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Improvement The Erosion Resistance of Turbine Blades Using Different Material with Different Surface Treatment

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Abstract. This paper presents effect of using different materials on surface properties and erosion resistance of turbine blades, three basic material copper, aluminum and steel where used in this work. Steel exposed to three surface treatment hardening, flame hardening and carburizing processes to improvement their surface properties. Wear rate, hardness and impact resistance were measured for each group. the results showed that using of copper or aluminum is not recommended, steel showed good surface properties, best result obtained after thermal surface treatment, carburizing give higher wear resistance, greater surface hardness compared to hardening and flame hardening process respectively, while flame hardening provided the specimens with greater toughness as compared to carburizing and hardening process respectively. Microstructural investigation was achieved using SEM and EDS technique.

Keywords: Surface treatment, erosion resistance, turbine blades, SEM analysis

1. Introduction

Turbine blade materials have progressed rapidly beyond traditional ferrous alloys and continuously being developed to meet the challenging requirements of modern turbine engines. Because of the serious consequences of erosion on turbine life and performance, it is necessary to gain a better understanding of the blade surface degradation mechanisms. A complex phenomenon such as blade surface deterioration by erosion requires experimental research efforts [1]. Near the exhaust of a steam turbine engine (also known as the penult stage or final stage), the low-pressure working condition favors phase transformation, and small water drops are produced by the condensation of steam. Once formed, the water drops move with the flow and some of them may impact the blade surface with a velocity over 200m/s— upon consecutive impact on the turbine blades, the surface material may spall off and this is known as the water drop erosion which severely affects the system reliability [2]. So this work investigates the effect of different material including steel with different surface treatments on the properties related to erosion.

R. Chotěborský studied the effect of heat treatment on the microstructure, hardness and abrasive wear resistance, results from the study shows that the hardness, fracture toughness and abrasive wear resistance are influenced by temperature of destabilization heat treatment and air and furnace cooling conditions, respectively [3]. A. ÖZ et.al investigated the effect of heat treatment on the wear and corrosion behaviors of a gray cast iron and observed that the corrosion and wear resistance of the coatings increased along with the reduction of porosity and roughness by the heat treatment [4].



2. Materials and Specimens

Three types of materials were used in this work medium carbon steel, aluminum with 99.8% purity and copper with 97% purity, all metals were provided from Fluka company in rod form steel were subjected to three different surface treatment (hardening, flame hardening and carburizing). Specimens from each metals and for each treatment were prepared for three mechanical test (wear, hardness and impact). Specimens of wear with cylindrical of 10mm in diameter and 20mm height according to ASTM G56 [5], disc specimens for hardness with 20mm diameter and 6 mm height according to ASTM E10-17[6], while rectangular specimens (55x10x10) mm were prepared for charpy impact test according to ASTM E23 – 07a[7]. Figure (1) shows the specimens for all tests.

