International Journal of Water & Hydro Constructions – IJWHC
Volume 1 : Issue 3 *[ISSN 2374 –1600]*
Publication Date : 30 September, 2014

EFFECT of Cr_2O_3 and TiN COATINGS on 13Cr-4Ni TURBINE BLADE MATERIAL by HVOF PROCESS: A Review

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Abstract—In this paper, we investigate the effect of Chromium oxide (Cr_2O_3) and Titanium nitride (TiN) coatings on 13Cr-4Ni turbine blade material by high-velocity oxyfuel (HVOF) process in order to improve its wear characteristic, erosion and corrosion behavior and other mechanical properties. In the present paper studies carried out by various investigators has been discussed. Based on the literature survey various theoretical, and case studies have been discussed with some remedial measures suggested by various investigators. On the basis of several papers we gone through, we are going to compare the above mentioned properties with and without coatings and also find that the coating done by HVOF process can reduce the silt erosion problem in hydro turbine at a certain level.

Keywords-HVOF,Cr_2O_3 and TiN coatings, silt erosion.

1. Introduction

1.1 In hydro turbines, silt erosion is a very acute problem which leads to huge losses in hydro industry. It depends upon different parameters such as velocity of water, concentration, hardness, silt size and base material properties (hardness, strength, corrosion, wear behavior of base material).

By controlling the above mentioned parameters erosion can be minimized. But during rainy season it is impossible to control these parameters. During rainy season, the wear rate of blade material increases and hence decreases the efficiency of turbine. So to avoid the above mentioned problem, the coated blades can be used to decrease the wear and erosion of the blade material.

1.2 Water Turbine Blade materials

Commonly used blade materials are:
- 13Cr-4Ni.
- 13Cr-1Ni.
- 16Cr-5Ni.

Table 1.2.1:% of Turbine Blade Material [ref 14].

MATERIAL	%C	%Mn	%Si	%Cr	%Ni	%P
13Cr4Ni	.05	.50-1.0	.30-.60	12-14	3.50-4.50	.030

1.3 Properties of Water Turbine Blade material

As the blade materials have high Cr and Ni so they posses high hardness and corrosion resistance. But repeated actions of erodent due to silt causes silt erosion and wear in them. So they still needed to be more hardened and tougher and need improved wear characteristics.

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1.4 Coatings

In hydro turbine, ceramic coatings are generally used due to some important properties which are as follows:
- Wear protection for surfaces,
- Corrosion protection,
- Protection from impingement,
- Protection from erosion,
- Improving the hardness.

In this study, we focused on following widely used coatings Cr_2O_3 and TiN.

1.5 Application of Cr_2O_3

- Wear protection for surfaces of components construct of cheap base material or base materials that fulfill structural demands (strength, formability) in an optimal way.
- Partially in combination with corrosion protection.
- Partially in combination with especially surface properties like high or low wettability by different media.
- Abradable coatings for clearance control.
- High resistance against wear by impingement.

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1.6 Application of TiN

• It is extremely hard ceramic material often used as coating in titanium alloys base steel to improve the substrate surface properties.

• TiN Powder produced by nitridation of titanium with ammonia or nitrogen at 1200^0C.

• Titanium nitrides are also sputtered on a variety of melting point material such as stainless steel and titanium and its alloy [1].

• Its Young modulus (between 450 to 590 GPa on the basis of literature) means that thick coating tend to flake away, making them less durable than thin ones [2].

• It reduces corrosion and cavitations problem in stainless steel.

2. Thermal Spraying Processes

Thermal Spray is a generic term for a group of processes that utilize a heat source to melt material in powder, wire or shaft form. The molten or semi-molten material is propelled in the direction of a prepared surface by intensifying process gases [3]. The particles quench rapidly, upon collision with the surface, and bond with the part successive impacting particles generate a coating buildup [4]. On the basis of the energy source, thermal spray processes can be divided into a few main groups: plasma spray (atmospheric plasma APS, vacuum plasma VPS and low pressure plasma LPPS), combustion flame spray (flame spray), high velocity oxy/air-fuel methods (HVOF/HVAF), electrical arc (wire arc), detonation method (D-Gun) and as the latest technology, cold gas methods (CGS) [5].The chief advantage of thermal spray processes is the extremely broad variety of materials that can be used to produce coatings [5, 6].Along with the commercially available thermal spray coating techniques, High Velocity Oxy Fuel (HVOF) spray is one of the best option to get hard, dense and wear resistant coatings as desired [7].

2.1 Benefits of Thermal Spraying Processes:

- Comprehensive choice of coating material: metal alloys, ceramics, cermets and carbides.
- Coating with high thickness can be applied at high deposition rates.
- Coatings are automatically bonded to the substrate- can frequently spray coating material which are metallurgical in compatible with substrate.
- Part can be rebuilt quickly and at low cost and usually at a fraction of price of replacement[8].
- By using a good quality material for the thermal spray coating, coated component can out live new part.

• Thermal spray coating may be applied both manually and automatically [8].

In Fig 2.1.1.the typical operation ranges for various spray processes are presented.

