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Material Degradation Due to Erosion and Preventive Measures

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Abstract - **In industrial applications, surface of different equipments are damaged by solid particles entrained in a fluid stream. This type of wear is generally characterized as erosion. Probably the most considerable erosion problems which found in industry are those connected with the equipment used such as in coal-fired power plants, hydraulic turbines, fluid-bed system and coal purification plants etc. Erosion may come into play, when the moving particles strike-out the material from the surface of the equipment which reduces the life and efficiency of the plant equipments. The various factors named as particle shape, particle velocity, angle of impingement and properties of target material, affect the erosion rate. Hardfacing is one of simple and most effective technique to increase the erosion resistance by different welding processes. The soft surface of the component is deposited by suitable alloys or composites which enhance the surface properties. Hardfacing is a useful technique for either repair of failed components or manufacturing of new components.**
Keywords: **Erosion, Particles, Hardfacing, Surface Properties**

I.INTRODUCTION

In few applications solid particle erosion (SPE) is beneficial as in sand blasting, abrasive deburring and water jet cutting, but in industrial applications and power generation, SPE decreases the life of the component surface. This is a critical phenomenon which has been affecting the plant outputs by failure of the components from a long. In coal based power generation plants, hydraulic turbines, fluid-bed systems and petroleum purification, the components are found in the under of particle attack of slurry transportation [1]. Metal components may be failed not by breaking but due to erosion by changing dimensions mostly changing in volume of upper surface of components. Erosion is a dynamic process in which material is eroded from outer surface interaction between particles and surface [2]. When the particle flows at high velocities, a notorious attack has been observed. The groove may be seen on the target place which is the removal of material. The pure behavior of wear is erosion which comes out from the impact of high speed solids or slurry [3]. This mechanism involved of material removal from surface by magnitude force impingement during contact of flowing particles and part surface. The striking particles remove the upper layer of material from component surface [4]. The erosive action of high velocity particles makes severe damage in industry. For example in gas turbine the moving particles eroded the blade surface which reduces the life of the turbine parts [5]. The components degradation due to erosion causes reduce the efficiency of power plants and engines [6]. In hydropower plants, the mixing of solid rock particles in water produces significant erosion of important parts in the rainy season [7]. The mechanism of material degradation by particles is complex. Velocity of particles, hardness, impingement angle and shape of erodent etc. are some of the factors which affect the erosion rate. The erosion resistance of heat treated steel increase with the hardness and ductility at ambient temperature but in some cases there are no correlations between the hardness and ductility with erosion rate [8]. Researchers have stated the dependence of erosion rate on the mechanical properties of the component material. In brittle materials, the cracking and chipping are the mechanisms for material removal but in ductile erosion, the mechanisms include cutting, extrusion and forging [9]. The material removal rate depends upon relation: erosion rate = KVn, where‘V’ is velocity, ‘K’ is constant and ‘n’ has the value in range of 2-6.5 for metallic materials [10]. In erosive wear, the erodent particles strike the components for a short time. The time duration for the contact between erodent and surface of part is quite small, which make the erosion different from other types like abrasion and grinding. Erosion takes place due to cutting and deformation. Cutting is associated with the velocity alongside to the surface and deformation is related with normal to wear surface. Erosion in the pipelines is carried-out by cutting action of suspended particles [11]. The erosion failures of small components in power plants minimize efficiency either due to by shutdown or due to repairing / replacing the damaged parts. The working hours of the power plant gets reduced during shutdown which is the financial loss to the plant. Erosion of structural components in coal fired boilers reportedly produces about 50% downtime at power generation plants [12].

A.TYPES OF EROSION

- Erosion-corrosion (E-C): It is a combination of electrochemical corrosion and mechanical wear. The chemical attack on the metallic surface leads to damage and is named as E-C. It is the degradation of metal surface due to mechanical action often by impingement of liquid, slurry or particles suspended in liquid or gas, bubbles or droplets. The synergistic effect is produced in which the formation of protective film is retarded by erosion effect and decrease the surface hardness by corrosion [13].

- Erosion oxidation: In this the combined effect of erosion and oxidation results in more metal loss in comparison to the sum of individual mechanisms. Due to the rusty environment on the iron surface, when iron reacts with oxygen then it gets weakened and is eroded [14].
- Slurry erosion: It is also known as abrasive wear in which the material is removed from surface by slurry transportation of inert particles by striking on the surface. Interaction of slurry with component enlarges erosion rate. It is the loss of material from the outer side by hard grain present in the slurry form and it can result in significant costs if not adequately controlled [15]. Slurry erosion problems get enlarged in rainy seasons because of the addition of hard particles and strikes on components surface especially where filtration is quite difficult [7].
- Capitation erosion: It is a specific case of erosion by liquid beads. This is process of surface degradation and surface loss due to formation of vapor or gas chambers inside the passage of liquid. Cavitations may occur in a liquid when the static pressure becomes lower than the vapor pressure of the liquid itself, and vapor clouds are therefore nucleated [16]. The addition of split in the flowing water in Himalaya region causes 400% increase in erosion rate from clean water. Cavitations phenomenon reproduces the formation, growth and collapse of bubbles counted at high velocity and pressure change [17].
- Impact erosion: It is considered as surface retardation by impact of abrasives in pneumatic transport of solids in tubes. These problems come into play, where the fan applications create dirty environment. The fans throw the particles with impact force on the parts of the components [18].

