316L SS, Cr and Ni. Type 316L SS powder was selected (in preference to type 304L SS) for achieving surface alloying with Mo. Table 1 presents chemical composition of laser surface alloyed specimens, as determined by EDXRF. The results of potentiodynamic polarization study performed on laser surface treated as well as on type 304L SS substrate in 0.5M NaCl solution demonstrated excellent beneficial effect of laser surface alloying (fig L.10.1). Pitting potential of laser treated specimen alloyed with Cr & Mo registered a significant increase from 310mV to 720mV. On the other hand, surface alloying with Cr, Mo and Ni served to further rise pitting potential to 980mV. Impedance tests exhibited that Cr, Mo and Ni alloyed specimen had highest polarization resistance followed by Cr & Mo alloyed specimen while untreated substrate registered lowest polarization resistance. The capacitance of Cr, Mo and Ni alloyed specimen was lowest followed by that of Cr and Mo alloyed specimen and untreated substrate.

Table 1: Chemical composition (in wt%), as determined by EDXRF

Specimen	Targeted composition	Actual Composition				
		Cr	Ni	Mn	Mo	Fe
SUBSTRATE		19.48	10.68	1.08	1566 ppm	67.99
CR & MO ALLOYED	CR : 25-30; NI: 8-10; MO : 1.5; FE: BAL	24.23	9.04	0.63	2.06	64.05
CR, MO & NI ALLOYED	CR: 25-30; NI: 25-30; MO : 1.5; FE: BAL	24.42	21.72	0.27	1.37	52.22

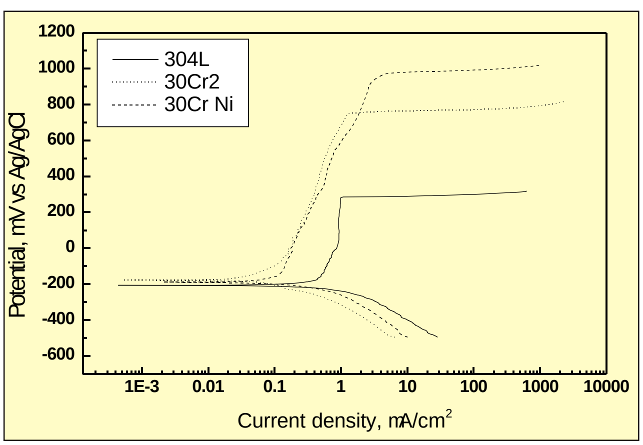

Fig. L.10.1 *Potentiodynamic polarization curves of laser treated specimens and the substrate in 0.5M NaCl solution. (304 L substrate; 30Cr2 - Cr & Mo alloyed; 30CrNi Cr, Mo & Ni alloyed)*

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

L.11 Laser alloying produces corrosion-resistant surface for HNO_3 environment

Type 304L austenitic stainless steel (SS) is a major material of construction in chemical and reprocessing plants involving extensive use of HNO_3. Normally protective Cr_2O_3 film on the surface of SS is rapidly dissolved when acid concentration rises beyond 8 N or its temperature rises above 353 K. The stability of Cr_2O_3 film is enhanced by addition of Cr and Ni. Si is another important alloying element influencing corrosion resistance of ASS in HNO_3 environment. Si offers excellent corrosion resistance when its concentration is either below 0.2 wt% or above 1.6 wt%. With 0.4-1 wt% Si content, the alloy suffers excessive inter granular corrosion [A.J. Sedricks, Corrosion of Stainless Steels, John-Wiley and Sons, New York 1979]. ASTM specifications allow up to 1 wt% Si in type 304L SS. Hence, surface enrichment of Si above 1.6 wt% offers an effective way to enhance corrosion resistance of type 304L SS in concentrated boiling HNO_3 environment.

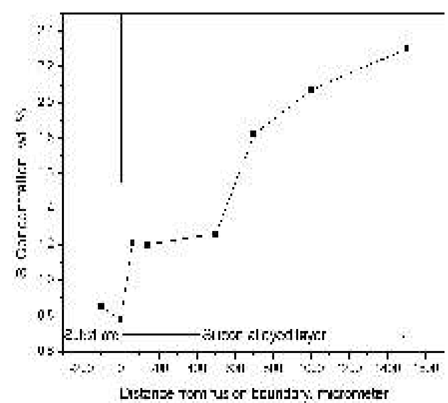

Fig. L.11.1 Si concentration profile across the cross-section of laser alloyed specimen

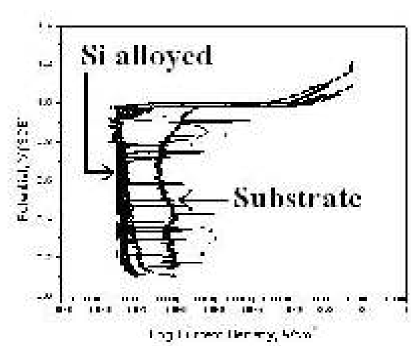

Fig. L.11.2 Potentiodynamic polarization curves of substrate and silicon alloyed samples

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.

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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.

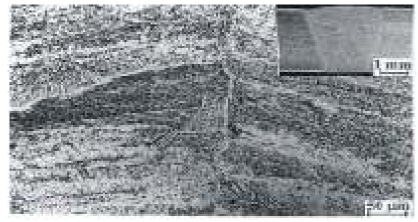

Fig.L.12.2 *Cross-section of bend tested LCW specimen*

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