**STSM Report: Advanced studies of the friction properties in polypropylene/rubber blends**

***By Alex Laikhtman – Holon Institute of Technology (HIT), Israel***

Thermoplastic elastomers (TPEs) are generally a combination of thermoplastics and elastomers. As such, they exhibit properties of elastomers but can be processed like thermoplastics. The most important feature of TPEs is recyclability of scrap and rejects in manufacturing process as well as of used TPEs products. On the other hand, easy recycling and repairing is the factor that emphasis the use of thermoplastic elastomers over conventional thermoset rubbers. The mechanical properties of polypropylene (PP) can be significantly improved by addition of some elastomers and by the rubber phase impregnation into PP matrix which results in a considerable enhancement of flexibility. In our recent studies we started to investigate the wear and friction variation due to energy dissipation in polypropylene/rubber blends. We found that dwell time between the ball passes on our flat samples substantially affects the frictional properties of the PP/rubber blends. Our findings have been referred to energy dissipation inside the tracks and the creep in our viscous material (PP). However, we were still unable to separate the dwell time effect and the energy dissipation effect. For this purpose, in the current project we performed further experiments by using different sliding speeds and investigating the creep effect in our studied materials.

We used the same set of the samples as before which were prepared by the host group. So the studied materials are: PP blended with: (1) natural rubber (NR), (2) styrene-butadiene rubber (SBR), and (3) a 1:1 (wt.) mixture of SBR and NR. TPEs for this project were synthesized in a mixing device at 190°C and 60 rpm. PP was melt in the mixer for 2 min and then NR or SBR, or a mixture of NR+SBR with additives and curing agents was added in the weight proportion of 50 % of PP and 50 % of the appropriate rubber. The mixing lasted for 3 min. At the end of the mixing cycle, the materials were collected and fabricated into a 120×120×2 mm sheet by a compression molding.

As listed above, the main goal of this study was to separate the dwell time effect and the energy dissipation effect by applying different sliding speeds and to investigate the creep effect. For this purpose the new generation Bruker’s Universal Mechanical Tester (UMT) instrument was used for performing different speed friction tests with simultaneous recording of the penetration depth (wear estimation) and the creep effect. The morphology of so obtained tracks was analyzed using Bruker’s optical microscope CONTOUR GT-K based on vertical scanning interferometry (VSI mode). Its maximal scan range is 10 mm and a vertical resolution below 0.01 nm.

Dry friction tests were performed using ball-on-plate method at ambient temperature (21 °C) and humidity (50%). Three different sliding speeds were applied. The time of the experiments was limited by 300 cycles. A stainless still ball 3 mm in diameter was used for this purpose.

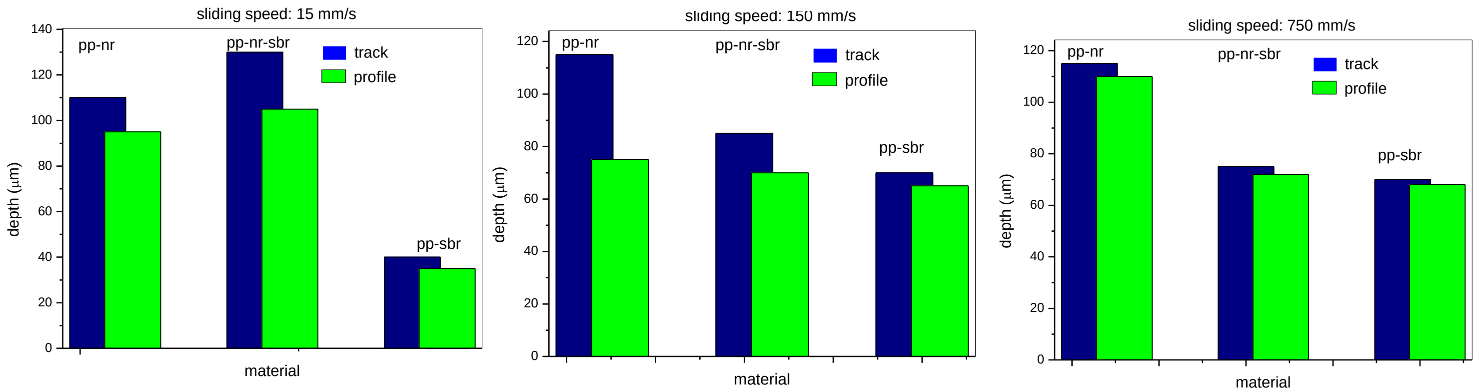


Fig. 1. Maximal track depth and track profiles for different samples and sliding speeds.