B.FACTORS AFFECTING EROSION

There are number of factors which affect the erosion rate and are discussed as follows:

- Angle of impingement- for ductile materials, the maximum wear rate is found at an angle of 15^0 to 30^0 while the brittle materials get maximum erosion at normal impingement angle 90^0.
- Size, velocity and rotation of erodent particles during impingement accounts for more erosion rate.
- Surface properties of components like hardness, surface finish, strength and strain energy.
- Shape and stress level of the target surface.
- Particle concentration between surface and stream [8, 19].

II.METHODS TO FIGHT EROSION

A number of methods to fight erosion are discussed in literature. Surface treatments and the hardfacing are the most common and effective methods to protect the materials from erosive degradation. These methods are discussed thoroughly in the succeeding sub-sections.

A.SURFACE TREATMENT

The surface loss due to erosion needs repair and replacement of components. Surface treatment of metal surface plays an enormous role in extending the life of the components. By repairing, the components can be used again which also has a financial benefit to the industry [20]. The outer surface of the components usually makes stronger erosion resistances compared to the remaining due to economic factor. If all the cross-section of the material is found having similar properties as outer surface has then it may be too costly. Treatment of surface is a method of both cleaning and surface activation [10]. Therefore small amount of tougher core material is deposited on the surface to achieve enhanced surface properties like hardness, wear resistance and surface finish. The purpose of this is to improve/enhance the surface energy level [21]. The surface treatments fall under the main categories viz. mechanical, physical and chemical processes or by combination of these. Thermal spraying is one of the techniques used for strengthening materials against erosive wear and corrosion. Alloys and composites are jetted into flames or streams to be dissolved and sprayed on the surfaces of components in order to increase erosion resistance [22]. Laser sintering process is employed to develop metal matrix composites on the surface of components to achieve higher wear resistance. The technology merge metal powder into a solid part by melting it locally using the focused laser beam [23]. Chemical vapor deposition (CVD) is relatively a young process used to deposit silicon or carbon on the soft matrix. In this process, the vapors of these materials are produced and deposited through chemical action. The advantage of this process is that it can be used on metals as well as non-metals [22].

B.HARDFACING

Hardfacing by welding is another method used for treatment of surface subjected to wear, corrosion and oxidation. This technique extends the life of part by repairing as well as manufacturing of new components. It is one of the cost effective methods to increase the erosion resistance of the target surface. The surface properties can be improved to prevent different kinds of erosion and chemical phenomenon on the surface of the components [24]. It is the metalworking process where harder or tougher material is deposited on the surface of the substrate. The target surface becomes harder than the base metal during this process and therefore the process is named hardfacing. The homogenous composites are mounted on the soft surface of the components by using different types of welding techniques. The motives of the deposition of composites on the surface are to enhance the surface properties like hardness and toughness without the loss of other properties [20]. During the use of hardface alloys or composites, one thing should be kept at priority that the great bonding may be introduced between substrate material and the deposited alloy with higher deposition rate. The great bonding between the substrate and hardfacing material improve the results. If there is no tendency of good bonding between substrate and deposit alloy then the achievement of enhanced properties is not possible. Therefore there is a need to use suitable hardface material for deposition by different processes [25]. A tough matrix of coating is made on the soft surface of component with addition of suitable materials to increase the erosion resistance. The hardfacing layers are highly resistant against erosion due to desired surface properties and strong metallurgical bond with the base material. The hard carbides of WC, TiC, SiC, Cr etc. are used to increase erosion resistance of substrate. Sometimes post heat treatment is employed for betterment. The dimensions of the failed equipments can be regained by means of hardface welding (hard+surface+welding) which is very cost-effective in industrial applications. The composition of the deposit layers varies according to the alloys which affects the amount of carbides and type of carbide [26]. The substrates which have irrelevant properties can be treated by welding techniques to enhance surface properties. The types of welding used for hardfacing are mainly arc welding (submerged, flux cored and shielded metal), gas welding (oxy-acetylene) and combination of gas and arc (TIG, MIG). From few decades, due to increase in cost of the base materials as well as requirement of good properties, hardfacing has become an attractive alternative to increase the surface properties in an easy manner. Hardfacing by welding may be applied on IC engine components, earth moving equipments and various components which are subjected to erosion, wear, abrasion etc, [27]. Hardfacing is achieved by various processes ranging from traditional (oxy-acetylene) process to new plasma arc and laser technology. The deposit alloys like C, Si, Cr, Ni etc. affect the hardness and wear resistant properties. The surface properties improves with the addition of carbon and chromium content [28].

III.CONCLUSION

- The life of the components decreases due to erosion. The shut down reduces the plant efficiencies.
- Erosion rate depends mainly upon the attacking particle concentration as well as on their velocity, size, angle and rotation at the target surface.
- By hardfacing of the components, longer life can be achieved by deposition of hard alloy on soft surfaces of components.
- The wide variety of welding techniques can be used for hardfacing which are simple and economical.

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