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Wear of nickel-tungsten layer on carbon steel with varying contact surface temperature

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Abstract. The aim of Nickel-Tungsten coatings on the material of carbon steel is to improve the wear resistance of the material. However, with the elevated contact temperature due to friction force in the surface area of sliding may alter the wear resistance of Nickel-Tungsten layers. If the elevated temperature is quite high to reduce the hardness performance of Nickel-Tungsten layers, the layers may be degraded more quickly. In this work, Nickel-Tungsten was deposited on the surface of medium carbon steel in the process of flame powder spray coating with layer thickness of about 0.2 mm. The wear test was conducted using linear reciprocating ball-on-plat with varying surface temperature of about 30°C up to about 250°C. The wear rate and wear mechanism of Nickel-Tungsten layer is investigated.

1. Introduction

Wear is failure of material at the surface as material removed from the surface due to the mechanical action of a contacting bodies [1, 2]. This failure of surfaces can change the profile of the component and cause its working performance to decrease. In the sliding contacting bodies, the two contacting bodies will develop a friction load and generate surface temperature. When the friction load increase, the elevated of surface temperature will increase and this may cause the surface of the material to fail more quickly.

The wear is not an essential property of the material and occurs due to interaction of two contacting working bodies, therefore the wear of materials is possible to be controlled by changing surface properties [3]. Altering surface properties of the material by increasing the hardness of the material surfaces can improve the wear resistant of the material. This can becomes an alternative solution to increase the working life of the components by improving part of the surface components/materials that come into direct contact. One method that can be used is by coating the surface of material with a material that has a better hardness. For this purpose, thermal coating can be selected.

The thermal coating is a coating method by spraying the melted deposited material to the surface of the substrate. The deposited coating material is melted by the combustion of gasses, an electric arc or a plasma [2]. The quality of the result of a coating layers depends on the variable coating process which includes temperature, spraying distance (distance of tip of the nozzle to the surface of the substrate) [4], the speed of the gun over the surface of the substrate, and the speed of the spray coating particles (flow rate of particle deposited) out of the nozzle spray-torch [5]. The quality of the coating layer can be identified from the physical coating characteristics, such as number of porosity, unmelted particles and oxidation state [4, 7].

In this work, powder flame spray coating is selected and performed with Ni-W alloy powder as a deposit material and commercial carbon steel ST 70 is selected as a substrate. Wear test using linear reciprocating ball-on-plat with varying surface temperature of about 30°C up to about 250°C was conducted to determine the wear rate of the Ni-W coating and the mechanism of wear is investigated.



2. Method

In this work, commercial medium carbon steel ST 70 with the carbon content is about 0.5% [8] and hardness of about 273 HVn was selected as the substrate and Nickel Tungsten (Ni-W) with 53.61% Ni, 19.0% W (Table 1) was used for the coating material.

Table 1. Chemical composition of the Ni-W powder

Compound	SI	P	Ca	Cr	Mn	Fe	Ni	W	others
Cons. unit %	2.20	0.47	0.23	13.70	0.31	3.50	53.61	19.00	6.98

The test specimen (medium carbon steel) was formed in the size of 20x15x8 mm (Figure 1). Some preparations of the surface of the specimen (substrate) was performed before the coating process, such as cleaning the surface from any contaminations, roughening the surface and pre-heating of the substrate. The surface of the substrate is roughen by the process of sand-blasting with particles blasting of Aluminum Oxide (Al_2O_3), with air pressure of 8 bar, spraying distance of 40 mm and within about 60 seconds. Pre-heating to the surface of the substrate with temperature of about 250°C was done just before performing the coating process.

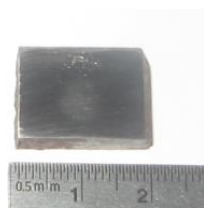


Figure 1. The form of test specimens

The thermal coating is conducted by using the powder flame spray coating. The melted Ni-W powder was sprayed into the surface of the substrate through the powder-spray-torch with spraying distance of 40 mm and with the powder-spray-nozzle torch is perpendicular to the surface of substrate. The parameter of coating process are organize with powder-feeder of about 300 g/minute, Oxygen pressure of about 4×10^5 Pa and Acetylene pressure of about 0.9×10^5 Pa. Before the wear test was performed, the surface of Ni-W coating layer was grinded and polished for creating a roughness surfaces about 0.1 – 0.3 μm .

