

2-body micro abrasion of a Nylon coated Carbon steel

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Introduction

The application of polymeric composite coatings for protecting the internal surface of water injector tubulars against corrosion used in the oil industry is an active area of research in the University of Southampton. Polymer matrix based coatings such as thermoplastics and thermosets have been suggested to be candidate systems for such application. These coatings can be deposited on carbon steel tubulars after a thin layer of primer has been applied to facilitate the adhesion between the coating and the metallic substrate. In addition to acting as a corrosion barrier, these coatings also have to resist impact and abrasion induced by wireline tools. The investigation of the tribological performance of the polymeric coatings has typically used the pin-on-wire test apparatus to study the 2-body wireline abrasion of the coatings. However, these tests lack reproducibility and repeatability. The lack of suitable test methods has meant that the current understanding of the wear behaviour of polymer coatings is deficient. Thus, an alternative method, micro abrasion, was considered in this study to investigate the tribological properties of a thermoplastic Nylon-based coating. This method, which is used to test thin coatings, not only offers good reproducibility and repeatability but also allows continuous measurement of the depth of wear scar during the test. Hence, this paper presents current work on the two-body grooving micro-abrasion performance of Nylon coating.

Methodology

In this study, a 25 mm diameter pitted hardened carbon steel ball was loaded against the sample and rotated in the presence of 5 μm SiC and 3-10 μm spherical glass bead abrasive slurries (see Figure 1). The concentration was kept constant at 0.375 g/cm^3 . The optimum test conditions for the coating were established after a series of trial test. Wear rates exhibited by this coating are compared with typical wear rates from pin-on-wire wear test and with monolithic Nylon 6 (5 mm thick).

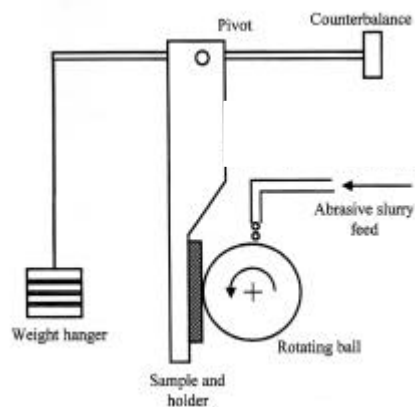
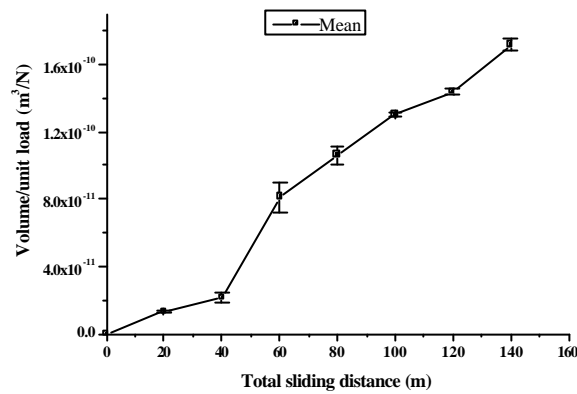


Figure 1: *schematic of the test rig.*

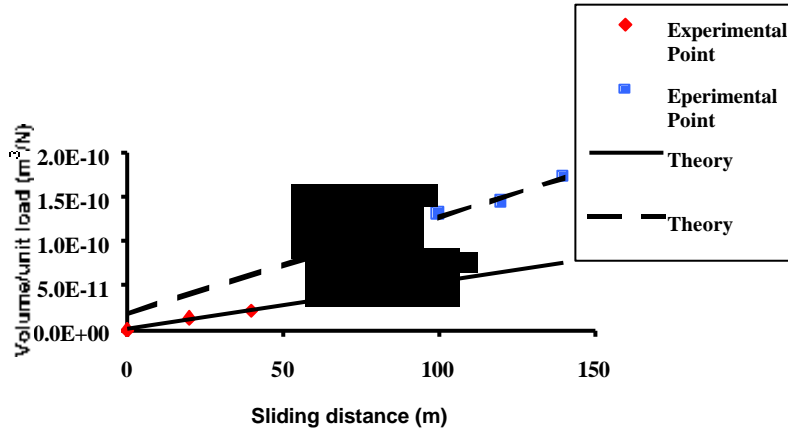
Results and Discussion

The evolution of the wear scars were examined using 3-D Talysurf profilometry enabling the wear scars to be measured with greater accuracy than optical microscopy. The results show that

