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RESEARCH

An Experimental Investigation and Improvement of Insulated Rail Joints

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ABSTRACT

In this study the effect of sliding speed, applied load and period of time on the wear resistance of end post materials of Nylon12 (N12), Nylon66 (N66), Nylon66a (N66a), Epoxy Glass (EG) and Phenolic Resin Bonded Fabric materials were investigated. Wear tests were implemented in dry and wet conditions on a Block-on-Ring apparatus. The tests were carried out at different sliding speeds of 1.5 m/sec., 3.3 m/sec., and 7.2 m/sec., applied loads of 10 N, 30 N and 50 N, and three periods of time 5 min., 30 min. and 60 min. The obtained results in dry condition tests showed that the wear resistance of Nylon and composite materials used in this study decreases with an increase in applied load and sliding speed due to increase in contact temperature. But the impact of these increases in sliding speed and applied load was less on the wear resistance of composite materials. Unexpected results were that in wet test condition for Nylon66 materials where the wear resistance was less compared with the same material in a dry test.

1. INTRODUCTION

Insulated rail joints (IRJs) are one of the essential parts in track circuits. They contains from two fishplates bolted to each side of the rail and an insulating material layer (end post) is placed in the gap between the adjacent rail ends as can be seen in Fig. 1. IRJs are employed as part of signalling system. They are used to connect adjoining rails and make the rail network electrically isolated and dividing into track circuits [1]. IRJs are considered to be weak point in the rail track [2]. IRJs failure is a serious safety case. The steel parts such as the joint bars and bolts may break and the rail head material may flow both due to excessive load from wheels and impact forces at the IRJs. The end post may crack and come out of the gap between rails in the joint which may allow the rails to touch when they are extended or when the joint is loaded [2-4]. The main failure modes are insulation failures 29 % [5]. In a dressing the problem, it is important to know the reasons that cause these failures to improve the performance of insulated joints. One of the reasons that leads to the damage of end posts is sliding wear. In this work the sliding wear resistance of five end post materials: N12, N66, N66a, EG and PRBF, was investigated. The end post materials of N12, N66, N66a are classified as thermoplastic materials and EG and PRBF materials are classified as thermosetting materials according to melting point temperature. The test materials are specified in Table 1.

Fig. 1. Insulated Rail Joints (IRJs) [6].

Table 1. Summary of End Post Material Tested with Selected Properties.

Material	Density (g/cm^3)	Vickers Hardness (HV)		Melting Point (C^0)
		Dry	Wet	
N12	1.02	232.43	190.98	179
N66	1.14	230.39	131.27	210
N66a	1.20	239.38	194.37	210
EG	1.92	742.65	701.40	-
PRBF	1.35	592.66	547.43	-

2. EXPERIMENTAL DETAILS

2.1 Test Apparatus

Block-on-ring testing has been used extensively in the field of sliding wear [7-9]. The ring can represent the "wheel" and the "block" the end post. Figure 2 displays the block-on-ring rig utilized to carry out the testing. The maximum speed that can be used on the rig is 7.2 m/sec. And the minimum speed is 1.5 m/sec. And 50 n is the maximum that load can be used. An electrical motor provided the required velocity via a transmission belt and six different pulleys that allow nine different speeds to be achieved. The test block and ring are loaded together. The rig was driven at a controlled sliding velocity with a 100 % slip ratio between the contacting steel ring and specimen block. The test conditions were compared with the energy within the contact in the field. In this case it can be calculated as tγ (normal force x friction coefficient x slip in the contact) and scaled via the contact area.

Tγ/a for the rig was 0.084 to 6.20 n/mm^2. In the rail head/wheel tread contact typical field values for tγ/a are 0 to 10 (n/mm^2). The -on-ring tests are in the right regime. The volume Loss was determined in the test from the mass loss and density data.

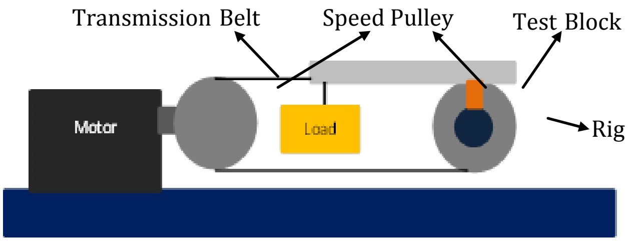

Fig. 2. Block-on-Ring Rig.