Wear test was conducted using linear reciprocating ball-on-plat with varying contact surface temperature, i.e., 30°C, 50°C, 100°C, 150°C, 200°C and 250°C as shown in the schematic drawing of wear test (Figure 2). Load W is given through ball indenter with a diameter of 8 mm, with a load of 25 N, length 10 mm step of loading. The test was done up to 100 m which is equal to 5000 cycles loading.

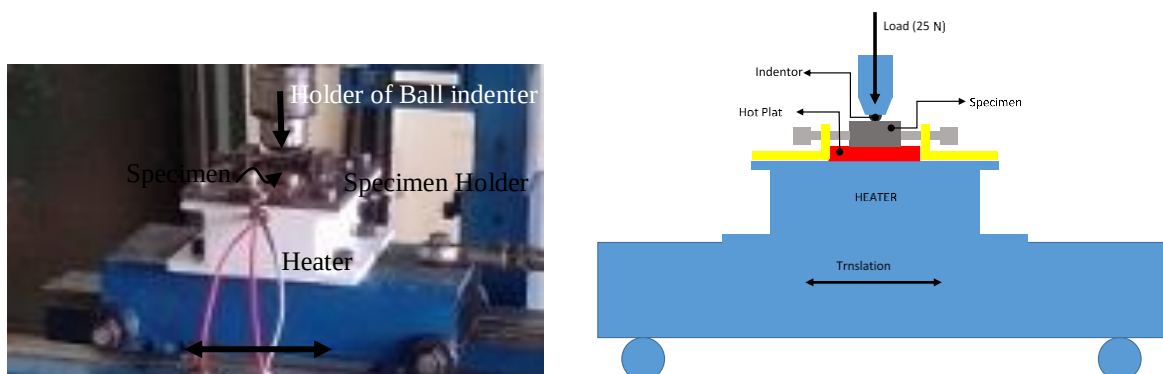


Figure 2. The diagram of the wear test.

3. Results and Discussion

Figure 3 shows the hardness and wear rate of the Ni-W coating layer with varying temperature of the contact surfaces. One graph with dot marks represents the hardness of the Ni-W layer with varying surfaces temperature and the second graph with triangle marks represents the wear rate of the Ni-W layer with varying surfaces temperature. In general, the hardness of the Ni-W coating decreases with increasing the surface temperature. For the surface temperature of about 30°C, the hardness of the Ni-W coating layer is about 857 HVn. With increasing the surface temperature up to 100°C, the hardness of the Ni-W coating layer decreases to 715 HVn and the hardness of the Ni-W layer decreases to 567 HVn with increasing surface temperature up to 200°C. However, with increasing the surface temperature from 100 to 150°C, the surface hardness of the Ni-W coating relatively increases from 715 up to about 736 HVn. The similar hardness performance was also found in the increase of surface temperature from 200 up to 250°C, which is the surface hardness increases from 567 up to 656 HVn with increasing surface temperature from 200 to 250°C. This may be caused by the form of contaminant layer such as oxide layer on the surface of Ni-W due to dry oxidation which is relatively strong.

From the second graph (triangle marks), the increase of the surface temperature from 30 up to about 100°C cause the wear rate of Ni-W layer to decrease from 0.0040×10^{-3} gr/m for surface temperature of 30°C to 0.0017×10^{-3} gr/m for surface temperature of 100°C. Then, with increasing the surface temperature up to 250°C, the wear rate of the Ni-W gradually increase, i.e., the wear rate of about 0.0027×10^{-3} for surface temperature of 150°C, the wear rate of about 0.0050×10^{-3} and 0.0055×10^{-3} gr/m for the surface temperature of 200°C and 250°C respectively. The increase of wear rate with increasing surface temperature is caused by the reduction of the hardness of the material. At this stage, the surface temperature is relatively high enough to reduce the hardness of the material.

The decrease of hardness with increasing surface temperature that occurred in the range of surface temperature 30 to 100°C was not followed by the reduction of the wear rate. This condition may be caused by existing the contaminant (i.e., oxide layer) at the surface due to a surface temperature which is reducing the friction, resulting wear rate to decrease. At this range of surface temperature (i.e., from 30 to 100°C), the oxide layer maybe gives a greater effect to the wear rate so that the wear rate decrease although the hardness of the Ni-W decreases.

