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# OXIDATION AND CORROSION BEHAVIOUR OF INCONEL-600 IN AIR AND SALT AT 800$^0$ C IN 50 CYCLIC CONDITION

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**Abstract -** *This paper is contribution to the knowledge of the oxidation behavior of the Inconel-600 in an air and salt 50 cyclic condition. In this paper study is also given to oxide scales which were separated and fell down in boat while oxidation process was going on. The objective of the work is to analyze the role of D- gun spray coating to enhance the properties of surface of substrate to counter the problems like erosion, residual hardness, thermal behavior and corrosion etc. Thermal spraying has emerged as an important tool of increasingly sophisticated surface engineering technology. Flame Detonation Gun. Oxidation behavior of Ti metallic coatings using high-velocity oxy-fuel and air plasma spray process on 9Cr-1Mo substrate steel was observed in the temperature range of 800- 9500C. The kinetics of hot corrosion like formation of protective oxide scale, diffusion of nickel from the coatings to the substrate and the diffusion of iron from the substrate to the coatings for longer exposures to steam oxidation was investigated.*

**Key Words - Alloys corrosion, Alloys oxidation, Inconel-600, Power coating method, Experiment procedure in labs, Final result with graph.**

## 1. INTRODUCTION

Corrosion is property of metals or its properties because of reaction with its environment. Many times the corrosion produce weight gain, many times it a weight reduction, many times the mechanical properties are change. Solid particle waste is a serious problem for the power production, costing a projected 7000 million rupees a year in lost efficiency, forced outages, and repair costs . Hot corrosion is observed mainly within the range of temp 900-1000$^0$C. Hot temp hot corrosion starts with the condensation of metal salts on the surface of metal. The super alloy have been developed to enhance their oxidation resistance by utilizing the concept of selective oxidation which are affected by alloy composition, surface condition, gas environment and cracking behavior of the oxide scale.

## 2. CORROSION IN ALLOYS

**Table-1:** Salts melting point

| **Salts** | **Melting Point($^0$C)** |
|---|---|
| $Na_2So_4$ | 884 |
| $CoSo_4$ | 735 |
| $V_2O_5$ | 690 |
| $Na_2O$ | 1132 |
| $NaAlO_2$ | 1800 |
| $MgO$-$Al_2O_3$-$SiO_2$ | 1355 |
| $CaO$-$Al_2O_3$-$SiO_2$ | 1170 |

### 2.1 High Temperature Hot Corrosion

This form of hot corrosion is observed mainly within the temperature range 800–900°C. High temp hot corrosion starts with the condensation of metal salts on the surface of the metals. A cycle of subsequent chemical reactions takes place, initially attacking the protective oxide film and progressing to deplete the waste element from the substrate metals. With chromium depletion, oxidation of the base material accelerates and porous scale begins to form. The macroscopic appearance of high temp hot corrosion is characterized in many cases by severe peeling of metal and by significant colour changes. For instance, a greenish tone appears on the surface of metals and alloys due to the formation of NiO in the area of accelerated attack. Microscopically, the morphology of Type I is characterized by a depletion region beneath the porous, non-protective scale. The reaction products frequently exhibit oxide precipitates dispersed in the salt film.

### 2.2 Low Temperature Hot Corrosion

LTHC is observed mainly within the temperature range 700–850 C. In this form of hot corrosion, low melting point eutectic mixtures of $Na_2SO_4$ and $CoSO_4$ cause typical pitting in the localized areas. The localized nature of attack is related to localized failure of the scale as a result of thermal cycling, erosion or chemical reactions. As opposed to Type I hot corrosion, in Type II corrosion neither microscopic chromium depletion is generally observed.

