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Sliding wear behavior of electro-carburized low carbon steel at high speed

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ABSTRACT – Commercialized mild steel has been subjected to electro-carburization in carbonate salts mixtures of Na_2CO_3-NaCl at 860˚C and 4.5 volt. Wear behavior of carburized steel was evaluated using ball-on-disc under various speeds and loads. Coefficient of friction and wear volume obtained were studied. Carburized steel was capable to maintain low wear volume loss even at high speed. The wear resistance for steel carburized 1 hour was better compared to steel carburized 3 hours.

1. INTRODUCTION

Metal surface is well known as the most susceptible region to crack initiation and fatigue failure. Carburization as the most conventional surface hardening process has been studied by metallurgist. It involves intentional diffusion of carbon into the surface of iron-based alloy creating distinctive temperature and time dependence diffusion profile while maintaining the primary chemical composition at the core. The carbon rich layer is then transform into selected microstructure (martensite, bainite etc) in accordance with the cooling rate after the carburization process and subsequent treatment.

Cyanide had been utilized as the carbon source in the carburization process despite its toxicity. Replacement of cyanide with other substances had been explored [1]. Siambun et al. [2,3] had developed an electro-carburization process using carbonate salts mixture as substitution owing to non-toxicity. The present work is an extended investigation of wear behavior of the aforementioned process.

2. METHODOLOGY

2.1. *Carburization Process*

The carburizing temperature was maintained at 860˚ ± 10˚C with a constant voltage supply at 4.5 V, followed by quenching in water. Mild steel with 50 mm diameter and 8 mm thickness is selected for carburization. Na_2CO_3-NaCl (ratio of 4:1) were used as the electrolyte and the carbon source for the carburization process. Details of the set-up had been described in ref. [2].

The basic electro-chemical reaction occurred is shown as in Eqn. (1):

$$CO_3^{2-} + Fe + 4e^- \rightarrow C\text{-}Fe + 3O^{2-} \quad (1)$$

Where C-Fe represents the diffusion of carbon in the steel.

2.2. *Sliding Tests*

A Ducom TR-20EV-M3 ball-on-disc tester was used for investigation of wear characteristics of carburized steel disc. Uncoated cemented carbide balls with hardness of 1600 HV were used to slide on the steel disc. The chemical compositions of the mild steel used for the carburizing process are stated in Table 1.

Table 1 Chemical compositions of the mild steel (wt%)

C	Si	Mn	P	S	Fe
0.2	0.19	0.60	0.014	0.018	balance

Tests were carried out in ambient air at 30, 50 and 90 N with speed of 10 and 70 m/min for both as received and carburized steels. The sliding distance was 1000 m. The coefficient of friction (COF) was recorded throughout the test. The morphology of the worn surface was examined using a scanning electron microscope (SEM) and optical microscope. A stylus profilometer was used to measure the volume loss of the worn surface.

3. RESULTS AND DISCUSSION

Figures 1 and 2 show the wear volume loss of the carburized and as received steel under different loads and speeds of 10 and 70 m/min. Carburized steels exhibited better wear resistance than as received steel. However, carburized steels show more pronounced wear resistance at high speed of 70 m/min. Figure 3 shows that steel carburized for 3 hours suffer higher wear volume loss than steel carburized 1 hour. This could be attributed to lower cracking resistance owing to larger grained size and higher formation of cementite at the grain boundaries of the carburized steel.

The COF of both low and high speed reached around 0.35 eventually and show less fluctuation in high speed as shown in Figure 4 and 5. This may due to the softening effect which also resulted in the increase in the wear volume loss as depicted in Figure 3. This effect has been explained by Wang and Lei [4]. Frictional heating at high speed caused austenization at the sliding interface, resulting in transformation of martensite to fine grained tempered martensite which capable of providing better wear resistance.