the Nylon coating exhibited a steady state specific wear rate of about $(1.3 \times 10^{-12} \text{ m}^3/\text{Nm})$ from the optimised test conditions, about 1700 times higher than a typical wireline wear rate obtained on the pin-on-wire ($7.3 \times 10^{-16} \text{ m}^3/\text{Nm}$) and 6.5 times higher than the glass beads abrasive tests ($2.0 \times 10^{-13} \text{ m}^3/\text{Nm}$). The large difference in wear rate has been attributed to the difference in the morphology and size of the abrasives compared to the wireline asperities. Variables such as load, sliding distance and speed noticeably influence the wear rate for both the SiC and glass bead abrasive tests. For example, two distinct regions of wear rates were observed between 0 – 40 m and 60 – 150 m, when the volume of wear was plotted against the total sliding distance for the SiC abrasive tests. (See Figure 2 for the SiC test and Figure 3 for the glass beads test result).



(a)



(b)

Figure 2 (a and b): (a) Wear volume against total sliding distance at 6N load and 75rpm. (b) Showing two regions of wear rates.

The wear scars were examined using SEM and 3-D Talysurf profilometry utilising surface mapping software and sphere fitting routines. Abrasion in the Nylon coating occurs predominantly through micro-ploughing, micro cutting and tearing, which generated grooves, caused by the 2-body abrasion of the SiC abrasives. The SEM images of the worn samples suggest a mechanistic change between 40 m and 150 m SD. This is thought to be due to a “skin effect” possibly due to UV radiation. The depth of the skin appears to be 60 μm . For glass bead tests, embedment of the glass abrasives was identified to affect the wear of the coating for the

glass bead abrasive tests. This is thought to be due to the effect of frictional heating generated at the sliding contact as

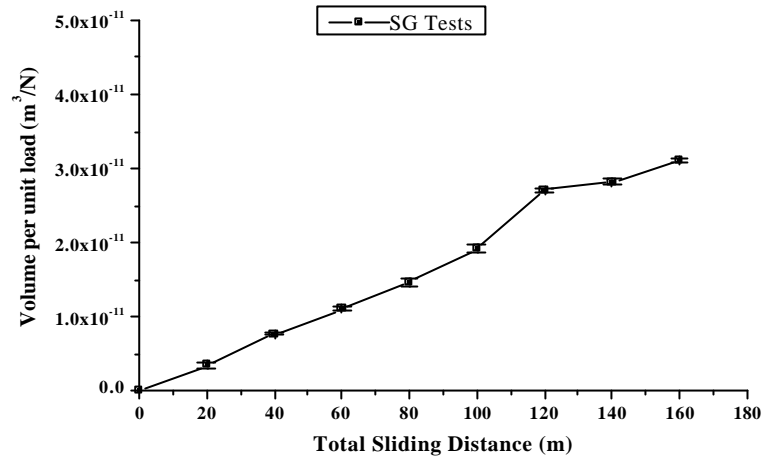


Figure 3: Wear volume against total sliding distance at 6N load and 75rpm for the glass bead test.

the sliding speed increased. In addition, the grooves formed by the SiC and glass beads abrasive tests were noticeably distinct in nature. For example, the grooves generated by the SiC abrasive tests predominantly evolved with smooth sharp peaks and deep troughs while the grooves produced by the glass bead tests are rough and discontinuous in most cases, see Figures 4 and 5.

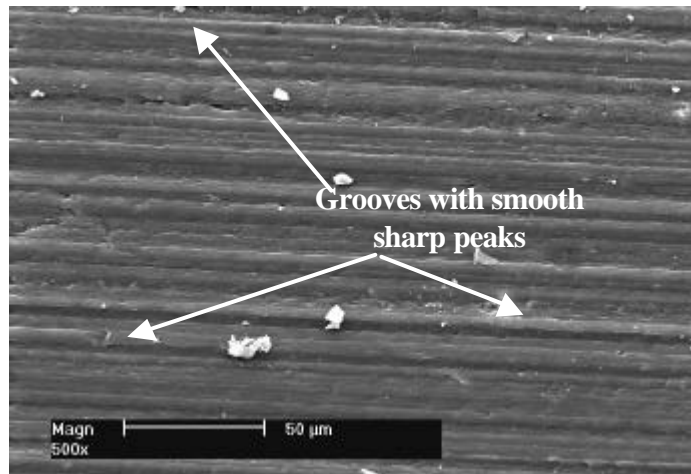


Figure 4: SEM of a Nylon coating showing the groove produced by the SiC abrasive tests. Load (10N) and Sliding distance of (159m)

