SURVEY ON CLADDING LOW CARBON STEEL WITH NICKEL BASED ALLOYS BY USING GMAW PROCESS

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Abstract - *Coating of Inconel find wide applications in the field of aerospace and automotive industries. These materials finds its applications either by directly using the alloy or surfacing with the steel alloying. In the present study the tribo-corrosion resistance properties of Inconel 617, Inconel 725 and Inconel 625 were studied and compared. The literature survey conducted were based on wear, corrosion and tribo-corrosion behavior of Inconel 617 coating with stainless steel, Inconel 725 has better resistance properties. Inconel have higher content of molybdenum so, it's used to H_2S formation. Studies revealed that on hard-facing Inconel 617 with AISI 304 austenitic stainless steel had better wear resistance and the Inconel 725 had better corrosion resistance than hot work tool steel. The studies indicated that the wear tests had been carried on high temperature environment at 750^0 C. Corrosion test were conducted in sour brine environment. When the wear Resistance test is performed, the wear resistance of the Inconel 617 is much better than hot work tool steel. The Inconel 617 sample was much more resistant to oxidation and to softening than the hot work tool steel, providing a superior resistance to thermal fatigue cracking. The adhesive oxides increasing gradually and the Inconel 617 sustains the more wear resistance at high temperature. Taken the same coated material for the corrosion test, the Inconel 725 had more corrosion resistance. A Ni-Cr-Mo-Nb alloy, it had highly resistant to the corrosion and the Inconel 625 is an excellent choice for marine applications, it had more tensile strength, high corrosion-fatigue strength.*

Key words: Inconel 617, Inconel 625, Inconel 725, wear, corrosion, gas metal arc welding, tribo-corrosion.

1. INTRODUCTION:

The nickel base alloys available in form of Inconel, Monel, Hast alloy, Stellite alloys find its application on aerospace engineering. The nickel based alloys for aerospace use are selected based on their ability to resist high temperature oxidation, corrosion. The material is either used as wrought or coated with steel substrate through Hard-facing and Thermal spraying (Cladding). The Hard-facing technique involves surfacing of the materials by welding through pre-heat treatment and post heat treatment process with controlled atmosphere. Generally the hard-facing techniques are carried in GMAW (gas metal arc welding) - TIG (Tungsten inert gas welding) and MIG/MAG (metal inert gas welding). The fact of TIG welding uses no consumable electrodes. The MIG/MAG welding utilizes a consumable electrode. Generally, the quality of the welding is directly depends on the welding input of parameters during the welding process.

Inconel is the family of Ni-Cr-Mo-Nb based super alloy. Dissimilar joints of Inconel 617 and austenitic stainless steel are widely used in the nuclear, petrochemical industries. Inconel is a relatively expensive alloy, a cheaper material with good properties can be used in lower risk conditions to reduce material costs. Austenitic stainless steel is a prevalent material used in high temperature applications. The materials used to build this sub scale boiler were AISI 316 stainless steel for the condenser and Inconel 617 with a type 304L stainless steel wick for the boiler.

The critical issue in the joining of Ni-based super alloy and austenitic stainless steel is the penetration and dilution of clad material and base substrate there by selection of improved parameters like wire feed rate, selection of proper filler rod, filler wire etc.,. Gas tungsten Arc welding for joining of Inconel 617 and AISI 304 using nickel base corresponding to Inconel 617, Inconel 725, Inconel 625 and 310 austenitic stainless steels.

High temperature wear is one of the life-limiting factors when metallic surfaces are in repeated contact. High forming temperatures impact the wear behavior of tools through loss of mechanical strength and enhanced oxidation. It is well known that oxidation leads to material degradation and consequently, reduces the material resistance to wear. However, a surface oxide may reduce the oxidation rate and help to decrease the wear loss if it is dense and strong. The role of oxide scale in the wear of metals was discussed extensively both for ambient and high temperature wear while the mechanisms of oxidation wear. Some new approaches on the interpretation of oxidation wear mechanisms have also been proposed.

High temperature wear is identified to be a potential failure mechanism for thixoforging tools. While thixoforging is a very attractive processing route for the manufacture of steel parts for drive units and chassis components, it is very demanding on tool materials with high process temperatures involved (>1300 ◦C). The conventional hot work tool steels were shown to rapidly deteriorate under such severe conditions. With a dispersion of hard carbide particles in a cobalt-rich solid solution matrix, cobalt-base alloys are exceptionally good for applications requiring resistance to oxidation and wear. Ni-base alloys are also attractive at high temperature materials owing to an excellent oxidation resistance, creep strength and phase stability at high temperature. Co- and Ni-based high temperature alloys were tested recently for their potential to withstand the steel thixoforging environment. Their thermal fatigue performance is encouraging. It is thus of great technological interest to explore their wear resistance at high temperatures. While the ambient temperature wear performance has been investigated in detail, published information on the wear performance of these alloys at high temperatures is scarce. The present work was undertaken to investigate the high temperature sliding wear resistance of Inconel 617 alloys and rate their performance in hot forging of steel components (AISI 304).