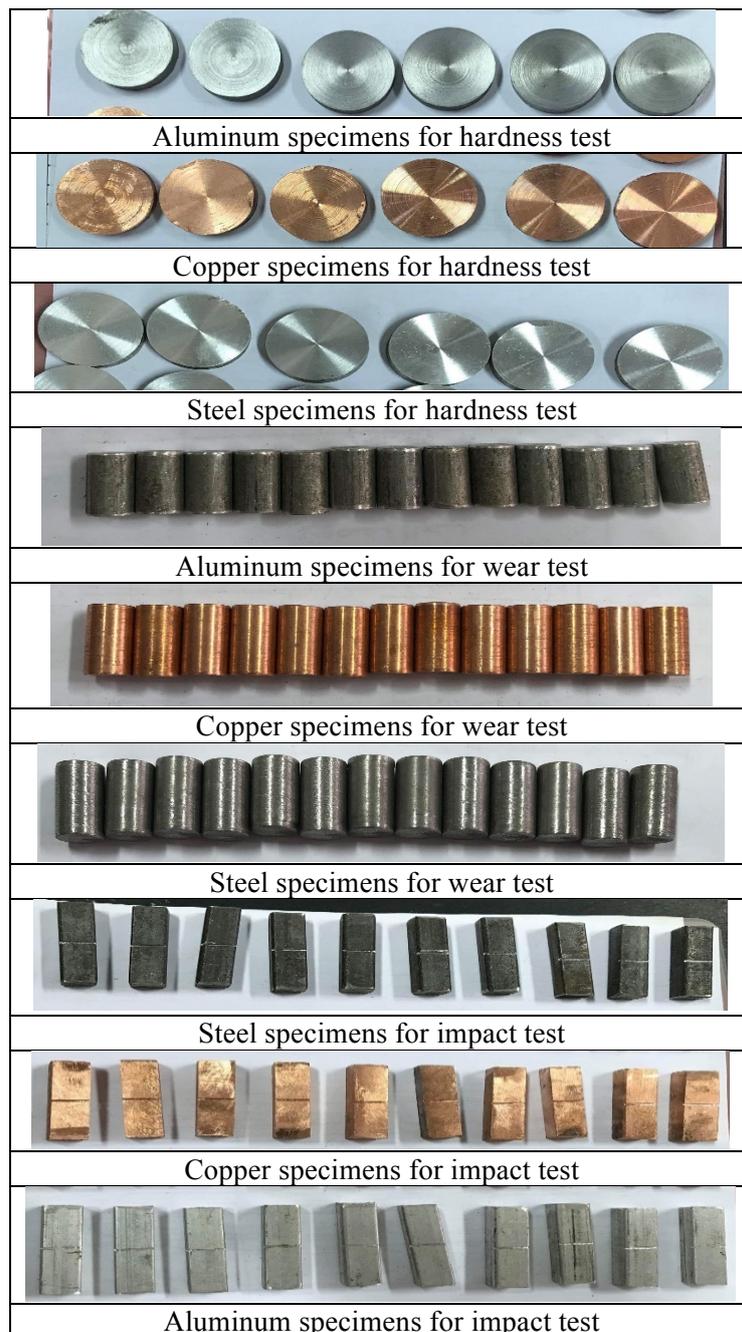


Figure 1. specimens used in the study

3. Surface Treatment

3.1 Flame Hardening

Flame hardening consists of austenitizing the surface of steel by heating with an oxyacetylene torch and immediately quenching with water. After quenching, the microstructure of the surface layer consists of hard martensitic phase over a lower-strength interior core of other steel morphologies such as ferrite and pearlite [8].

3.2 Hardening

This treatment includes heating the specimens to 1000° C (austenite region) then quenching in water. When the final quench is from a temperature high enough to allow the development of full core hardness, the hardness variation at any location will be that of the hardenability band of the steel at the corresponding position on the end-quenched hardenability specimens [8].

3.3 Carburizing

Carburizing is the addition of carbon to the surface of low-carbon steels at temperatures (generally between 850° and 950° C) at which austenite, with its high solubility for carbon, is the stable crystal structure. Hardening of the component is accomplished by removing the part and quenching or allowing the part to slowly cool and then reheating to the austenitizing temperature to maintain the very hard surface property [8].

4. Testing

4.1 Sliding wear testing

The wear test was performed according to ASTM G56 [5] by using pin-on-disk test instrument shown in the Figure (3). The wear rate calculated according to eq. (1), all tests were conducted at room temperature with constant speed 940 rpm and for time 300sec. with loads (5, 10, 15 and 20 N). Initial weight of the specimens was measured using sensitive balance weight with an accuracy of (10⁻⁴ g). After testing the specimens were removed, cleaned with acetone, dried and weighed to determine the weight loss due to wear.

$$W_r = \frac{\Delta W}{2\pi r N t} \quad (1)$$

Where:

W_r : wear rate in gm/cm

N: speed (rpm)

$2\pi r$: the sliding distance (cm).

t : time.

$$\Delta W = W_2 - W_1$$

Where W_1 : the weight before wear test. (gm)

W_2 : the weight after wear test. (gm)

4.2 Charpy Impact Test

Toughness of specimens were measured using charpy impact machine according to ASTM E23– 07a [7]. The impact test is a method for evaluating the toughness and notch sensitivity of engineering materials. It is usually used to test the toughness of metals, The Charpy impact test is a dynamic test in which a test piece V-notched in the middle and supported at each end, is broken by a single blow of a freely swinging pendulum. The energy absorbed is measured. This absorbed energy is a measure of the impact strength of material.

4.3 Brinell Hardness Test

The Brinell Test is an indentation hardness test consisting of two steps. Step one, the indenter is brought in contact with the tests specimen perpendicular to the surface and the specified test force is applied. The test force held for the specified time and then withdrawn. Step two, the diameter of the indentation is measured in at least two directions perpendicular to each other. The Brinell hardness value is computed from the mean of the diameter measurements by the use of a mathematical formula designed for this purpose according to ASTM E10-17 [6].