2.2 Specimens

The ring specimens were cut from railway wheel steel sections. They had a 42 mm diameter with a contact width of 10 mm as shown in Fig. 3. The surface roughness of contact surface was 1 micron. The block specimens were cut from end post N12, N66, N66a, EG and PRBF materials into 5 mm x 5 mm x 32 mm as shown in Fig. 4. The contact surfaces were ground to a roughness of 1 micron.

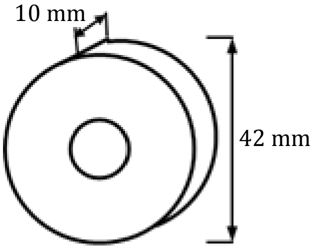

Fig. 3. Schematic of Ring Specimen.

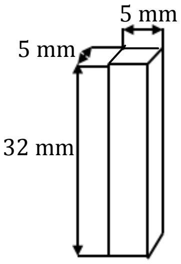

Fig. 4. Schematic of Block Specimen.

3. RESULTS AND DISCUSSIONS

3.1. Thermoplastic Materials

Nylon 12 Material: the wear resistance of N 12 was affected slightly in the case of increasing sliding speeds from 1.5 m/sec to 7.2 m/sec at an applied load of 10 N (see Fig. 5) and in case of increasing sliding speeds from 1.5 m/sec to 3.3 m/sec, at a load of 30 N (see Fig. 6). The rubbing surface was partly smooth. Pits and ploughing parallel to the sliding orientation were observed. The amount of material removed rose massively in the case of a sliding speed of 7.2 m/sec, at a constant load of 30 N. The worn surface was coarse. Pits and scratches parallel to the sliding direction were appeared. This was due probably to adhesive wear. Whilst the amount of volume loss increased massively when sliding speed rose to 7.2 m/sec at a load of 50 N as shown in Fig. 7 where the material was melted (thermal wear) (see Figs. 11 and 12). The thermal wear occurring when material contact temperature rise over the material melting point, so the material become very hot and melt. On the other side, there was a positive impact of water on the material wear resistance in wet tests condition where contact temperature was decreased during the test which led to increasing wear resistance of material (see Figs. 8-10). The rubbing surface was partly rough and characterised by pits, smooth and plough was parallel to the sliding direction (see Fig. 13).

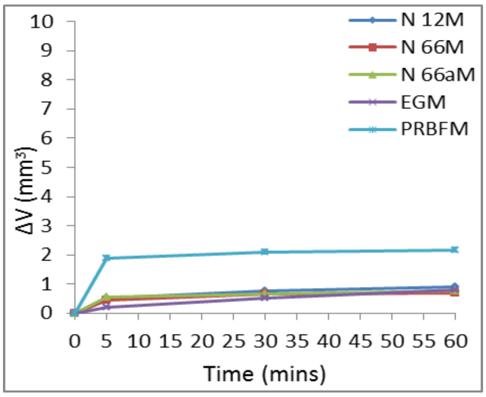

Fig. 5. Sliding Test at 1.5 m/sec and 10 N.

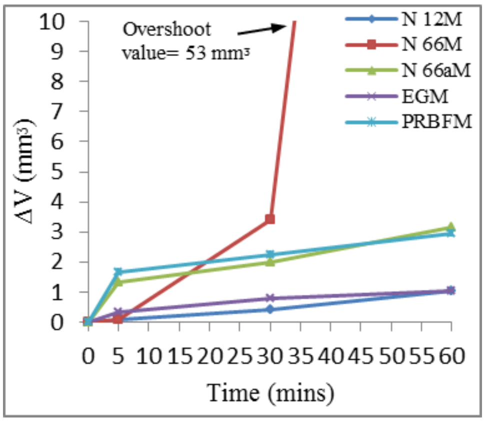

Fig. 6. Dry Test at 3.3 m/sec and 30 N.

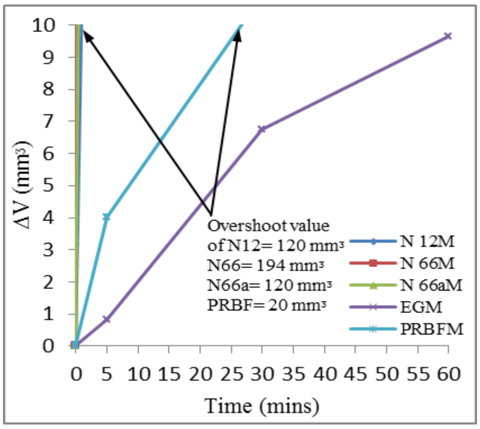

Fig. 7. Dry Sliding Test at 7.2 m/sec and 50 N.

