International Journal of Science and Research (IJSR)
ISSN (Online): 2319-7064
Index Copernicus Value (2016): 79.57 | Impact Factor (2017): 7.296

Erosive Wear Study of Nitronic Steel Welds

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Abstract: ***The objective of the study was the examination of erosion wear rate of Nitronic steel welds using a slurry jet at high speed where impingement angle and time of particles attacking were controlled. Here the experiments were conducted on the apparatus which impinge high velocity jet of slurry of silica sand particles. The angle in this study was varied from 30 degree to 90 degree and time was varied from 30 min to 90 min. The examined samples include base metal (21-4-N steel) as well as two types of gas tungsten arc welded samples by ER2209 filler metal with argon as shielding gas with and without small amount of nitrogen gas content. The erosive wear study was conducted by silica sand particles of size varying from 100 µm to 500 µm. The results of the study were plotted as the calculated mass loss of eroded samples versus the angle of impingement and time of erosion.***

Keywords: Nitronic steel, erosion, ER2209 filler metal

1. Introduction

Due to increasing demand of alternative sources of electric energy production, the hydro power plant are being made in rivers where silt content is high thus blades used in Hydro turbines for electric energy production is subjected to serious situations that make erosion to the blades of turbine. Materials of these items are chosen to help oppose erosion and drag out their financial life. A standout amongst the most widely recognized materials in the manufacture of hydro turbine blades is 304l stainless steel which is having good erosion resistance properties. The research is being done to get the alternative material which is having more erosion resistance than existing material. One of the materials is High nitrogen steels.

High-quality austenitic stainless steels can be created by supplanting carbon with nitrogen. The solid-solubility of nitrogen is more than carbon, is an intense interstitial solid-solution strengthener, solid austenite stabilizer, and enhances resistance to corrosion due to pitting. Despite the fact that in liquid iron the solvency of nitrogen is low, 0.045 wt.% at 1600°C at atm. pressure, through alloying and concentrated high-pressure dissolving techniques[1], the nitrogen levels which can be acquired is over 1 wt.% and An austenitic stainless steel ought to be viewed as "high-nitrogen" on the off chance that it contains the amount of nitrogen more than that can be present in material by preparing at atm. Pressure, for most of the alloys and this limiting point is around 0.4 wt.%.

1.1 Applications of High Nitrogen Steels

- Bearings in aviation turbines, Ball screw gearing shafts which move airplane's flap traces.
- Rams in water cooled turbo drills and screws, Fasteners for the chemical, car.
- Water supply and control structures, Sewage treatment plant structures, mining equipment – magnetic ore separator screens, Bulk solids handling equipment – conveyor parts and many other applications.

1.2 Wear

Wear is the loss of material from a portion in view of a mechanical relationship with another object. Many sorts of solids, liquids, and even gasses at high speed can evacuate material and change the physical measurement and usefulness of a segment. Corrosion and erosion are the essential drivers of wear. Corrosion is achieved by concoction response of material with its encompassing. Erosion wear is a direct result of presentation to moving liquids and gasses, which could contain hard particulate. Effect of erosion wear in hydro turbines is pervasive increasingly when stood out from the corrosion. The administration life of hardware of slurry transport system is decreased by erosion brought on by strong liquid mix moving through the slurry transport structure. So slurry erosion is basic field should be investigated.

Types of Wear

There are several types and mechanisms of wear. These are:-
Abrasive wear
Adhesive wear
Erosion wear
Corrosive wear
Fatigue Wear

Abrasive Wear

Abrasive wear can be characterized as the sort of wear that happens when a hard surface slides or contuse to have relative movement with a milder surface. Hard materials or asperity that cut groves amid this movement produces abrasive wear. These asperities can be those present in the tangling surface or any remote material. This generation of wear sections hurries the procedure of wear if not evacuated.

Adhesive Wear

Adhesive wear can be characterized as the sort of wear that happens because of localized bonding between the reaching and the mating surfaces. In this sort of wear there is real exchange of material between the mating surfaces. This exchange relies on the level of hardness of the two mating surface. Be that as it may, the precondition for this sort of wear is the intimate contact between the two surfaces. However, the use of greasing up surface, oil or grease diminishes the inclination of this sort of wear.