5. Results and Discussion

5.1 Results of Wear Test

Wear rate were measured for all specimens in this work as shown in figure (2). Copper showed highest wear rate because of its softness compared to aluminum and steel, while aluminum showed moderate wear rate which increase with increasing loading rate, steel indicated higher wear resistance compared with other metals this belong to its strong nature. Heat treatment affect the wear resistance greatly for steel specimens as indicated in Figure (2) the clear decreasing in wear resistance was recognized after carburizing, quenching hardening and flame hardening which gave good wear resistance respectively. This improvement in wear resistance after heat treatment belong to the many changes occur in microstructure from soft pearlite and ferrite phase to hard martensitic phase which gained after heat treatment. This hard structure made the steel least affected by loading rate as in indicated in the figure, these agreed with A. Öz et.al and J.O. Agunsoye work [4,9].

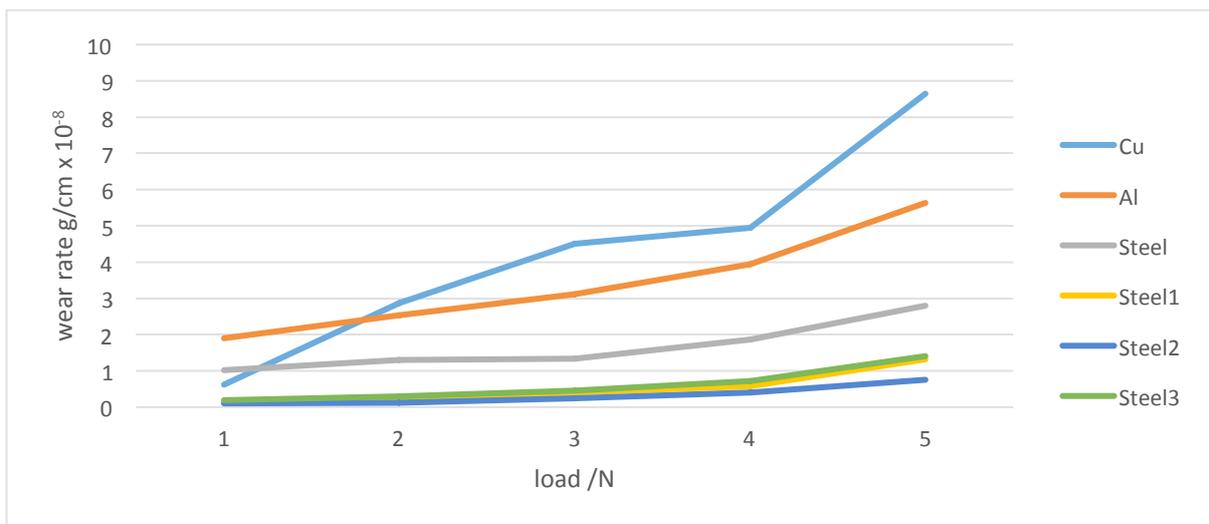


Figure 2. Wear Rate for All Material Used in The Study.

Note: steel: specimens without treatment, Steel1: specimens with hardening treatment
Steel2: specimens with carburizing treatment, Steel3: specimens with flame hardening treatment

5.2 Results of Impact Test

Impact test consider a valuable indicator to the toughness of material and its resistance to fracture in this test the magnitude of energy required to failure would be calculated, Figure (3) showed the result for specimens used in this wok. Same trend in improvement of wear resistance can be recognized in impact or shock resistance, aluminum gave the lower toughness while steel after flame hardening showed highest toughness, copper, steel, quenched steel, carburize steel respectively indicated moderate shock resistance. Surface heat treatment improved the toughness of material because of surface microstructure changed which give hard surface (martensitic phase) with soft core (pearlite and ferrite phases) these results agreed with Jon S. Magdeski and O.O. Daramola [10,11] works.

