Laser surface alloying experiment involving silicon enrichment was performed with a 2.5kW CW CO_2 laser. Surface chemical composition of 304L SS substrate was modified by laser deposition with premixed powders of type 304L SS and Si. Si content of the surface alloyed layer was controlled, by controlling the ratio of type 304L SS and Si powders in the powder mixture. Graded surface alloying of silicon was achieved by sequential deposition of graded clad layers of progressively increasing silicon content.

EDS analysis of laser treated specimen exhibited a gradual increase in Si concentration from about 0.59 wt% in the substrate to 2.3 wt% near the top surface of the specimen, as shown in fig. L.11.1. Polarization study of laser surface alloyed samples demonstrated that in comparison to untreated substrate, which showed an average passive current density of about 1 mA/cm^2, laser Si alloyed samples showed significant decrease in passive current density below 0.1 mA/cm^2 (fig. L.11.2). This is indicative of improved corrosion behavior of laser surface alloyed samples with respect to the substrate. However, the trans-passive potentials of the substrate and laser surface alloyed samples did not show any significant change in the corrosion behavior.

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

L.12 Laser welding of laser-cut stainless steel sheet

Lasers are finding extensive industrial application in metal sheet cutting. Efficiency of laser cutting in ferrous materials is enhanced by using oxygen as an assist gas and the resultant iron oxide, by virtue of its low adherence, is easily blown out of the cut front. Many times, laser-cut sheets are required to be welded. Weldability of laser-cut sheets is influenced by (i) thickness and the chemistry of the oxide layer left on the cut surface and (ii) roughness of the cut edge. It is reported that for achieving good weldability (by GTAW) of laser-cut SS sheets, cutting must be performed with inert gas mixtures, which cause significant reduction in cutting speed [S.E. Nielsen, and G. Broden, Proc. Int. Conf. Power Beam Technology, J. D. Russell, Ed., 10-12 Sept 1986 (Brighton, U.K), The Welding Institute, 1987, p 256- 267].

The present study had been undertaken with the objective to produce acceptable quality laser butt welds between 3 mm thick type 304 stainless steel (SS) sheets, laser-cut with oxygen as an active shear gas. In order to control heat input during laser cutting of SS sheets, an important parameter influencing surface roughness and thickness of oxide layer on the cut surface (which, in turn affects weldability), the process was carried out in pulsed mode.

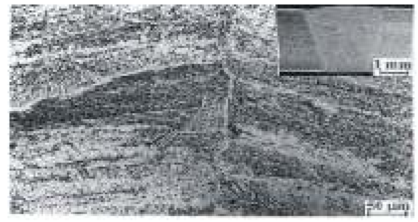


Fig.L.12.2 *Cross-section of bend tested LCW specimen*

Fig.L.12.1 *Fusion zone microstructure of LCW specimen. Inset: Low magnified view of laser weldment.*

Laser welding produced sound welds between 3 mm thick laser-cut sheets of type 304 SS sheets. Fig. L.12.1 presents microstructure of the weld metal (WM) of one of these welds. The resultant weldments exhibit similar tensile strength as that of the substrate, as shown in Table 1. However, presence of finely dispersed oxide inclusions in WM reduced ductility of laser-cut & laser-welded specimen with respect to substrate and bead-on-plate laser welds. These welds also carried higher notch sensitivity than the substrate. However, laser-cut and laser welded specimens were still ductile enough to pass guided bend test. Fig. L.12.2 presents transverse cross-section of one of the guided bend tested laser-cut & laser-welded specimens.