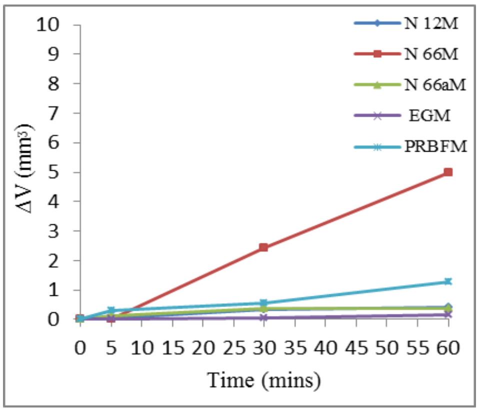

Fig. 8. Wet Sliding Test at 1.5 m/sec and 10 N.

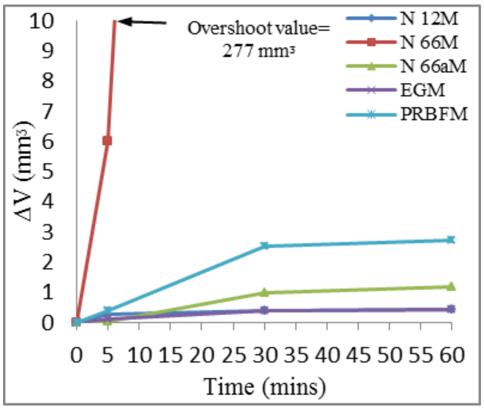

Fig. 9. Wet Sliding Test at 3.3 m/sec and 30 N.

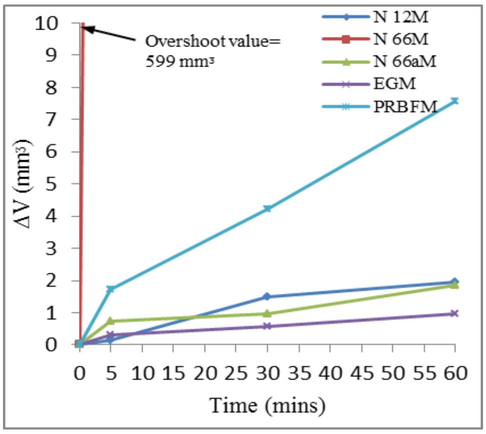

Fig. 10. Wet Sliding Test at 7.2 m/sec and 50 N.

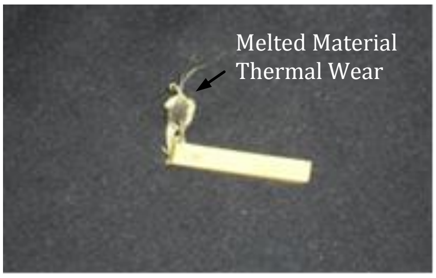

Fig. 11. Nylon 12 Melted.

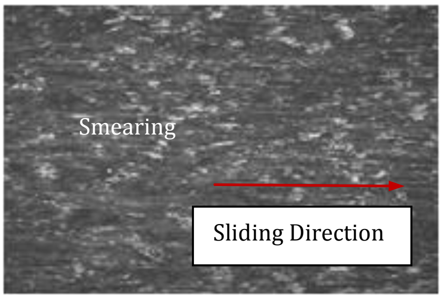

Fig. 12. Contact Surface of N12 in Dry Test at 7.2 m/sec and 50 N.

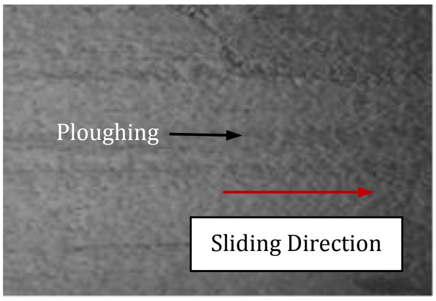

Fig. 13. Contact Surface of N12 in Wet Test at 7.2 m/sec and 50 N.