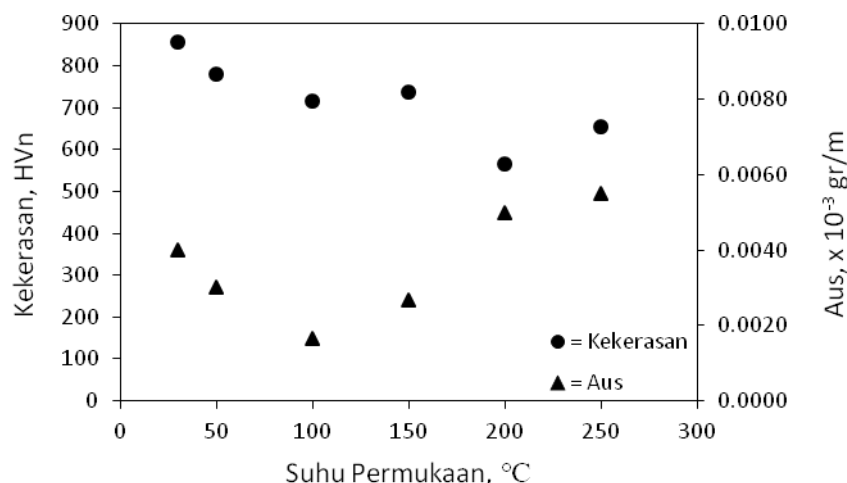


Figure 3. Hardness and wear rate of NiW coating layer with varying temperature of contact surfaces

Figure 4 to 9 show the SEM photograph of the part of the worn surfaces of Ni-W coating with a varying surface temperature in the range of 30 to 250°C. The worn surfaces look like many little

fracture particles that released off the surface and no visible long scratches or long and wide debris, this shows that the Ni-W coating is a brittle material and well resistance to wear failure. This mean that the surface temperature in the range of 30 to 250°C is not high enough to soften the Ni-W material become a ductile material.

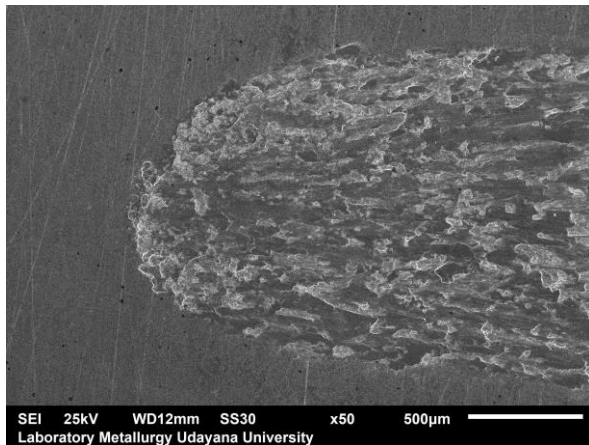


Figure 4. SEM photograph of wear surface of NiW layers with surface temperature of about 30°C.

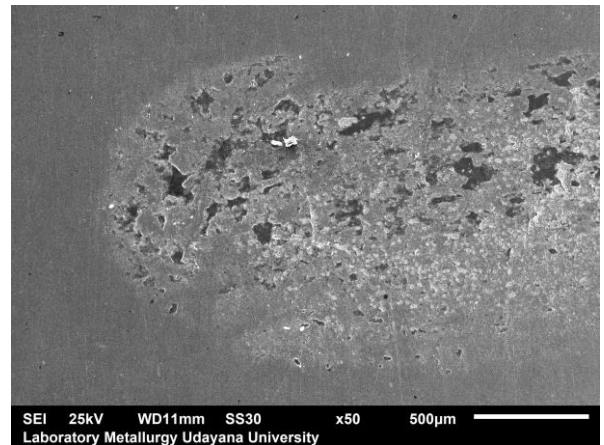


Figure 5. SEM photograph of wear surface of NiW layers with surface temperature of about 50°C.