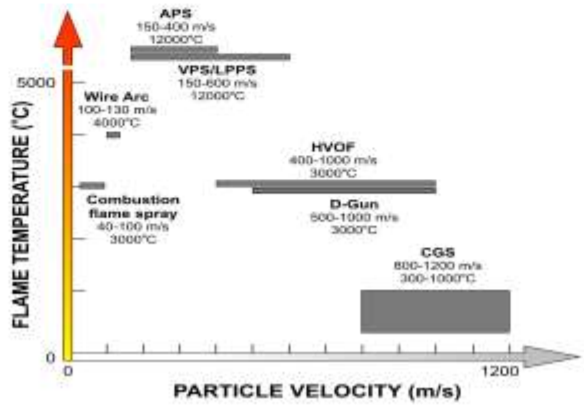

Fig 2.1.1.typical flame temperature and particle velocity ranges for various thermal spray processes [ref 5].

2.2 High-Velocity, Oxyfuel Processes (HVOF):

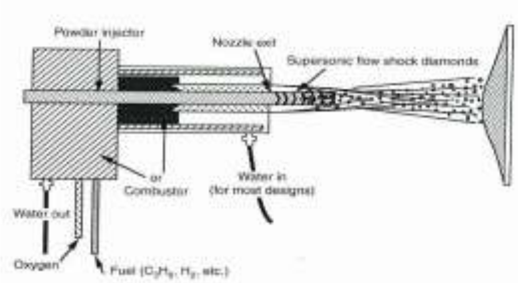

Fig. 2.2.1.High-Velocity, Oxy-Fuel (HVOF) device [ref 9].

A schematic of a high-velocity, oxy-fuel (HVOF) device is shown in Fig.2.2.1. HVOF devices are a subset of flame spray. HVOF utilizes confined combustion and an extended nozzle to heat and accelerate the powdered coating material. Typical HVOF devices work at hypersonic gas velocities, i.e. greater than MACH 5. The extreme velocities provide kinetic energy which help produce coatings that are very dense and very well adhered in the as-sprayed condition [8].
In HVOF spraying, heat is produced by flaming mixture of oxygen and fuel such as hydrogen, kerosene, natural gas, propane, propylene, ethylene, or acetylene.

2.2.1. HVOF Process have several Advantage over other Thermal Spraying Process-

• HVOF coating have high density and produce low porosity as compare to other thermal spraying process.

• It improve the toughness .Depending on the chemistry and some other factor, it can produce wear resistant coating with high impact resistance.

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- The high density and exceptional metallurgical properties of HVOF coating provide enhanced resistance to the effect of corrosion.

- It can demonstrate superior resistance to sliding/adhesive wear, erosion or cavitations depending on material and parameters which are used in the process.

3.0 Theoretical Investigations for Silt erosion in Hydro turbines:

- Krause and Grein (1996) designed a test rig to simulate the flow condition in a turbine by carried out model tests with varying parameters with the X5Cr Ni13/4Steel normally used materials in hydro turbines. A natural sand water mixture taken from a power plant reservoir and sand containing 99% quartz in various grain sizes were used for the tests. They have concluded that the abrasion rate is a function of velocity, sand contain and proportion of hard components and size of sand particles. The maximum abrasion occurred in arrange of 40-70 m [10].

- Mann and Arya (2001) studied the slit erosion characteristics of plasma nitrating and HVOF coatings along with commonly used steel in hydro turbines. For slit erosion characterization hydro foils scaled down to 1..10 of the actual hydro turbine blades were selected. The abrasion wear characterization was carried out as per ASTMG-65. Angel of incident velocity and Reynolds Number were maintained similar to those that commonly occur in hydro turbines, simulating low as well as high-energy impingement wear. They concluded that HVOF coating showed better performance than plasma nitride steel. HVOF sprayed tungsten carbide on steel appears to be an excellent erosion resistance shield to combat low and high-energy particle impingement wear. It can provide an appropriate solution to the hydropower stations severely affected due to silt [11].

Kjolle(5) studied the causes of damages in hydro turbines and found that the main causes of damage of water turbines were due to cavitation problems, sand erosion, material defects and fatigue. The turbine parts bared to cavitation are the runners and draft tube cones for the Francis, Kaplan and the needles, nozzles and the runner buckets of the Pelton turbines. The effect of hydraulic design and production of components, adopting erosion resistant materials and cavitation erosion was found to be reduced by improving the arrangement of the turbines for operations within the good range of acceptable cavitations conditions [12].

M. K. Padhy et.at. studied the performance of pelton turbine under silt erosion condition. They found that the loss in efficiency of hydro turbine depend on silt parameter and operating situation. They develop a relation which may be useful during manufacturing of turbine to prophesy the efficiency loss of pelton turbine under a given silt content water for a particular site [13].

Conclusion

On the basis of present study we can conclude that in order to improve wear characteristics, corrosion and other mechanical properties of widely used 13Cr4Ni type blade material coated with Cr_2O_3 and TiN could be used as they serve wear protection for the surfaces of base material in combination with corrosion protection with surface properties like high and low wettability, abradability and high resistance again it wear by impingement. We can use other thermal spraying processes but on the basis of literature survey for silt erosion in hydro turbine, HVOF could be best suited for coating the base metal.

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