The present study attempts to analyze the properties of the Inconel, which is coated on low carbon steel and the join method is to be GMAW.

Table no-1: Chemical composition of AISI 304 & Inconel

MATERIAL	C	Si	Mn	Cr	Mo	Ni	Nb	Fe	Others
AISI 304 (stainless steel)	0.063	0.28	0.9	18.4	0.22	8.11	0.010	Bal	0.032(P), 0.001(S)
Inconel	0.080	0.945	0.513	21.88	8.177	53.861	0.010	2.850	0.167(Al), 10.872(Co), 0.304(Cu), 0.211(Ti)

2. LITERATURE SURVEY:

Kai Feng [1] et al, discuss the fabrication of Inconel 625 coatings by shielded metal arc welding and laser cladding through which at both room and elevated temperatures the microstructures, hardness and wear resistance are investigated. The coating Laser clad has the greater hardness because to finer microstructure with alleviated segregation. It has a lesser wear rate because of not greater dilution of iron where it must be rigidly controlled for achieving higher hardness and wear resistance. This work has been done to investigate and compare at both room and elevated temperatures, the microstructure, hardness and wear resistance of arc welded and laser clad Inconel 625coatings for steam turbine valves hard facing. The wear test results show that abrasive wear is evident at room temperature, whereas adhesive wear is supreme at elevated temperature. In differentiating, laser clad coating has a lesser wear rate because of lower dilution of iron and higher hardness. Therefore, laser clad Inconel 625 coating is preferred because of its better mechanical performance at both room and raising temperature. As a conclusion to above research work it is found that aggravated dilution of iron and Coarser microstructure in arc welded Inconel 625 coating is responsible for the reduction of hardness.

Vemanaboina [2] et al, discuss made an attempt to investigate to multi pass weld the Inconel to Inconel material using the PCGTAW (Pulsed current gas tungsten arc welding) and also double v-grooved weld ability, metallurgical and mechanical properties of the PCGTA welded with Inconel 600 similar materials. Fusion welding process has high efficiency at joints to be fabricated, it has a simple set up as well as flexible and the process completes at low cost The work result addresses on the weld ability, microstructure and mechanical properties of the similar joints of precipitation hardened Ni-based super alloy Inconel 600 and Inconel 600 using PCGTA welding process employing fillers As a conclusion to this research work, successfully multi-pass weldments of Inconel 600 could be obtained from the PCGTA welding technique , tensile failures occurred at the weld region and the average tensile strength is 719.684MPa of the PCGTA weldments of similar metals Inconel 600 employing ERNiCrMo-3 was found to be 254.67 HV, the presence of richer amounts of Nb, Ti and Mo contributed for enhanced mechanical properties.

Lukas Fidler [3] et al, demonstrates the impact of laser cladding parameters on the corrosion behavior of the resulting surface. Laser claddings are metallurgically bonded to the substrate. It means that some mixing of the substrate with the cladding material occur which provides high adhesion of the cladding layer. Coatings deposited by the HVOF (high-velocity oxy-fuel spraying) process do not undergo such dilution and are only bonded through limited diffusion between the materials. Dilution in the laser cladding layer increases with the melt pool temperature. In this process, it was confirmed that the level of dilution has profound impact on the corrosion resistance and that dilution has to be minimized. The cladding process was optimized to achieve maximum corrosion resistance. As a conclusion, parameters for cladding deposition of corrosion-resistant layers of the austenitic Metco41C steel and the Inconel 625 nickel alloy were found and optimized, corrosion testing of the products demonstrated adequate corrosion resistance at a level comparable with wrought materials and with relatively small specimens, each bead is deposited onto hotter substrate surface than the earlier one. As a result, the cladding geometry as well as the iron content varies in several initial tracks.

M.H. Amushahi [4] et al, demonstrates hard-facing of low carbon steel using a boron-rich cored wire electrode. Boride-rich cored wires have found wide industrial applications in cladding and hard surfacing, especially where corrosion and wear resistance are important. One of the commercial cored wire electrodes is Alpha 1800 which is generally used for hard facing by arc spraying or gas metal arc welding. Arc spraying and gas metal arc welding (GMAW) techniques were employed to form a series of boride-rich coatings on the surface of St52 steel. In gas metal arc welding, a graded type coating was obtained and the microstructure consisted of a mixture of Fe_2B, α-Fe and some Fe, with strong metallurgical bonding to the substrate .As a result, composition of the layers through coating depth was fairly uniform in arc spraying, but in GMAW dilution caused the relative amount of boride phases to decrease from the coating surface toward the interface as proved by the intensity of X-ray diffraction peaks.