## 3. OXIDATION OF ALLOYS

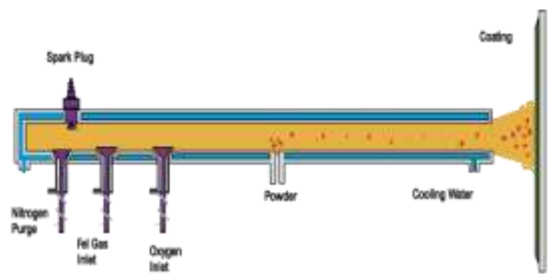
All of the principles that have been described have been for oxidation of metal but this theory can also be applied to alloys. However the oxidation of alloys can be a lot more complex due to metal in the alloys having differing affinities to oxygen because of the different free energies of formation of the oxide. The different metal will also have varying diffusivities in the alloys and there ions will have different mobility in the oxide phase. This makes the prediction of oxidation behavior much more difficult for alloys. To have effective oxidation resistance the alloy needs to form a continuous scale via external oxidation. Ineffective protection can occur by precipitates forming inside the alloy during oxidation. This is called internal oxidation. To achieve effective oxidation resistance alloys aim to form compact scale with small rates of diffusion of the reactant ions. The oxidation of alloys generally produce more than one oxide. Selective oxidation occurs where the last noble alloying element in the alloy is oxidized first to form the outer protective layers. The alloying elements have oxide which demonstrates large difference in stability however the temperature, partial pressure of the oxygen and concentration of the active alloying element also affects selective oxidation [45]. Selective oxidation has led to alloys being designed to have certain alloying additions in them to increase their oxidation resistance in high temperature applications.

## 4. FACTOR AFFECTING HOT CORROSION

1. Erosion.
2. Fabrication conditions.
3. Specimen geometry
4. Salt compositions
5. Salt depositions rate.
6. Gas compositions.
7. Temperature.
8. Conditions of salt.
9. Alloy compositions.

## 5. COATING IN INCOREL-600 BY DETONATION GUN

Detonation-gun spray process is a thermal energy spray coating process, which gives an good adhesive strength, low porosity and coating surface with compressive low stresses. A precisely measured quantity of the combustion mixture consisting of $o_2$ and $C_2H_2$ is fed through a tubular barrel closed at one end. In order to prevent the possible back firing a blanket of nitrogen gas is allowed to cover the gas inlets. Simultaneously, a predetermined quantity of the coating powder is fed into the combustion chamber. The gas mixture inside the chamber is ignited by a simple spark plug. The combustion of the $C_2H_2$ AND $N_2$ generates high pressure shock waves, which then propagate through the gas stream. Depending upon the ratio of the combustion gases, the temperature of the hot gas stream can go up to 4000 deg C and the velocity of the shock wave can reach 3000m/sec. The hot gases generated in the detonation chamber travel down the barrel at a high velocity and in the process heat the particles to a plasticizing stage (only skin melting of particle) and also accelerate the particles to a velocity of 1000m/sec. These particles then come out of the barrel and impact the component held by the manipulator to form a coating.




**(Fig-1:** Detonation gun**)**

## 6. INCONEL-600

The nominal composition of substrate material is Ni- 72%, Cr- 14-17%, Mn-1%, Cu- 0.5%, Si- 0.5%, C-0.15%, S-0.015%. The specimens with dimensions of approximately (15×10×5)mm3. The specimens were polished using emery papers of 220, 400, 600 grit sizes and subsequently on 1/0, 2/0, 3/0 and 4/0 grades.

**(Fig-2:** Turbine Blades made of inconel 600**)**

## 7. EXPERIMENT PROCEDURE IN LABS

1. The silicon wire tube furnace was used to an accuracy of ±1°C.
2. The coated specimen and uncoated specimen were polished using polishing machining (.1µmaccuracy).
3. Dimension of the specimen were noted down using digital vernier caliper.
4. The specimen were then heated in an oven up to 200˚C, which helps in uniform application of salt mixture.
5. Salt mixture sample dissolved in distilled water was coated on the warm polished specimen using a brush.
6. The Alumina boats and the salt coated specimen were dried in the oven at 150˚C for 30 minutes duration-weighed precisely.
7. These specimen kept in aluminum boat were preheated to maintain the weight constant for high temperature cyclic corrosion studies.
8. The boat containing the specimen was introduced into hot zone in furnace whose temperature was set at 900˚C.
9. Holding time inside the furnace was maintained for 1 hour duration and then afterwards the boat with the specimen was taken out and cooled to room temperature in still air.
10. The boat with specimen was weighed precisely again using an Electronic balance was used to conduct the thermo gravimetric studies
11. Weight change method has been considered for the analysis.
12. At the end of each cycle, Visual observations were made to study the color change, the luster, formation of oxide scale.
13. The above study was carried out for 50 cycles.