Erosive Wear

This kind of wear is described as method of metal evacuation in view of impingement of strong particles on a surface. This can in like manner happen in light of gas and liquid however the erosion by this medium doesn't pass on. There are some specific properties of this kind of wear like: - when the edge of impingement is pretty much nothing, the wear made is solidly similar to corrosion. Exactly when the point of impingement is common then material streams by plastic stream or is expelled by crack due to brittleness.

Corrosive Wear

Most metals are thermodynamically unsteady in environment and respond with oxygen to frame oxides. These oxides frame layer or scales over the surface. These scales are inexactly attached to the surface. They can be effectively evacuated by treating it with acids, gasses, soluble base, and so on these sort of wear makes pits step by step and harm the metal surface.

Fatigue Wear

Fracture Wear or break emerges when the segments is subjected to cyclic tension and compression over a limit stress. The surface wears out in this procedure. It begins with the development of micro cracks and it bit by bit spreads and with rehashed stacking it really develops to the surface. Vibration is the regular reason for fatigue.

Erosion Wear

Erosion wear is a procedure of dynamic expulsion of material from an objective surface because of rehashed effects of solid particles. The particles suspended in the stream of strong fluid blend erode the targeting surface constraining the administration life of hydraulic turbines. Erosion wear brought on by the dynamic energy exchanged to target surface by impinging solid particles. Material loss of target material is higher for impinging molecule which is having higher kinetic energy. So speed at which particle impact has great influences on the Erosion wear of target material. Likewise Erosion wear relies on upon the angle at with which erodent strikes at target surface (effect edge), slurry focus, erodent measure, erodent shape and so on, the degree of Erosion wear changes material to material of target surface.

Erosion wear can be characterized into three classes:
1) Solid particle Erosion,
2) Slurry jet Erosion and
3) Cavitation Erosion.

Solid particle erosion is defined as the material volume loss when impingement of solid particles occurs on target material in the streaming liquid. The keep on striking of fluid stream on material surface causes slurry jet erosion. The disfigurement and expulsion of material from target surface because of rehashed nucleation, development and blastic fall of air pockets is known as cavitation.

1.3 Mechanism of Erosion Wear

Identifying the parameters which are affecting the erosion rates it is important to understand the mechanism by the removal of material occurs in erosion wear. Erosion wear is affected by following parameters:
1) Erodent material,
2) Impact speed,
3) Impact angle,
4) Target material,
5) Erodent size and shape, and
6) Carrier liquid.

The mechanism of erosive wear in ductile and brittle material is different. The mechanism of erosion wear includes ploughing, cutting and subsurface deformation and cracking.

Cutting Mechanism

When soft material is cut by hard material then the cutting wear is said to be occurred. So when the target material is impacted by impacting particle at positive rake angle and new surface is formed due to the cutting of chips from the material. The impinging particles shape in cutting wear is the main factor. The impinging particles having angular shape claims higher erosion wear due to cutting, because these impinging particles have sharp edges which act as cutting tool.

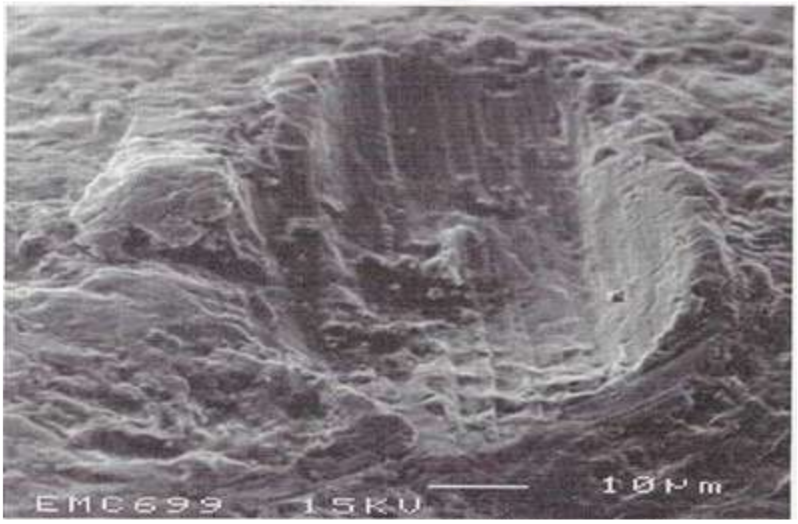

Figure 1.1: Cutting Mechanisms [19]