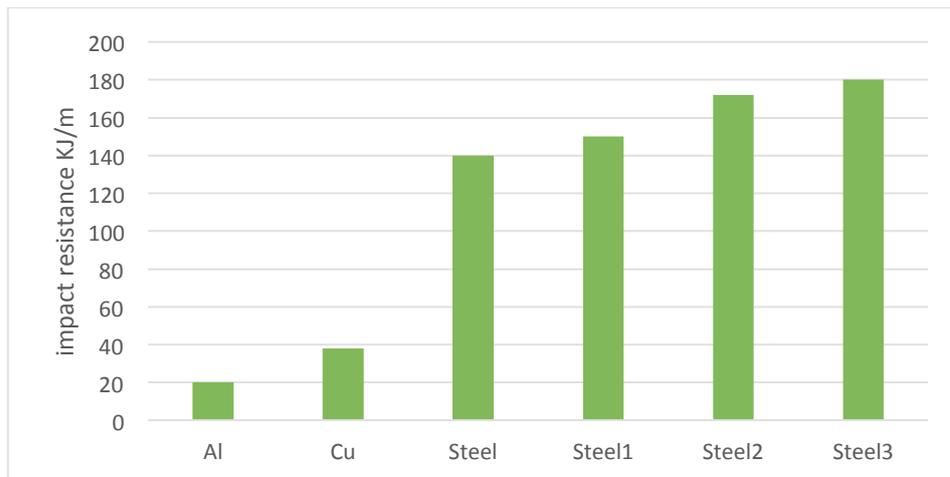


Figure 3. Results of impact test.

5.3 Results of Hardness Test

Brinell hardness test consider indicator to the ability of material to scratch the surface, Figure (4) showed the result for specimens used in this work. Same trend in improvement of wear resistance and impact resistance can be recognized in hardness results, aluminum gave the lower hardness while steel after flame hardening showed highest hardness, copper, steel, quenched steel, carburized steel respectively indicated moderate shock resistance. Surface heat treatment improved the surface hardness because of surface microstructure changed which give hard surface (martensitic phase) these results agreed with with Jon S. Magdeski and O.O. Daramola [10,11] works.

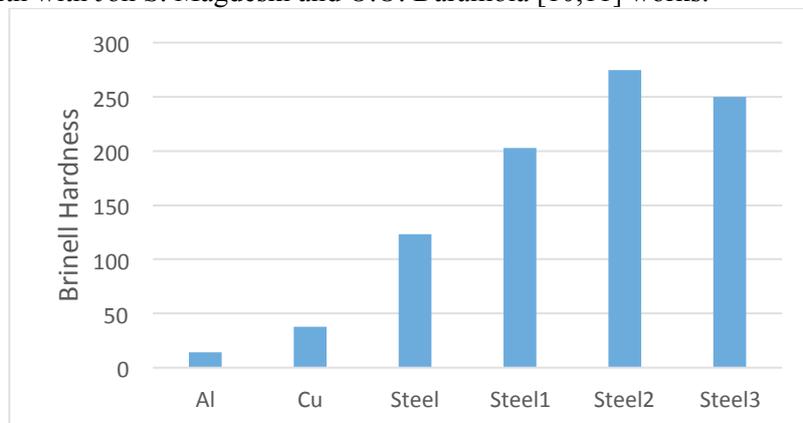


Figure 4. Results of Brinell hardness test

5.4 Results of SEM and EDX

The study of the microstructure for metals specimens was adopted. The samples were taken from the broken pieces obtained after testing specimens. The samples were dried at room temperature and then examined by SEM analysis with higher magnification. Figures (5), (6), (7), (8), (9) and (10) showed the micrograph and EDX analysis of steel, aluminum, copper, carburized steel, quenched steel and flame hardened steel. From SEM we recognized that steel specimens with one phase (pearlite) but after treatment showed multi phases because of formation of martensitic phase due to heat treatment which making steel harder and strongest than parent steel so they will be more applicable in turbine blade.