## 8. OXIDATION AND CORROSION TEST ON COATED INCOREL-600

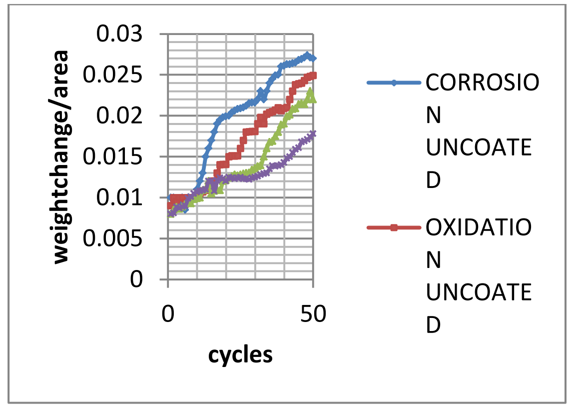



**Chart-1:** Weight change/Area vs. number of cycles plot for coated and uncoated Inconel-600 subjected to cyclic oxidation and corrosion for 50 cycles in air and molten salt environment at 800°C

**Table-2:** Value of parabolic rate constant

| Description | KP($10^{-6}$ $g^2$ $cm^{-4}$ $s^{-1}$) |
|---|---|
| Inconel-600 bare air oxidized | 2.98276 X $10^{-4}$ |
| Inconel-600 $Al_2O_3$ + 40%$TiO_2$ coated air oxidized | 1.6503 X $10^{-4}$ |
| Inconel-600 bare salt oxidized | 4.25534 X $10^{-4}$ |
| Inconel-600 $Al_2O_3$ + 40%$TiO_2$ coated salt oxidized | 2.21245 X $10^{-4}$ |

## 9. RESULT AND DISCUSTION

Degradation of metals and alloys due to hot corrosion has been acknowledged as a serious trouble for many high temperature aggressive environment applications. Alluminide coatings can be successfully deposited over the substrate material by HVOF, Detonation gun and Plasma Spray processes. $Al_2O_3$ + 40%$TiO_2$ coatings offer excellent corrosion and oxidation resistance, also having a high melting point and maintaining high resistance, strength and wear resistance at high temperature. It has been learnt from literature that detailed studies are needed to optimize the composition of cermets coatings for erosive-corrosive environments. The erosion resistance of cermets coatings increases with an increase in chromium carbide in the pre-sprayed powder. Researchers agree that carbide-based coatings provide excellent erosion protection, but disagree on the optimum amount of carbide for maximum erosion resistance.

The thermal sprayed coatings consist of oxides and voids originating from spraying process that are found at the splat boundaries, through which the coatings were mainly attacked. Consequently, the need arises to employ denser coatings which degrade less due to their more. DETONATION Gun with liquid petroleum gas as the fuel gas has been used successfully used to deposit $Al_2O_3$ + 40%$TiO_2$ alloy coatings on boiler tube materials. Under the given spray parameters, seemingly dense laminar structured coating with thickness in the desired range of 250 to 400 µm. The cumulative weight gain for all the Detonation Gun coated Inconel-600 materials are significantly lower than that of uncoated specimen subjected to hot corrosion in 50%Na2SO4+50%NaCl molten salt environment for 50 cycles at 800°C. Uncoated specimen suffered a higher corrosion rate and intense spalling of oxide scale was observed. The main constituent of oxide scale formed on all specimens is iron oxide. The acidic fluxing of the oxides by the molten salt mixture resulted in massive, porous oxide scale. All the coated specimen exhibit characteristic thick protective oxide scale, composed of oxides and spinel oxide of the active elements of the coating and imparted resistance to the hot corrosion in the given salt environment. The weight change curves for oxidation in both of the cases follow the parabolic law.

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