Ploughing Mechanism

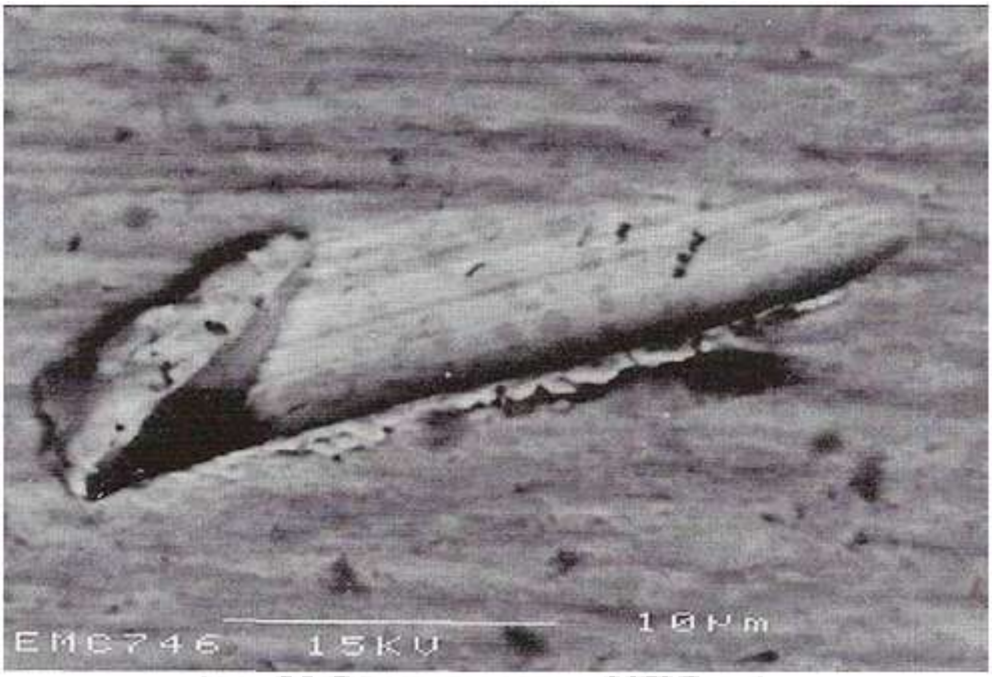

Figure 1.2: Ploughing Mechanism [19]

Ploughing wear occurs when target material is strike by the particles of spherical shape at bigger negative rake angle which in the front of particles and the side of crater results in the raises lips due to displacing and shearing the target material. This lip is framed toward movement of erodent molecule or more a specific basic speed the lip gets removed from targeted surface. Compared to other mechanism this wear announced very less wear.

1.4 Subsurface Deformation and Cracking

When the target material is impacted by spherical particles then the plastic deformation takes place at that point due to high velocity of impacting particles. This plastic deformation brings about cracks and crater arrangement which spread and brittle fracture leads to wear. Expelled shear lip is shaped due to molecule impact. The shear lip severed by weariness created by rehashed effect of particles.

1.5 Parameters Affecting Erosion Wear

The parameters affecting erosion are as follows:

1.5.1 Impact angle

Impact angle can be termed as the angle between the surface targeted and the direction of velocity of the jet slurry. The erosion wear varies with impact angle on the basis of the mechanical properties of the target material such as either ductile or brittle material.

1.5.2 Velocity of solid particles

Erosive wear is strongly affected by the velocity of solid particles. Erosive wear strongly increases as the velocity of slurry increases. The relationship between the erosive wear rate and the velocity of slurry can be correlated by using power law according to which the velocity power index varies in the range of 2-4.