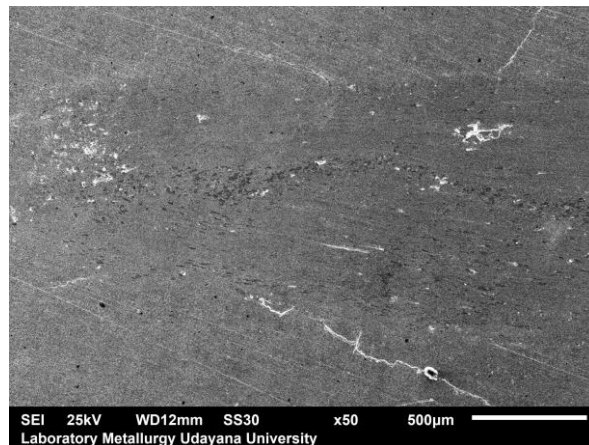


Figure 6. SEM photograph of wear surface of NiW layers with surface temperature of about 100°C.

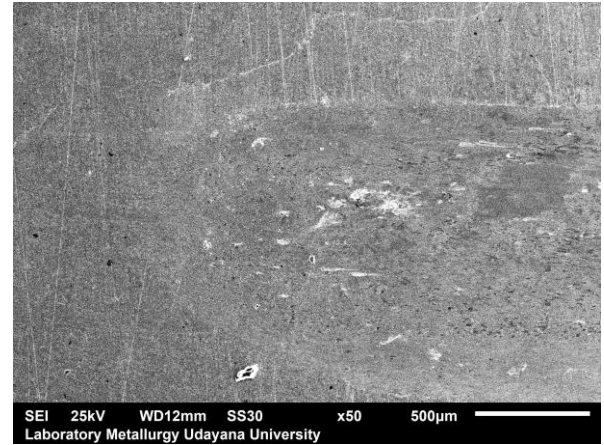


Figure 7. SEM photograph of wear surface of NiW layers with surface temperature of about 150°C.

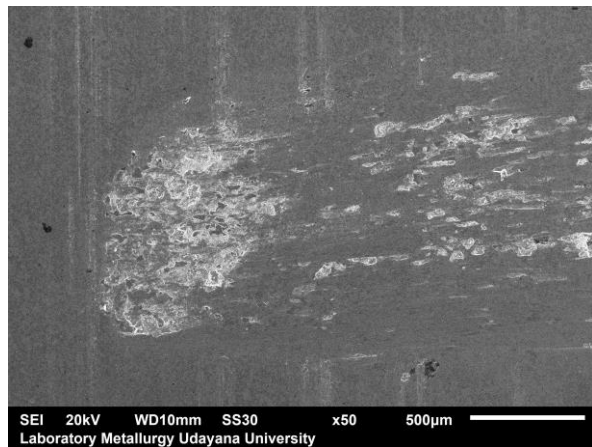


Figure 8. SEM photograph of wear surface of NiW layers with surface temperature of about 200°C

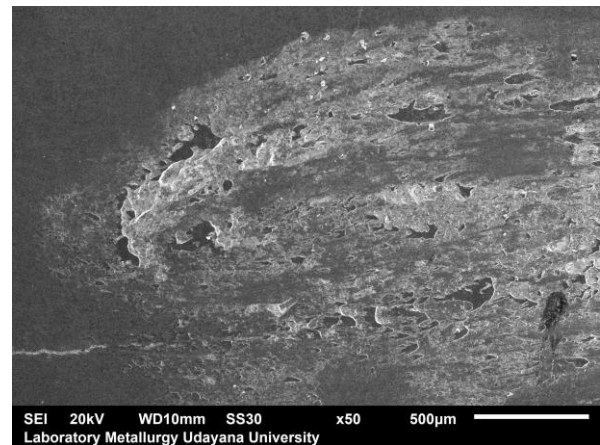


Figure 9 SEM photograph of wear surface of NiW layers with surface temperature of about 250°C.

4. Conclusions

The increase of surface temperature in the range of 30 to 250°C cause the hardness of the Ni-W layer to slightly decrease. Even though the hardness of the Ni-W layer decreases with increasing surface temperature from 30 to 100°C, the wear rate decrease. This is because the existing of oxide layer due to dry oxidation at those surface temperature maybe cause the contact friction to decrease and resulting the wear rate to decrease.

The mechanism of wear of Ni-W coating with a varying surface temperature in the range of 30 to 250°C was identified as abrasive wear with very small wear debris that removed from the surface without introduction any plastic deformations.

Acknowledgment

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