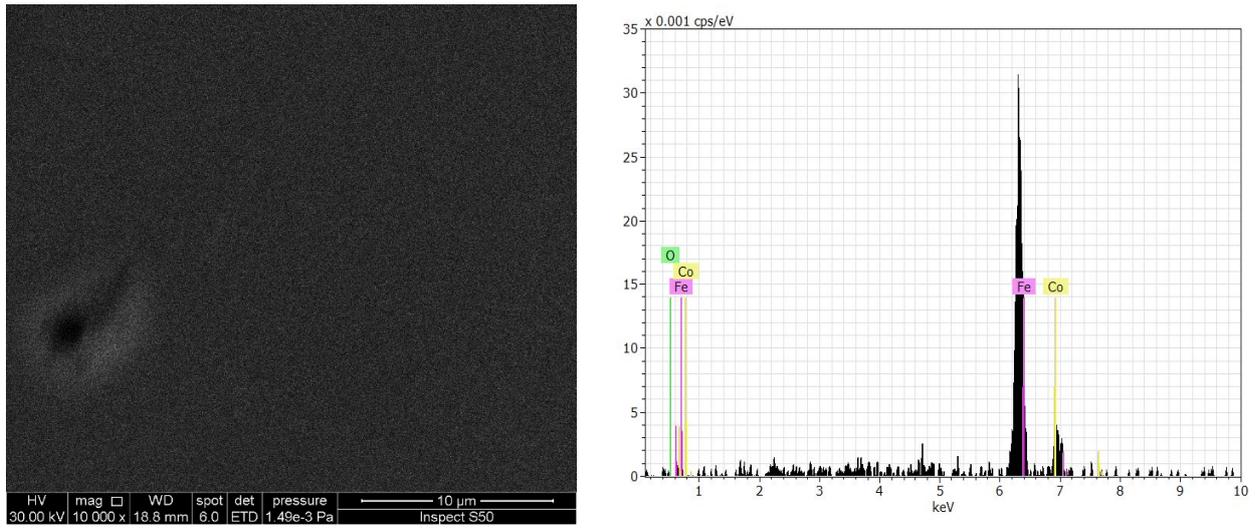


Figure 5. SEM and EDX of steel specimen.

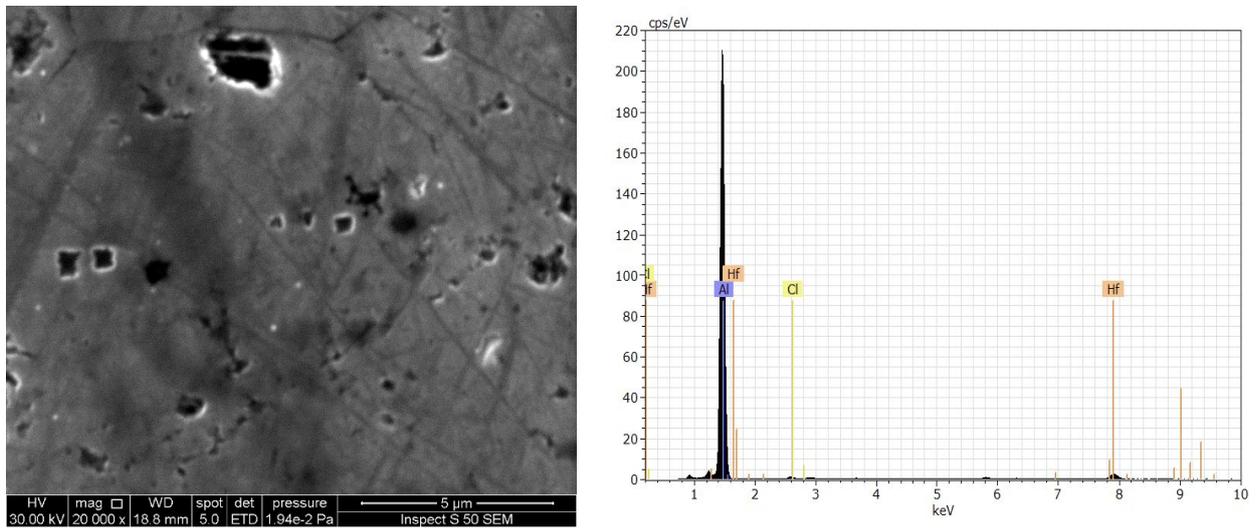


Figure 6. SEM and EDX of aluminium specimen.

