Graphene coatings for tribological applications

Yugal Rai

Centre for Process Innovation (CPI), National Formulation Centre, The Coxon Building, John Walker Road, NETPark, Sedgefield, County Durham, TS21 3FE

cpi

INTRODUCTION

Graphene is an allotrope of carbon with unique properties which is principally attributed to its 2D hexagonal lattice structure. They have been proven to exhibit an extremely high level of thermal conductivity, electrical conductivity along with superb mechanical strength. However, its use in the tribology field has been very limited.

Graphene, graphene oxide and other forms of modified graphene as filler materials in polymers and ceramic based surface coatings and as additives to conventional lubricants has presented promising applications of graphene in protective coatings [1]. Hence, in order to demonstrate the suitability of the tribological applications of graphene, the following study was conducted in CPI.

METHODS AND MATERIALS

A polymer based coatings with 5 and 10 weight % of graphene was produced, along with coating without graphene for comparison. The Graphene was dispersed in the polymer matrix with 3 methods of centrifugal mix, ultra turrex and three roll mill. The coatings were drawn onto a steel substrate and cured @ 200°C for 1 hour in an oven.

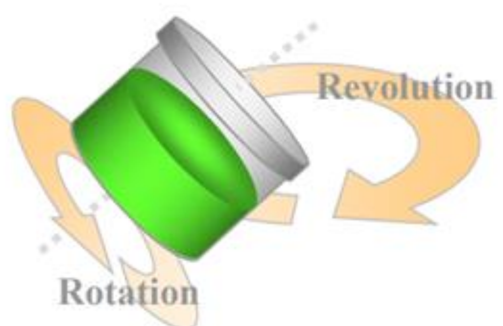

Figure 1. The centrifugal mixer (TM) uses a "planetary" mixing action with a combination of rotation and revolution.

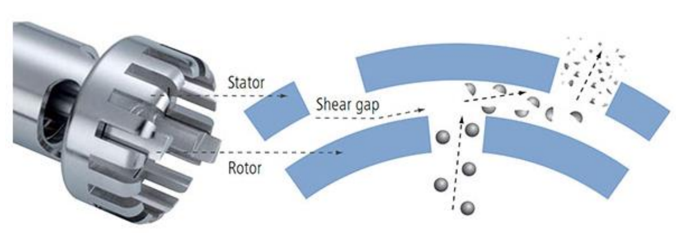

Figure 2. The Ultra Turrax (UT) is based on a rotor-stator principle which creates an extremely powerful shear force that effectively homogenizes, emulsifies and suspends miscible materials.

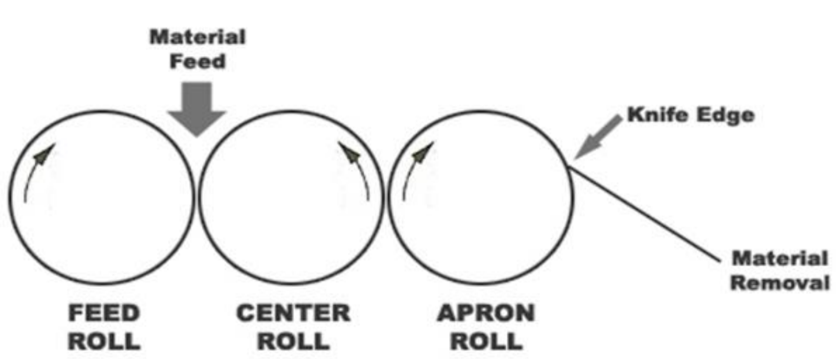

Figure 3. The three-roll mill (TRM) uses shear force created by three horizontally positioned rolls rotating in opposite directions and different speeds relative to each other, in order to mix, refine, disperse, or homogenize viscous materials fed into it.

RESULTS

The produced coatings were then initially analysed for roughness with the White Light interferometer and a scratch test conducted to understand the adhesion property of the coatings.