Table 1: Results of tensile testing

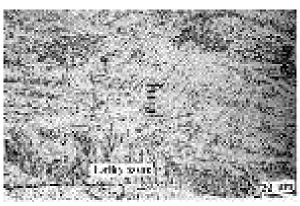
Specimen	Yield strength (MPa)	Tensile strength (MPa)	% Elongation (G.L = 15 mm)	Failure Location
Substrate	346, 305, 304	656, 631, 630	75, 68, 69	-
Laser cut & laser welded	353, 356, 335, 355	631, 637, 619, 635	56.5, 43.5, 49.5, 55	Weld
Bead-on-plate laser welded	345, 325, 349	634, 620, 621	59, 62, 65.6	Weld

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

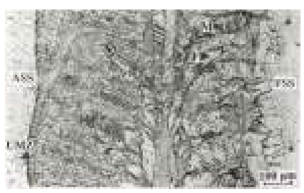
L.13 Laser welding (LW) of dissimilar metals : Austenitic and Ferritic stainless steels

The importance of joining of dissimilar metals has increased substantially in all aspects of manufacturing. Applications of dissimilar-metal welds (DMW) include cladding for corrosion/wear resistance and joining of metals with large difference in structure and properties. DMW between Austenitic Stainless Steel **(**ASS) and Ferritic Stainless Steel **(**FSS) is usually carried out by GTAW with type 309 SS filler to avoid formation of hard and brittle martensite and to produce a ductile austenitic weld metal (WM). However, the problem of extensive grain coarsening on FSS side, due to its higher diffusivity, cannot be avoided. The problem becomes more acute in thin sheet DMW, where no filler can be used.

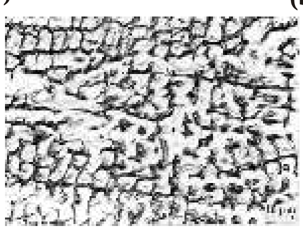
The present micro structural study had been undertaken with the objective to produce ductile autogeneous laser butt weld between type 304 ASS and stabilized 17% Cr ferritic SS. The microstructure of WM was favorably engineered by preferential displacement of focused laser beam towards ASS side. LW effectively reduced the extent of heat-affected zone, especially in ferritic SS. In contrast to coarse-grained micro-structure of the autogeneous GTA weld with large blocks of ferrite and martensite/retained austenite, LW produce highly refined microstructure in the WM. Largely austenitic WM was achieved by the use of nitrogen as the shroud gas. Fig. L.13.1 shows change in WM microstructure with different welding parameters. [R. Kaul, P. Ganesh and A. K. Nath, J. of Laser Applications 17(1), 2005].



(a)



(b)



(c)

Fig L.13.1 *Microstructure of LWM produced by, (a) focused laser beam at the center, (b) preferentially displaced focused laser beam towards ASS side (c) preferentially displaced focused laser beam towards ASS side with nitrogen as the shroud gas*

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L.14 Laser Rapid Manufacturing

Laser rapid manufacturing (LRM) is a new class of technology used for fabricating engineering components by direct deposition of metal powder according to 3D computer-aided design (CAD) data. Unlike CNC machines tools, which are subtractive in nature, RM systems fuse together metal powder to form complex parts. This is basically an extension of the laser cladding to three-dimensional deposition and a promising technology for low volume manufacturing.

(a)

(b)

(c)

(d)

Fig L.14 (a) SS316L walls of different thickness (0.8-1.2mm) on SS304L substrate, (b) Cu wall over SS304L substrate, (c) Cage and (d) Impeller

A LRM facility has been set up integrating the indigenously developed 3.5kW CW CO_2 laser with an in-house developed co-axial powder feeding system and a 5-axis CNC machine. The powder feeder can feed the SS316L metal powder from 2 g/min to 30 g/min with a 0.2g/min increment. A number engineering components of simple geometry have been fabricated, using SS316L, Inconel-625, Colmonoy-6, Cu powders over SS304L substrate. The fabricated components have dimensional accuracy about 100 microns and surface finish 5-7 Ra value for SS316L material. LRM deposited material has demonstrated high tensile properties with low ductility for SS316L and Inconel-625.

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

L.15 Quest for magnetic materials for newer technology

We are carrying out detailed experimental work (e.g., magnetization, magnetotransport, etc.) on the intermetallic compound Gd_5Ge_4 probing the FOMST and the different magnetic phases in the compound.

Gd_5Ge_4 is the parent compound of the $Gd_5(Ge_{1-x}Si_x)_4$ series. This series of compounds is under intense experimental study worldwide, in connection with the phenomena of giant magnetocaloric effect, giant magnetoresistance, and colossal magnetostriction. All these phenomena are due to simultaneous magnetic and crystallographic (Martensitic)