In Fig. 1 the depth of the tracks produced at 3 different velocities (15 mm/s, 150 mm/s and 750 mm/s) in all 3 types of materials (blue bars) is compared to the profile depth measured by the optical interferometer several minutes afterwards. In all cases the tracks we produced by the same maximal force of 5 N. The pronounced differences between the different speeds and the samples are quite evident. However, it can be clearly observed that the depth of the tracks decreases for all samples but the rate of such a decrease varies with the sample type. This indicate different recovery rates of the materials. A typical optical interferometer image of the friction track is shown in Fig. 2:

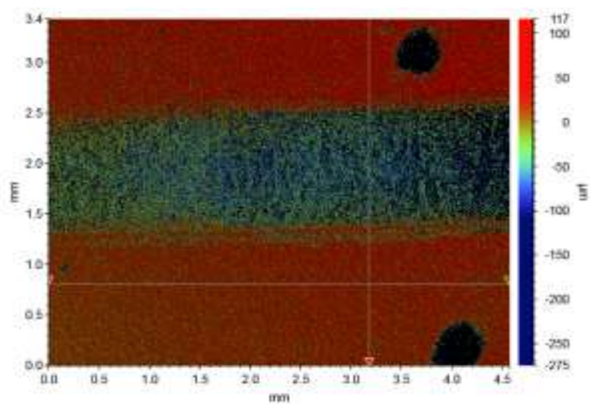


Fig. 2. Optical interferometry image of the track in PP-NR at the 150 mm/s sliding speed.

The corresponding plots showing the coefficient of friction are shown in Fig. 3:

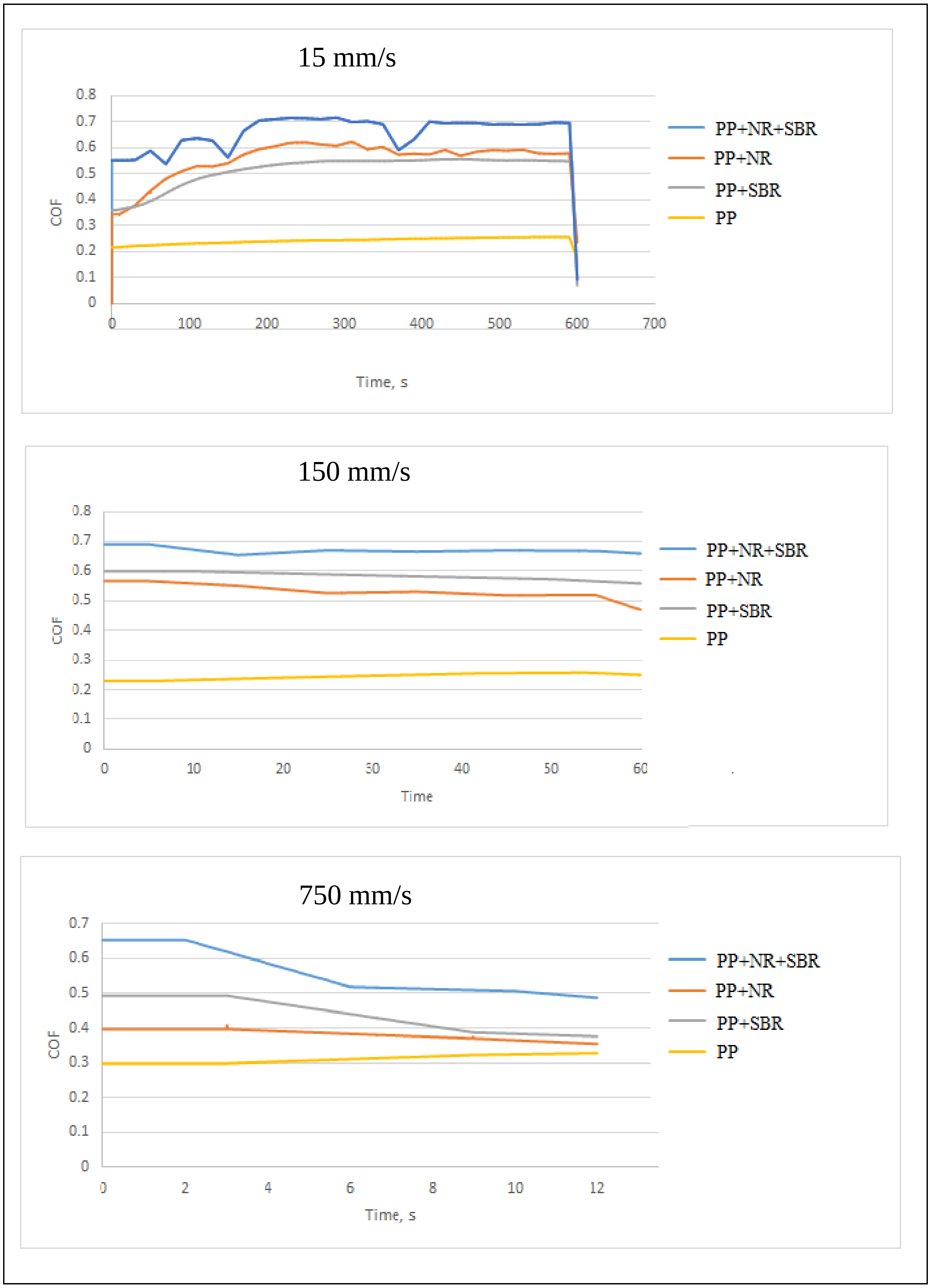


Fig. 3. Coefficient of friction measurements for different samples and sliding speeds.

Significant changes in the values friction coefficient due to the sliding speed increase was not observed for PP. Whereas for PP+NR+SBR we obtained the maximal friction coefficient variation with the friction speed.

Quite stable results were obtained for the 150 mm/s friction speed. However, for the sliding speeds of 15 mm/s and 750 mm/s, the friction coefficient variation was non-monotonic due to some morphological changes inside the friction track: third body wear particle formation for the low speed and the polymer film formation due to high temperature during the high speed friction. Low speed friction assisted by creep effect led to consecutive plugging of the specimen surface and continuous increasing of the coefficient of friction. These findings are in good agreement with our previous results (performed in Israel, March-April 2016), where we had stops between cycles resulting in the increase of the starting depth and the friction coefficient.

To stress out this issue, the creep effect measurements performed following 300 s of load are depicted in Fig. 4:

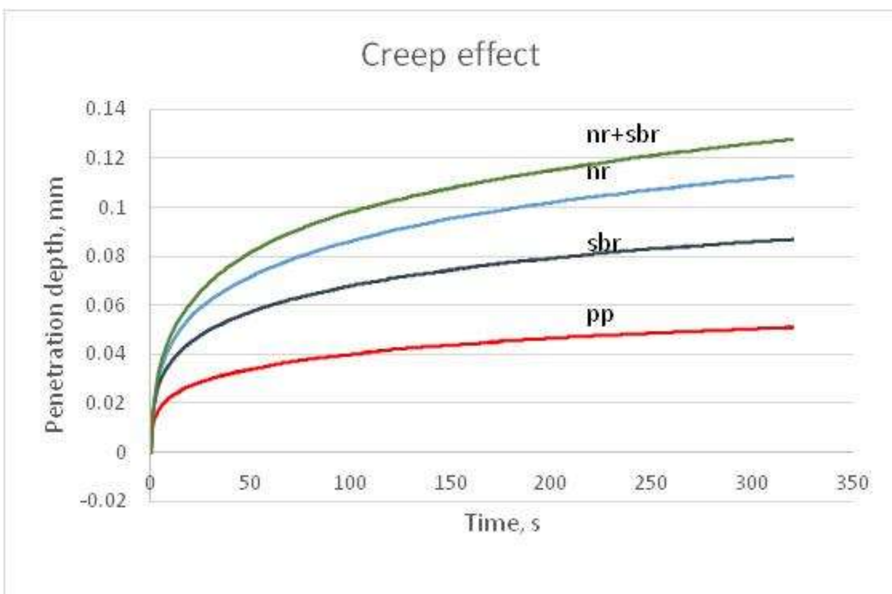


Fig. 4. Creep effect measurements for different samples and the sliding speeds.

The obtained results, when fully analyzed and summarized will know allow to complete the elucidation of the exact mechanism for the effects of the dwell time the energy dissipation.

This project largely contributed to our ongoing collaboration in the field of understanding of friction and wear properties of thermoplastic elastomers. The full results will be submitted for publication in an appropriate peer-review journal and presented at the scientific meetings.