Nylon 66 Material: the material wear resistance was affected slightly in the case of increasing sliding speeds from 1.5 m/sec to 7.2 m/sec at an applied load of 10 N (see Fig. 5). The contact surface became smooth and pits, cracks, waves and scratches parallel to sliding orientation were appeared across the surface. The wear resistance of the material was affected significantly in the case of increasing sliding velocity from 1.5 m/sec to 7.2 m/sec at a loads of 30 N and 50 N (see Figs. 6 and 7). The rubbing surface was coarse due probably to a adhesive wear at sliding speed of 3.3 m/sec and a load of 30 N and the wear surface became partly smoothened at sliding speed of 7.2 m/sec and an applied loads of 30 N and 50 N due to thermal wear as shown in Fig. 14. This is in agreement with Myshkin [10]. While in the case of wet tests, the material wear resistance was significantly reduced as seen in Figs. 8-10. This could have happened because:

i) material became weak and strength ced.

ii) the absorption of water caused in decrease of material hardness as shown in Table 1.

iii) chemical corrosion wear increased. This in agreement with the results obtained by Wang [11].

The rubbing surface was smoothened and characterised by scratches parallel to the sliding orientation as appeared in Fig. 15.

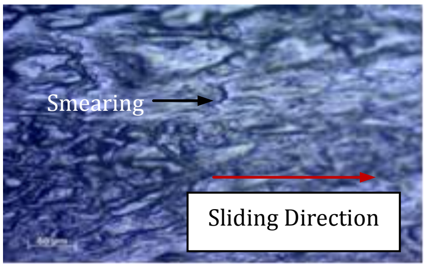

Fig. 14. Contact Surface of N66 in Dry Test at 7.2 m/sec and 50 N.

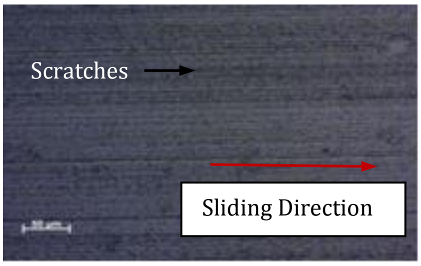

Fig. 15. Contact Surface of N66 in Wet Test at 7.2 m/sec and 50 N.

Nylon 66a Material: there was a slight influence on material wear resistance when sliding speed increased from 1.5 m/sec to 3.3 m/sec at a load of 10 N (see Fig. 5). The worn surface was partly smoothened. Scratches appeared on the surface parallel to the sliding direction. The effect of a sliding speed of 7.2 m/sec and a load of 10 N on the material wear resistance was more than that in prior cases. The material wear resistance decreased gradually when the sliding speed increased from 1.5 m/sec to 7.2 m/sec at an applied load of 30 N (see Fig. 6). The rubbing surface was rough. This was due to adhesive wear (when the temperature rise but lower than the melting point, the material become hot, hardness decreases and adhesive/abrasive wear increases). The material wear resistance was affected considerably when sliding speed increased from 1.5 m/sec to 7.2 m/sec at a load of 50 N as seen in Fig. 20 and the wear surface was smooth (see Fig. 16). This is in agreement with Myshkin [10]. This was due to thermal wear. In contrast, there was a positive effect of water on material wear resistance in case of wet tests condition compared with dry tests condition as shown in Figs. 8-10. The wear surface was more smoothened, cracks were observed and scratches existed on the surface (see Fig. 17).

Fig. 16. Contact Surface of N66a in Dry Test at 7.2 m/sec and 50 N.

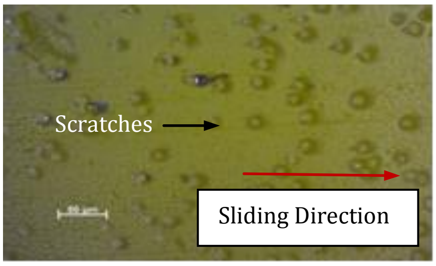

Fig. 17. Contact Surface of N66a in Wet Test at 7.2 m/sec and 50 N.

3.2. Thermosetting Materials

Epoxy Glass Material: the material wear resistance gradually decreased due to an increase of sliding speed from 1.5 m/sec to 7.2 m/sec at a load of 30 N (see Fig. 6). The worn contact surface was coarse. Fibres and scratches were observed on the surface. The wear resistance of the material reduced significantly when the sliding velocity rose from 1.5 m/sec to 7.2 m/sec at a load of 50 N as shown in Fig. 7. This is in agreement with Chowdhury [12]. The wear surface was more roughened and severe deterioration of fibre surface was observed due to the rise in temperature as shown in Figure 18. The material wear resistance was better in the case of wet test condition as seen in Figures 8-10. These happened because contact temperature reduced. The worn surface became smooth and the wear damage to be fibres exposed and scratches parallel to sliding direction (see Fig. 19).

