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Experiments on life cycle extensions of geothermal turbines by multi composite technology

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ABSTRACT

These days, many countries are involved in evaluation and development of geothermal projects, and this includes the installation and maintenance of geothermal steam turbine. High reliability and maintainability are required as a basic condition for the geothermal turbines and energetic components in order to provide a stable power supply. For increasing the reliability of geothermal steam turbines the lifespan assessment of materials under geothermal environment conditions is important. A leading cause of reduced availability in geothermal power plant, non-conventional energetic systems' components is corrosion damages in turbines, especially blades and rotors corrosion. Improved turbine mechanical integrity and increased rotor steam-turbine life cycle demand optimization is achieved thermal spray depositing using multi composite systems. This specific paper objective is design and synthesis of new complex powder mixtures NiCr/NiCoCr with different addition of ZrO_2 stabilized with Y_2O_3 that can be used to obtain protective layers with improved wear, thermal shock and abrasion resistance. These coating will be studied also in "in situ" conditions, in Hellisheiði geothermal system, to investigate the actual effects of geothermal steam on the surface coated with multi-composite structures. The results will be reported in a future paper for comparing laboratory and "in situ" conditions tests results.

1. Introduction

Current engineering practice in geothermal plant is increasingly focused on integrating current turbines life cycle versus new geometrical and functional design of the turbine rotors. In reality, both directions are necessary to stimulate geothermal plant expertise and research progress in this field. The product performance requirement results in a new class of composites coating technology for improved reliability (http://www.geoelec.eu, 2013).

Multi-composite materials technology provides the construction of the main components exposed to very corrosive environment. Rating the principal technological measures already applied to current geothermal turbines is studied and discussed (Sanjeet et al., 2013; Gudjonsdottir et al., 2015; Sullivan et al., 2001). The geothermal steam inlet pressure and temperature are relatively variable with time and a decreasing in geothermal steam initial parameters may appear. Even in the situation when the fluid reinjection is ensured, usually the source loses pressure, being necessary a period of time for renewing. The renewing time depends on the reservoir nature and its permeability (Gudjonsdottir et al., 2015; Sullivan et al., 2001). The geothermal experts' work with industry and national laboratories need to develop a new generation of turbines (Lund et al., 2011). One of the new and most promising geothermal projects in Iceland is the Icelandic deep drilling project (IDDP), where they were intending to drill down to super-critical conditions (extreme corrosion and erosion) in a

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Magma-EGS system (Eldersa et al., 2014). For now, the high temperature values were reached in IDDP-1, important expectation to supercritical conditions existing in IDDP-2 program planed at Reykjanes. The superheated steam from the IDDP-1 well in Krafla at the wellhead was extremely hot or about 450 °C and pressure around 145 bars and may be expected to yield ∼36 MW and expansion plan involve adding 50–75 MW steam turbine by addition of supplementary turbines (Eldersa et al., 2014; Frisleifsson et al., 2013). In this situation of superheated steam, some turbine components need to reduce liquid films on the blades, erosion and wetness loss (Wilfred et al., 2014; Machemer and Otakar, 2004; Frisleifsson et al., 2013).

Test conditions simulating geothermal environment were proposed in this work. This paper approaches a new solution for protecting the steel turbine components against aggressive corrosion by coating with multi-composite layers. Some of the layers may contain 3–5 wt% tungsten carbide (WC). The concentrated test evaluates corrosion and long-term usage condition of the turbine components could be easily enclosed in a mathematical model. Gaseous components such as hydrogen sulfide (H_2S), carbon dioxide (CO_2) are highly corrosive and promote corrosion damages; in this case, resistant material used for coating the blades surface have to be carefully selected (Bertani, 2012).

Geothermal steam contains various solid components which causes active erosion and massive deposition. Therefore countermeasures are necessary in order to prevent erosion, dry sliding effects and removing the scale deposits on the steam path surfaces during geothermal turbines components operation and steam piping (Lamarche et al., 2010; Hata et al., 2008).