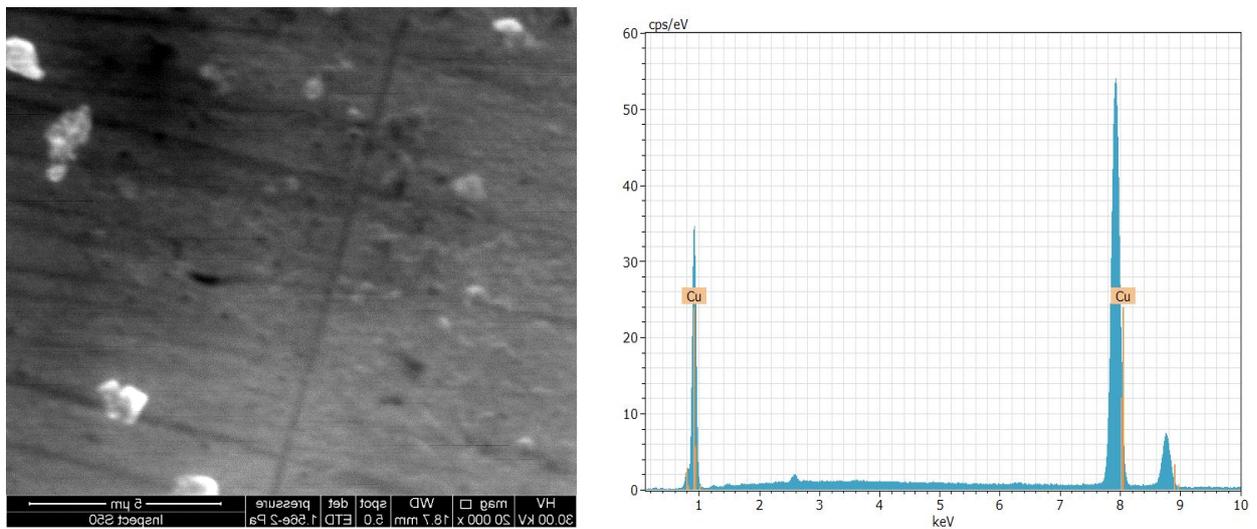


Figure 7. SEM and EDX of copper specimen.

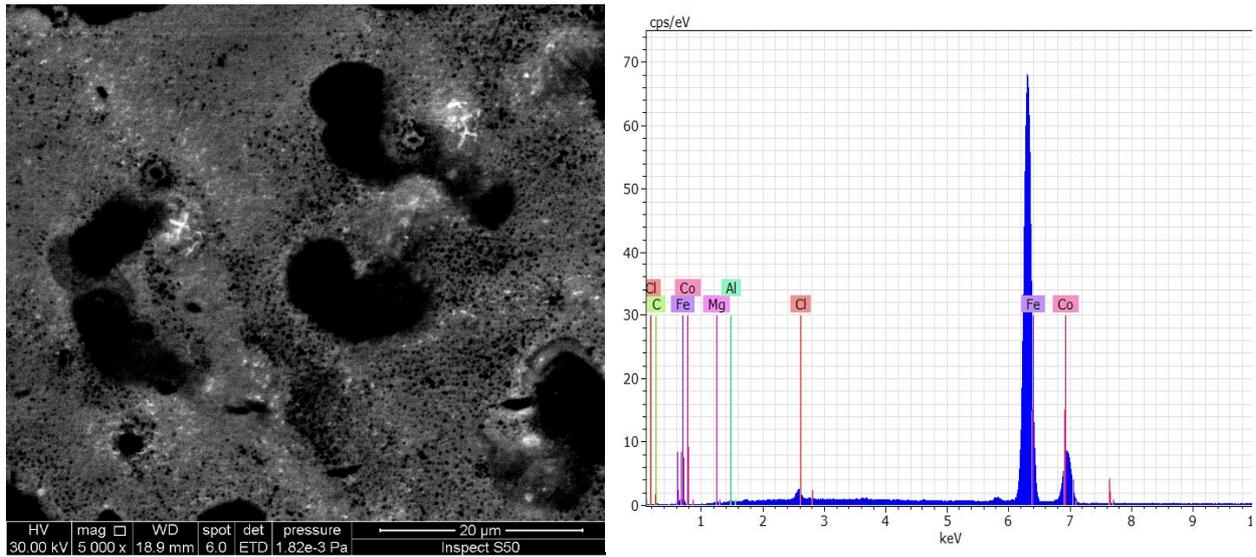


Figure 8. SEM and EDX of carburized steel specimen.