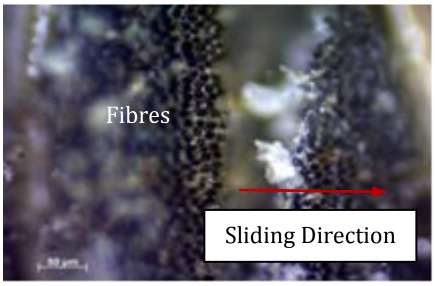

Fig. 18. Contact Surface of EG in Dry Test at 7.2 m/sec and 50 N.

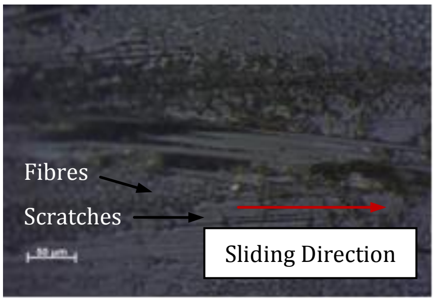

Fig. 19. Contact Surface of EG in Test at 7.2 m/sec and 50 N.

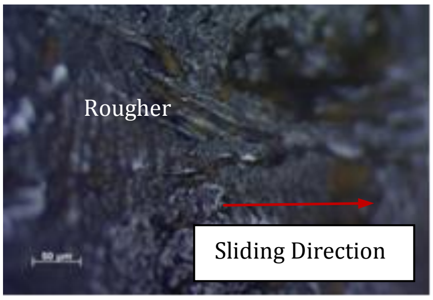

Fig. 20. Contact Surface of PRBF in Dry Test at 7.2 m/sec and 50 N.

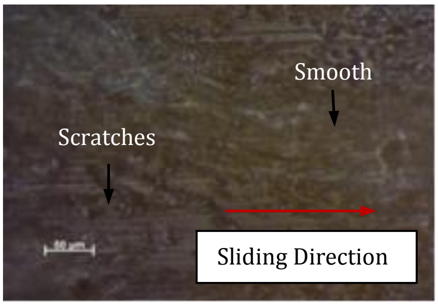

Fig. 21. Contact Surface of PRBF in Wet Test at 7.2 m/sec and 50 N.

Phenolic Resin Bonded Fabric Material: the material wear resistance influenced slightly in case of sliding speeds of 1.5 m/sec, 3.3 m/sec and 7.2 m/sec at a constant load of 10 N (see Fig. 5). The rubbing surface was partly smooth; scratches were formed on the surface. The wear resistance of the material decreased gradually when the sliding speed rose from 1.5 m/sec to

3.3 m/sec at a load of 30 N (see Fig. 6). The worn surface became partly rough due to increase in temperature and groove marks are appeared on the surface. While the material wear resistance decreased massively when sliding speed increased to 7.2 m/sec at loads of 30 N and 50 N as shown in Fig. 20. The worn surface was rough due to rise in the contact temperature (see Fig. 20). The material wear resistance rose significantly in case of wet tests condition compared with that in dry tests condition as seen in Figs. 8-10. The sources of wear damage to fibre, smears and scratches parallel to sliding direction as shown in Fig. 21.

4. CONCLUSIONS

The volume loss data obtained from experimental work for the studied end post materials (Nylon 12 N12, Nylon 66 N66, Nylon 66a N66a, Epoxy Glass EG and Phenolic Resin Bonded Fabric PRBF) using sliding velocities of 1.5 m/sec., 3.3 m/sec., and 7.2 m/sec. and three different loads of 10 N, 30 N, and 50 N shows that, the material resistance is affected by sliding speeds and applied loads in dry and wet test conditions. All thermoplastic end post materials have been melted when sliding speeds and an applied loads rose in the case of dry test condition. The wear resistance of thermoplastic materials were improved in wet test except Nylon 66. The thermosetting materials did not melt in all test conditions. Epoxy glass material has higher wear resistance. Thus the best material from the end post materials of N12, N66, N66a, EG, and PRBF which resist the sliding wear in the field of railway as appearing from the obtained experimental results in this study is epoxy glass materials (EG).

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