T.E. Abioye [5] et al, states how the corrosion execution of composite clad layers can be improved by minimizing the amount of tungsten carbide dissolution. Clad layers of Spherotene (a mixed tungsten carbide)/Inconel 625 wire composite suit-able for hard-facing in corrosive domains were deposited. The Spherotene dissolution enlarge as the energy per unit length of clad increases. Tungsten carbide (WC) combines favorable properties such as high hardness, low thermal expansion coefficient and good wettability with molten Ni alloys. The electrochemical corrosion execution of two typical composite clad layers formed at low and high Spherotene dissolution levels and Inconel 625 wire laser clad were investigated in de-aerated 3.5 wt. % NaCl solution. The outcomes indicate that microstructural in-homogeneity, caused by the formation of secondary phases, increases as the Spherotene dissolution increases. As a result, this study reveals that the corrosion mechanism in Spherotene Inconel 625 composite laser coatings is complex. This is as a result of large amount of microstructural modification and compositional in-homogeneity caused by the Spherotene dissolution in the composite coating.

Yucel Birol [6] et al, describes the wear behavior of three coating material such as X32CrMoV33 hot work steel, Inconel 617, Stellite 6 at the temperature of 750º C. In this experimental setup they have compare the wear resistance of the coating materials by using 'A CETR Universal Material Tester-2 model ball-on-disc type tribometer'. The alumina ball will pass over the coating surface at carried out at 750◦Cwith a sliding speed of 0.025 m/s, under 5N load for 60 min. As a result the wear resistance of Inconel 617 and the stellite 6 is better than X32CrMoV33 because Fe_3O_4 fails to survive the abrasion conditions and is readily detached from the surface.

O.T. Ola [7] et al, study about cold metal transfer clads in nickel-base Inconel 718 super alloy. It was figuring out the microstructural and geometrical characteristics of nickel base Inconel 718 super alloy. The result were showed the contact angle is 90^o, to existing clads were more difficult to add successive passes. Increasing the contact angle of greater than 115^o is more convenient to add successive passes.

P. Mithilesh [8] et al, describes on weldability, metallurgical and mechanical properties are investigated on dissimilar joints of Inconel 625 and AISI 304. This dissimilar joint was obtained by gas tungsten arc welding process to use ERNiCrMo-3.Parent metal of AISI 304 affect by Tensile fracture in all trials. Optical microscopy and SEM/EDAX techniques are used to evaluate on these dissimilar joints.

3. DISCUSSION:

The wear resistance of the Inconel 617 was high. In this, the coated material is test under high temperature ball-on-disc sliding wear test. A 0.001m diameter of alumina ball is pass over the coated surface.
Wear test carried out the sliding speed of 0.025 m/s, under 5N load for 60 min. The wear track was small and thin in

Inconel 617and also it will occurs the low rate of volume loss. Inconel 617 had good layer adhesive oxide and it was not suffered by material at this temperature. According to that the Inconel 617 has the least volumetric loss and better wear resistance at 750ºC.

The friction coefficients are measured in sliding wear test.

The Inconel 617 has initially started from 0.48 and it finished on 0.24 at the end of the experiment. It is fair to conclude that the friction and wear conditions are quite stable in the Inconel 617. Because the friction coefficient in indirectly proportional to the wear resistance. So, that the Inconel coated material has more wear resistance compared to others.

Corrosion resistance is also one of the major property of coating material. To surviving the corrosion resistance of Inconel the corrosion resistance will be more in Inconel 625.In this corrosion test the stainless steel is coated by Inconel 625. The specimen is exposed to fog at 35 ^{0}C for 48 hours. The corrosion resistance of the cladding was evaluated using GDOES spectroscopy.

By contrast, the cladding hardness in the plate center is approx. 70 HV less, as the heat from this part of the cladding dissipates the slowest, since this area is surrounded by the rest of the cladding. For 11 sample the hardness of the layer is the same about 170HV at the beginning and at the end of the cladding. The main differences in hardness are on the interface between layer and substrate. The room temperature is increased to 180^{o}C during cladding, which was reflected in the decrease of corrosion resistance and decrease in hardness in the HAZ.

From the studies, find on the Ni based alloys had more resistance compared to other materials. Due to excess material composition of Ni, Cr, Mo the Inconel 625 has good corrosion resistance.

4. CONCLUSION:

The following results should be obtained from the studies,

The adhesive and the relatively more plastic Cr_2O_3 on it sustains the sliding wear action without spalling and is to be improve the wear resistance of the Inconel 617 at 750^{0}C. Corrosion testing of the products demonstrated adequate corrosion resistance at a level comparable with wrought materials. The condition for achieving such results is the dilution level below 5 %. Above this limit value, the cladding becomes enriched in iron from the base material and tends to corrode. The Inconel 625 had material composition of Ni-Cr-Mo-Nb. So, that the corrosion resistance should be more in Inconel 625.

The Inconel coating is also resist the tribo-corrosion. Because, the major composition of Inconel were Ni, Cr, Fe, it was react with oxides and forms a NiO, Cr_2O_3 and Fe_2O_3, that oxides are known as hard oxides. So that the tribo-corrosion resistance will be more.

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