operated at high duty cycles (~80%) and Ar as shear gas for melt ejection. Dross-free cuts with no noticeable HAZ were obtained with high frequency modulated laser beam (~500 Hz) with low duty cycle (≤50%). Microscopic features of laser cut surfaces reflected the dynamic mechanism involved in laser cutting process.

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## L.7 Characterization of magneto-optic trap

A Magneto-Optic Trap (MOT) developed for cooling and trapping of Rb atoms is shown in Fig. L.7.1. It essentially