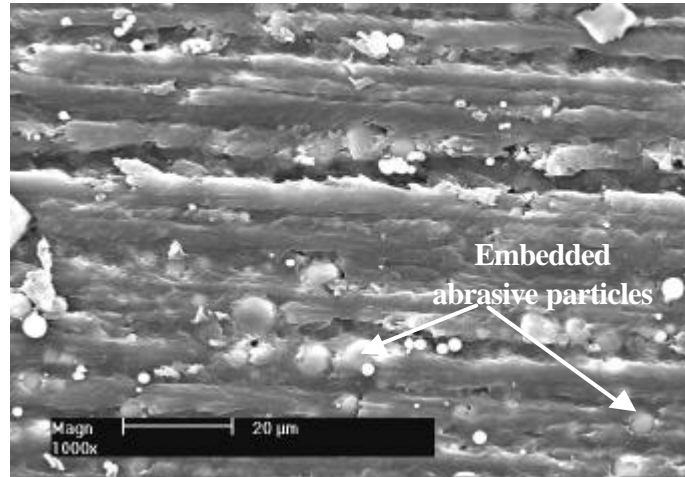


Figure 5: SEM of a Nylon coating showing the groove produced by the Glass bead abrasive tests. Load (6N), Sliding distance(100m) and Sliding speed (100rpm)

The test on the monolithic Nylon show marked agreement between 0 and 40 m sliding distance with the coating wear rate. In addition, the results show a stable wear rate up to 100m, beyond this point a sharp increase in the wear rate was observed. The reason for this behaviour is being investigated further (see Figure 6). The SEM micrographs suggest that the dominant wear mechanism is micro ploughing, with micro-polishing and tearing, however, the nature of the wear surface differ (see Figure 7). The monolithic Nylon shows 'No' skin effect.

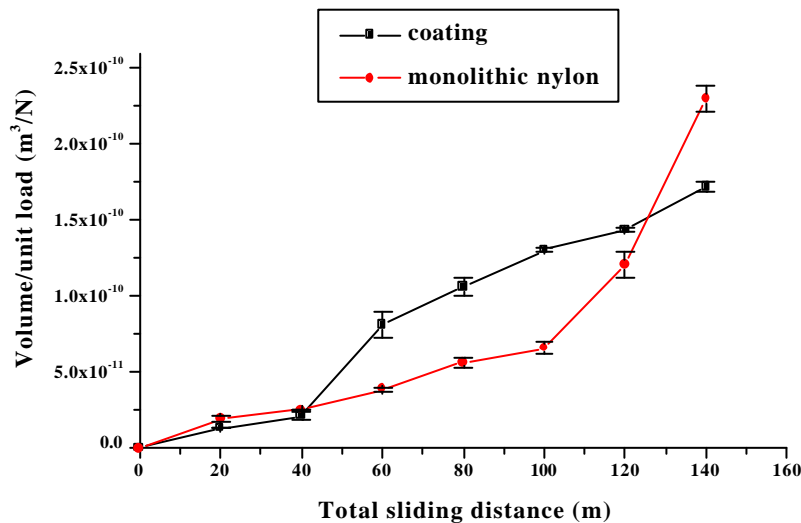


Figure 6: Comparison of the wear volume against total sliding distance for the coating and the monolithic Nylon. Applied load (6N), sliding speed (75rpm)