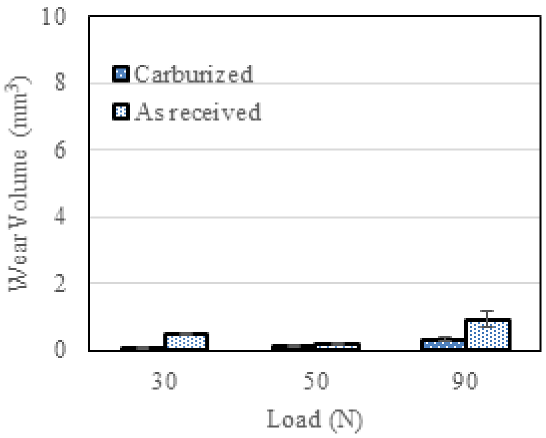

Figure 1 Comparison of wear volume loss between carburized 1 hour and as received steel at 10 m/min.

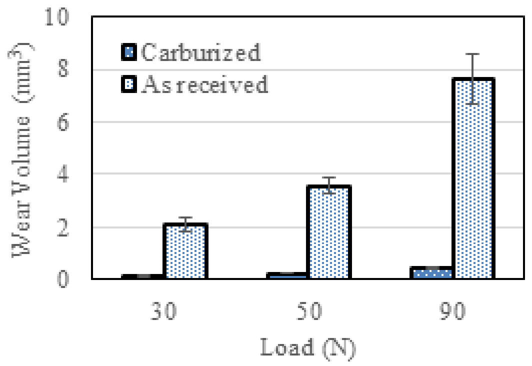

Figure 2 Comparison of wear volume loss between carburized 1 hour and as received steel at 70 m/min.

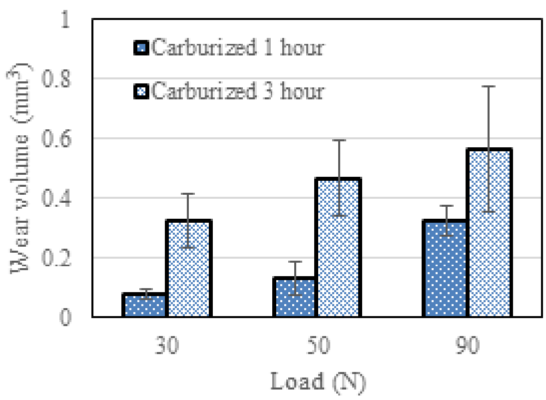

Figure 3 Comparison of wear volume loss between carburized 1 hour and 3 hour steel at 10 m/min.

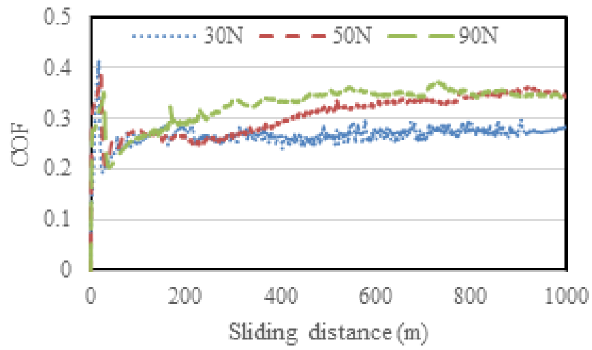

Figure 4 COF of 1 hour carburized steel at 10 m/min.

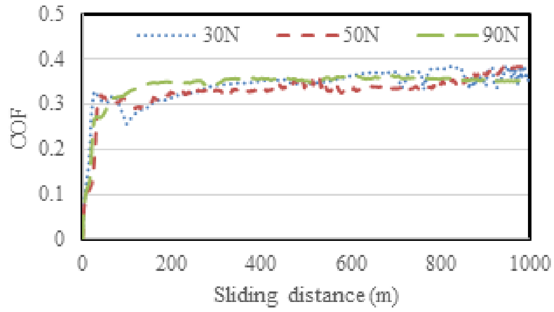

Figure 5 COF of 1 hour carburized steel at 70 m/min.

4. CONCLUSIONS

Electro-carburization was capable of providing better wear protection and prolonged carburizing process could cause reduction in wear resistance.

5. REFERENCES

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