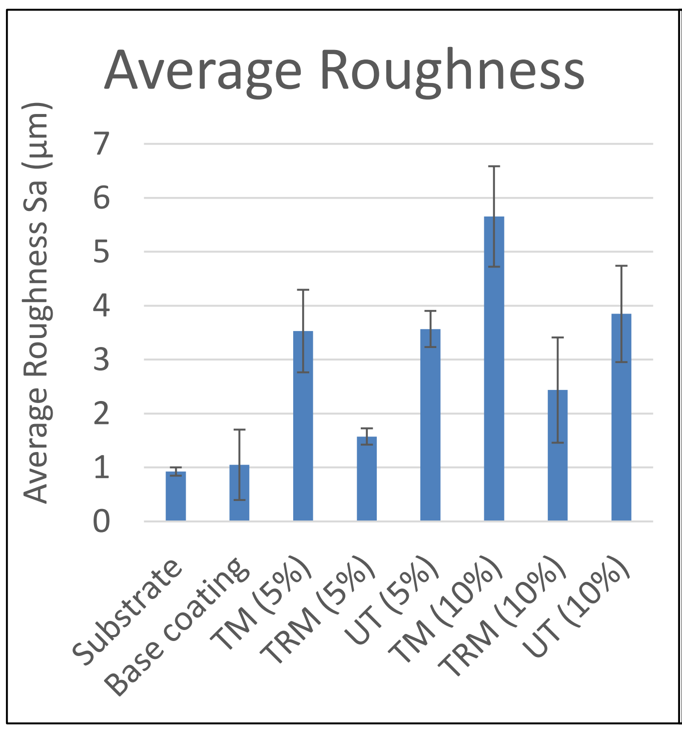

Chart 1. Average Roughness (Ra) value for various coatings.

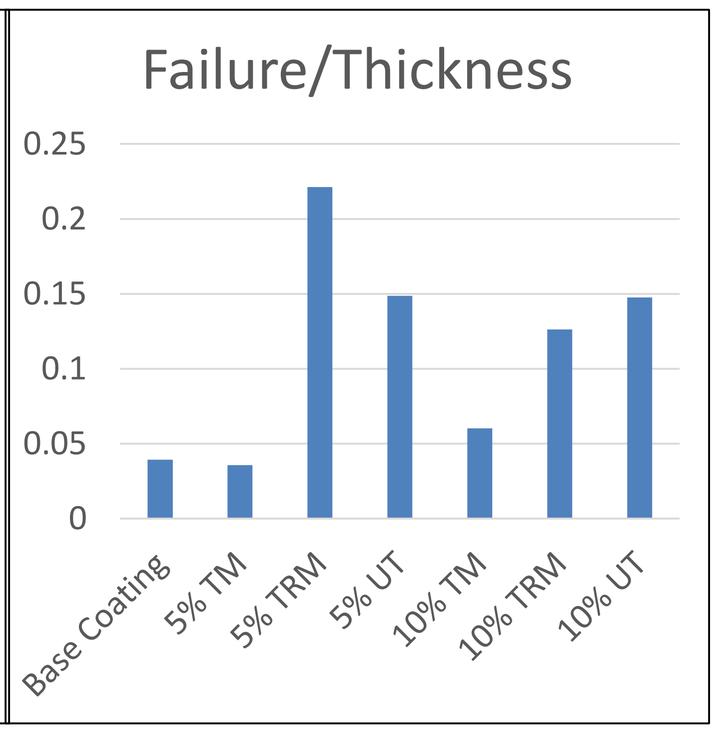

Chart 2. Ratio of scratch load failure over the thickness value for various coatings.

The roughness value is definitely affected with the inclusion of graphene particles. However, dispersion method is also shown to have an affect on the roughness of the coating.

Coating thickness has a high influence on the scratch properties, hence chart 2 has been produced as a ratio of scratch load failure against the coating thickness. Ratio of failure to thickness shows the 5% TRM has the highest resistance to the indenter. The centrifugal mixture (TM) has the least affect on the scratch properties.

TRIBO-TEST

Tribo-test were performed to understand the performance of the graphene under tribological conditions. Experiments were conducted with the three roll mill dispersed graphene coating, as this process showed the strongest adhesion property for the coating.

The tribo-test were conducted with the reciprocating and rotary motion, and comparative parameters for both test..