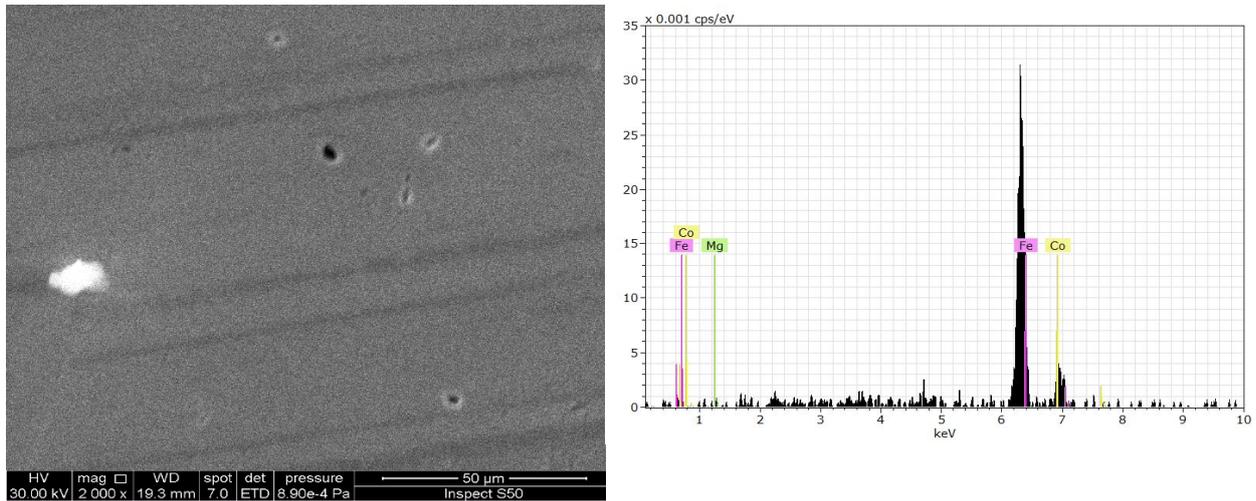


Figure 9. SEM and EDX of flame hardened steel specimen.

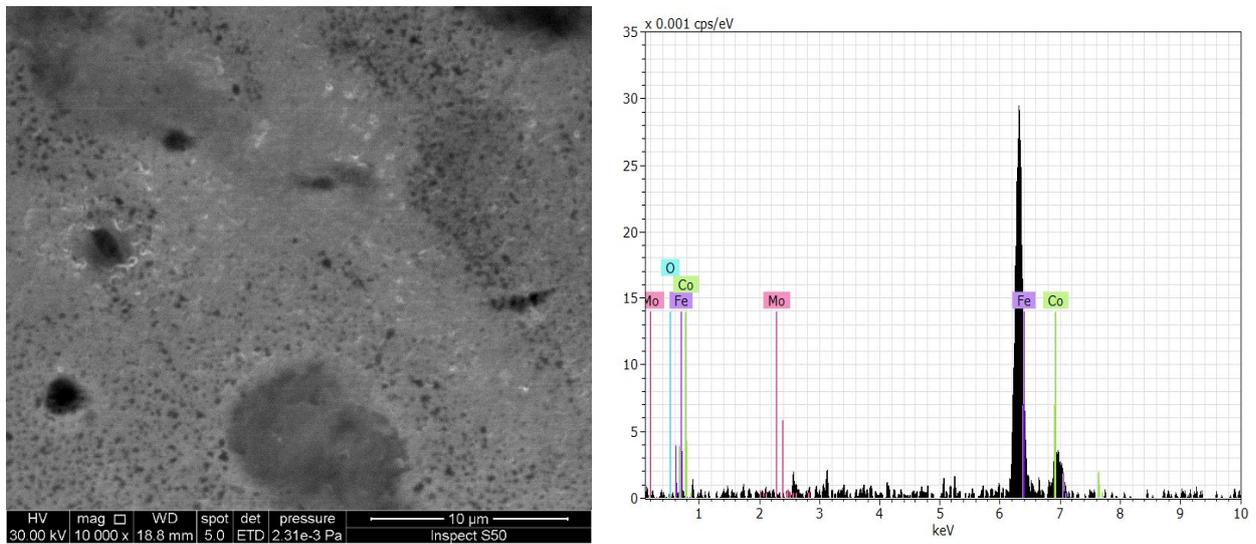


Figure 10. SEM and EDX of quenched steel specimen.

6. Conclusion

Based on the results presented in this research, the following conclusions can be drawn.

- Copper and aluminum specimens showed lower wear resistance, impact resistance and hardness so they are not recommended for applied in blade turbine
- Carburizing treatment showed the higher improvement in wear resistance followed by quenching hardening and flame hardening respectively
- Flame hardening treatment showed the higher improvement in both hardness and impact resistance followed by carburizing and quenching hardening respectively
- To obtain a blade turbine with higher erosion resistance it recommended to using steel after subjected to surface heat treatment.

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