1.5.3 Hardness

Hardness can be defined as the property of the material by which it resists to permanent deformation. Erosive wear has been profoundly affected by the hardness of the material. Hardness ratio can be characterized as the ratio of hardness of the material targeted and the hardness of the solid particles of the slurry.

1.5.4 Particle size and shape

Molecule shape and size is additionally the noticeable parameter, by which erosion wear is influenced. The size of solid particles has been considered important to erosion by many investigators. The power law determines the effect of increment in size of solid particle to the increment of erosive wear. The impact of molecule shape on the erosion is not set up because of challenges in characterizing the distinctive shape highlights. For the most part roundness calculation is taken thought. In the event that roundness component is one then the particles are impeccably circles and lower values demonstrate the molecule precision.

1.5.5 Solid concentration

Concentration is measure of strong particles by weight or by volume in the liquid. As convergence of molecule expands more particles strike the surface of impeller which increment the erosion rate, the concentration of slurries can shift from 2% to 50% on the sort of slurry. Be that as it may, at high concentration molecule cooperation increments and this abatements the striking speed of molecule at first glance.

1.6 Thesis Statement

The objective of this study is to experimentally determine the relative slurry rates of two different types of welds of nitronic steel. The functional relationships among the rate of erosion, angle of particle impingement and time of erosion are established. Graphical representations are provided that compare the rate for the two weld types plus base metal in terms of angle of slurry flow and time of erosion.

2. Problem Formulation

The martensitic chromium stainless steel (13/4 or CA6NM steel) has wide application in hydro turbines, pumps and compressors. But it has following limitations:

- Less resistance to cavitation erosion
- Poor mechanical properties of weld joint and repair welding

Since replacement of eroded runner assembly is very costly, weld repair of the runner assembly is a feasible option. During the various studies, it was observed that the performance of the welded runner assemblies is not satisfaction and fail prematurely, possibly due to the poor weldability of the martensitic steel. To overcome the problem of cavition erosion and poor weldability, a cavitation erosion resistant material was developed for the fabrication of the underwater parts of hydro turbines i.e. Nitronic steel (21-4-N steel). But the erosion resistance of the welds of the Nitronic steel is still under consideration because nitrogen content in the weld and matching filler.

So in this background the weld beads of 21-4-N Nitronic steel in hot rolled with GTAW welding using ER2209 filler wire and pure argon & argon+nitrogen as shielding gas are to be tested with jet type slurry erosion machine and the erosion resistance of the welds of this material to be studied.

So the basic objective of this work is to do study the erosion wear of the welds of this material and study the effects of various parameters (impingement angle, time etc) on erosion wear of the welds.

3. Conclusion

Wear is one of the most common problems encountered in hydro turbine blades in hydro power plants in which solid liquid mixture is comes in contact with the blades of turbine. The base material 21-4-N steel and its weld bead with GTAW welding with ER2209 filler metal with pure argon and argon + nitrogen as shielding gas were taken for the study of erosion wear. The erosion wear evaluated with varying the parameters impact angle and time of erosion using jet type slurry tester as test apparatus. Weight loss of specimens is the measure of erosion wear. The conclusions of the experimental work are listed below:

- Maximum erosion wear was reported at 90° impact angle and minimum at 30°.
- Base steel show better performance than both the weld beads in all conditions in which erosion wear tests were performed.
- Weld-1 (weld bead with pure argon shielding gas) shows the lesser wear than the weld-2 (bead with argon + nitrogen shielding gas).
- The erosion of all the samples under normal impact are found that at 30◦ impingement angle the erosion loss is primarily due to shear cutting of surface material, whereas at 90◦ impingement angle resultant erosion damage is due to strain hardening and embrittlement of target material.
- Erosion wear increases with increase in erosion test time duration.

4. Future Scope

1) The erosion wear studies can be performed after welding the steel with other welding filler wires of greater strength.
2) Other parameters of erosion can be varied to study the effect on erosion.
3) The computational approach can be used to simulate the similar work with different operating conditions.

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