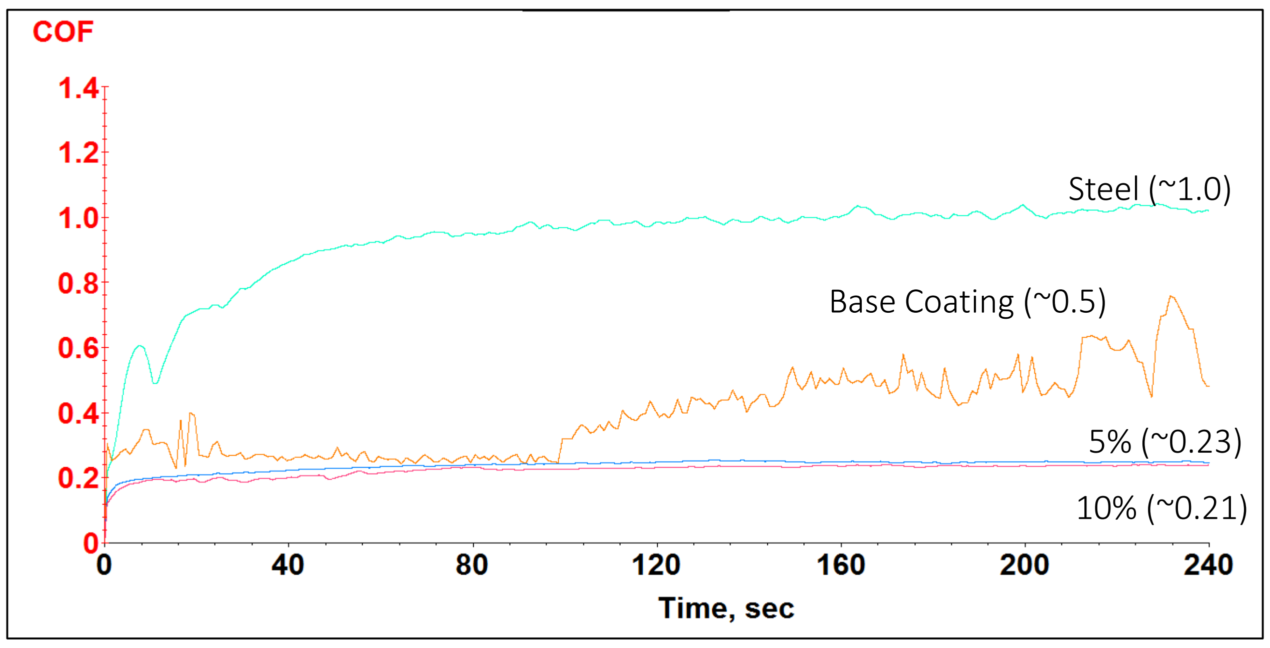

Chart 3. Coefficient of friction for the rotary test of various coatings and the averaged friction values.

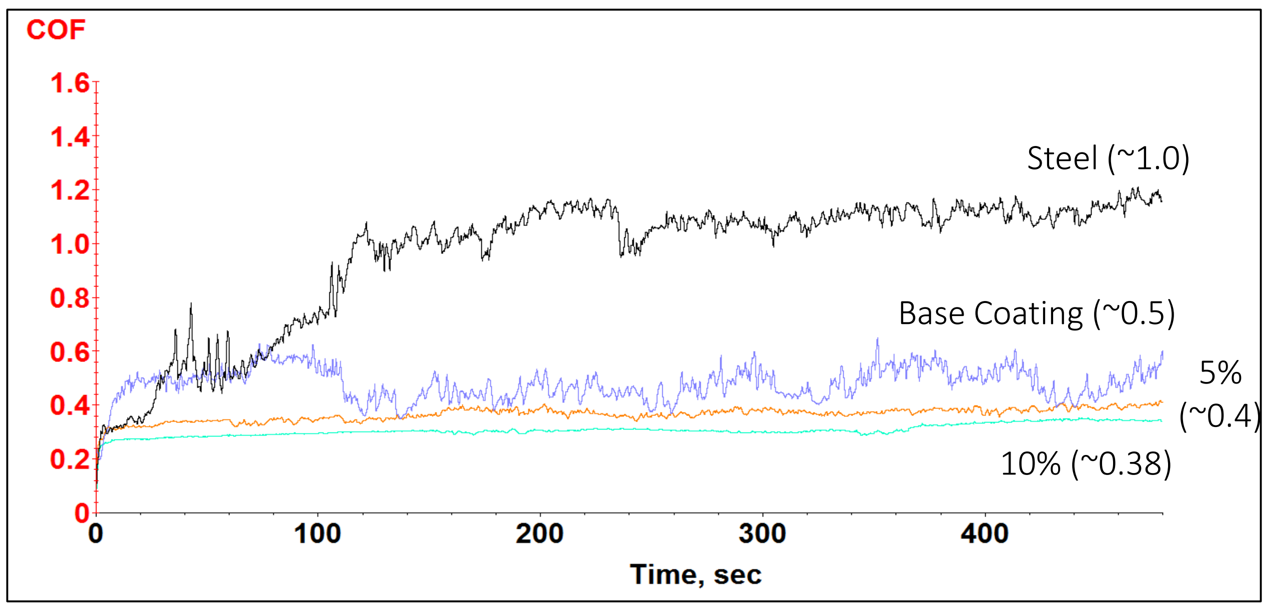

Chart 4. Coefficient of friction for the reciprocating test of various coatings and the averaged friction values.

The presence of graphene on the wear scar toward the end of the test for both motions were confirmed with the aid of Raman Spectroscopy.

CONCLUSION

- Dispersion method has a great affect on the roughness and the adhesion property of the coating.
- Inclusion of Graphene decreases the friction (for both motions) and the wear for rotary motion.
- The rotary (unidirectional) motion decreases the friction and the wear rate which we hypothesis is caused by unidirectional motion promoting graphene layers in the contact, compared to reciprocating motion.

REFERENCES

1. Nine, M., Cole, M., Tran, D. and Losic, D. (2015). Graphene: a multipurpose material for protective coatings. Journal of Materials Chemistry A, 3(24), pp.12580-12602.