2. Materials and technology for life cycle extensions of geothermal turbines and experimental conditions

Multi composite ceramic protective coatings of rotors and blades can be successfully used in the geothermal industry, to obtain improved reliability and extended life service of turbines components. Another significant reason for research activities growth is the plasma deposition of ceramic composites coatings which secures alternative protection of turbines under severe geothermal conditions. The principal goal of this work is to promote activity regarding the geothermal turbines life cycle extension by multi-composite technology and identify the most cost-effective routes to reliable corrosion protection of turbines components, particularly of blades in geothermal condition. During this development stage, the various components of the geothermal power plants and the necessary expertise for manufacture and use meet in a critical point. Thus the research activity in the field moves toward the increase of usage cycle of geothermal components, especially the viability increase of rotors and turbines in geothermal steam functioning conditions. Thermal spray optimization depositing by multi-composite systems and process for composite depositing layers demand secured mechanical integrity of turbines resulting in increased turbines components' life.

Table 1
Test materials for geothermal components turbines work.

Turbine components	Material	Complex powder mixtures tests
Blade material	6% Cr–4% Ni steel	NiCr/NiCoCr with 3% ZrO2
Rotor material	1% CrMoNiV steel	NiCr/NiCoCr with 5% ZrO_2

Current development efforts are organized around several problem areas including: powders and composite structures spray plasma-forming of graduate structures, wear resistant materials, rotors restoration and life extension of geothermal turbines. Some of the specific paper objectives are related to the: design and synthesis of new complex powder mixtures that can be used to obtain protective layers (Geewook, 2011) with improved wear, thermal shock and abrasion resistance. Similar composite materials for different percentages constituents, different plasma deposition parameters or alternative joint designs can be achieved and investigated. There are two types of material for geothermal turbine components, as shown in Table 1. The main condition for this steels materials is to have sulfur content below 0.005% according to Japanese researcher from Hitachi and Mitsubishi (Fukuda et al., 2010) indicating that sulfur values are lower than 0.005% for materials code GSR1 (Fukuda et al., 2008) and 10325MGB according to Japanese standard JIS G4303. This is necessary to limit the cracking effect due to corrosion (Fig. 1).

To reduce induced corrosion and materials fatigues due to the centrifugal forces and geothermal steam (containing different corrosive substances and non-condensable gases) general use of 12–16Cr steel is recommended and for example the steel used for Japanese turbine blades in Hellisheiðavirkjun power plant is 12Cr

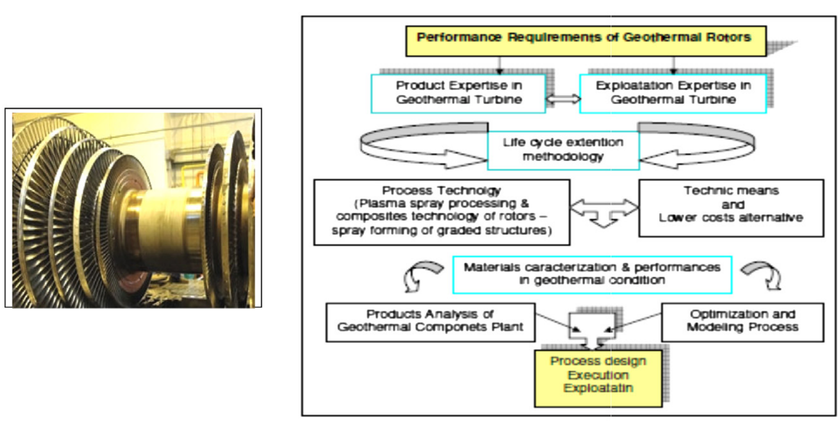

Fig. 1. The block-diagram principles for product–process design and life cycle extension of geothermal turbine rotors.

Table 2
Characteristics for complex powder used.

Characteristic & composition	Particle size (≥15 μm)	Flow density g/cm^3 in 30 s	Density (g/cm^3)	Are flow rate (l/min)	H flow rate (l/min)	Injection angle (0)	Current (A)	Voltage (V)	Porosity (%)
$5Y_2O_3$–ZrO_2	−120 mesh	2.3	5	30	2	90	600	70	1–8