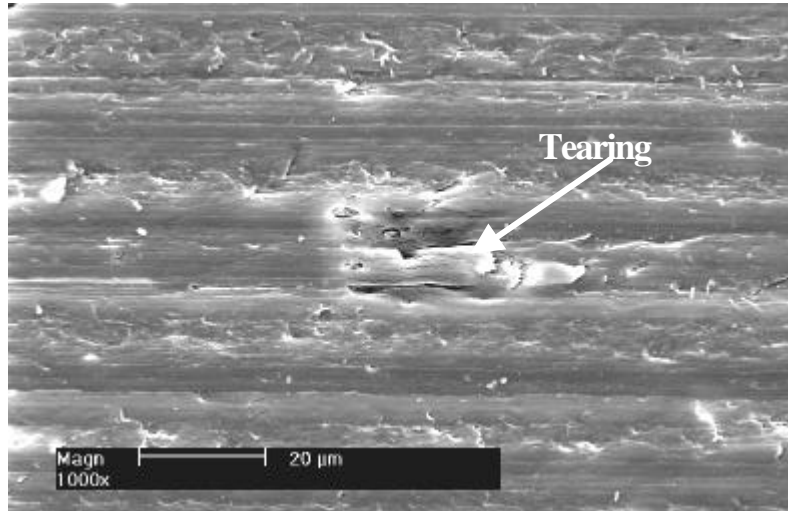


Figure 7: SEM of monolithic Nylon 6 showing the nature of the grooves and tearing produced after the test. Load (6N), Sliding distance(100m) and Sliding speed (100rpm)

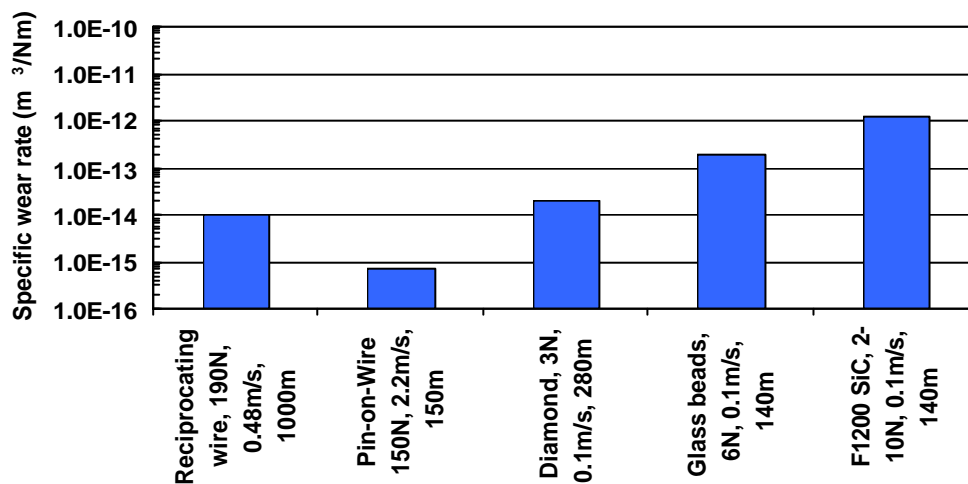


Figure 8: Comparing wear rates from different tests.

Conclusions

1. Micro-abrasion test more repeatable than Pin-on-Wire.
2. Replication of wireline wear mechanisms on Nylon coatings has been achieved.
3. Predominant wear mechanisms are micro-ploughing and micro-cutting mechanisms (little evidence of extrusion into tendrils).
4. Some micro-tearing evident. High wear rates associated with micro-polishing.
5. Micro-abrasion wear rates are 1000 times higher than wear rates generated in true tribo-couple (accelerated test).
6. SiC abrasive appears to replicate the wireline wear mechanisms.

7. Glass beads are embedded into the coating and reduce wear rates. Suggest fillers may reduce wear. Different wear mechanisms.
8. Wear rate of coating increases with penetration depth suggesting a '*skin effect*'.
9. Wear rate of coating initially agrees well with bulk Nylon 6 but with increasing sliding distance the coating out performs the bulk material.

Keywords: *Abrasion; wireline wear; Coatings; Tribology.*

REFERNCES

- [1] Bello, J. O., MPhil Thesis, University of Southampton (2001)
- [2] Bello, J. O and R. J. K Wood., Postgraduate conference, University of Southampton (Oct 2000/2001)
- [3] Allsopp, D. N. Trezona, R. I., Hutchings, I. M. The Effect of Ball Surface Condition in the Micro-Scale Abrasive Wear Test, *Tribology Letters* 5 (1998) 259-264
- [4] Trezona, R. I., Allsopp, D. N., Hutchings, I. M., Transitions between Two Body-Body and Three-Body Abrasive Wear: Influence of TEST conditions in the Micro -Scale Abrasive
- [5] Shipway, P. H., The Role of Test Conditions on the Micro-Abrasive Wear Behaviour of Soda-lime Glass, *Wear* 233-235 (1999) 191-199
- [6] Jorn Larsen-Basse, *Wear* 122 (1988) 135-149