Supplementary Information for

Effectiveness of glycerol-monooleate in high-performance polymer tribo-systems[†]

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SI 1: Viscosity of lubricants

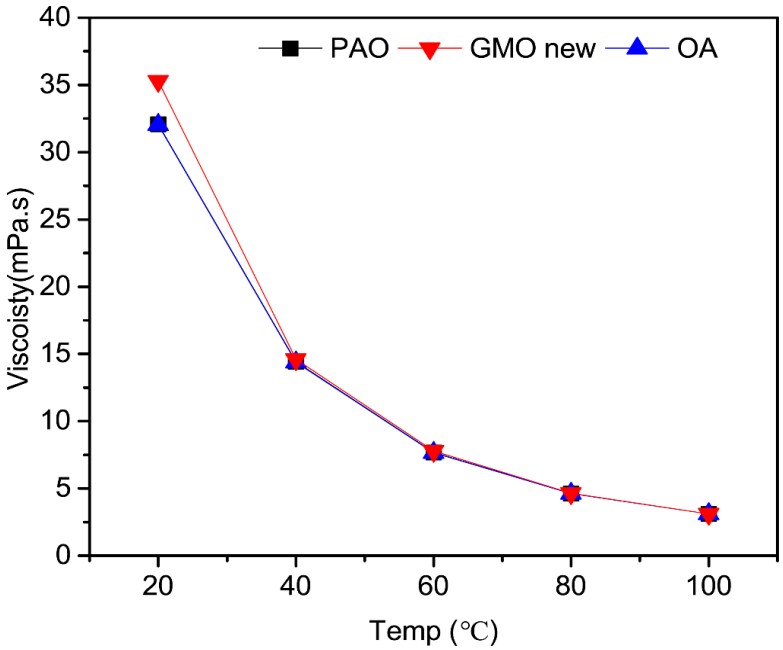

Figure S1 Viscosity-temperature relationship of tested lubricants in temperature ranged from 20 ℃ to 100 ℃

SI 2: Average Hertzian contact pressure for different contacts

Table S2-1. Average Hertzian contact pressure for different contacts.

Disc-ball	*2 N*	*6 N*	*9 N*
PAI-Steel	*67.4 MPa*	*97.2 MPa*	*111.27 MPa*
PAI-PAI	*43.11 MPa*	*62.17 MPa*	*71.13 MPa*
PEEK-Steel	*59.01 MPa*	*85.06 MPa*	*97.4 MPa*
PEEK-PEEK	*37.63 MPa*	*54.27 MPa*	*62.13 MPa*
Steel-Steel	*535.8 MPa*	*772.66 MPa*	*884.67 MPa*

SI 3: FTIR spectra of dry clean steel surfaces, PAO on steel and PAO+GMO on steel

Spectra of PAO4 (black) and PAO+GMO (red) were obtained by dropping some lubricant on a steel surface while dry, clean steel surface was tested as reference, see Figure S2.

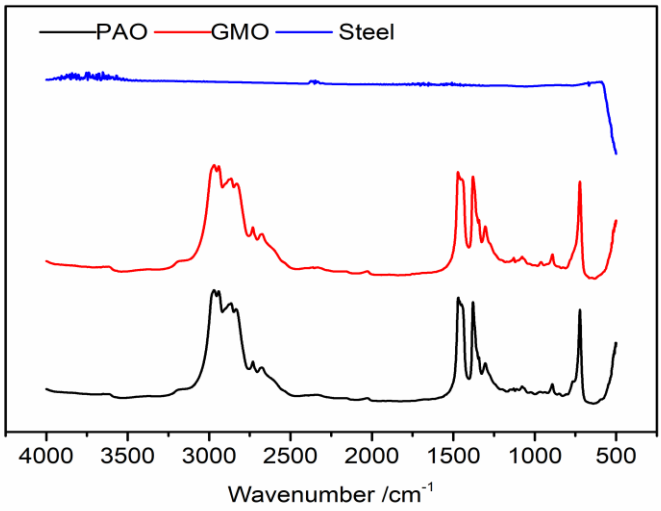

Figure S3-1: FTIR spectra of dry, clean steel surfaces (blue), PAO on steel (black) and PAO+GMO on steel (red).

SI 4 Friction curves of polymer-steel contacts

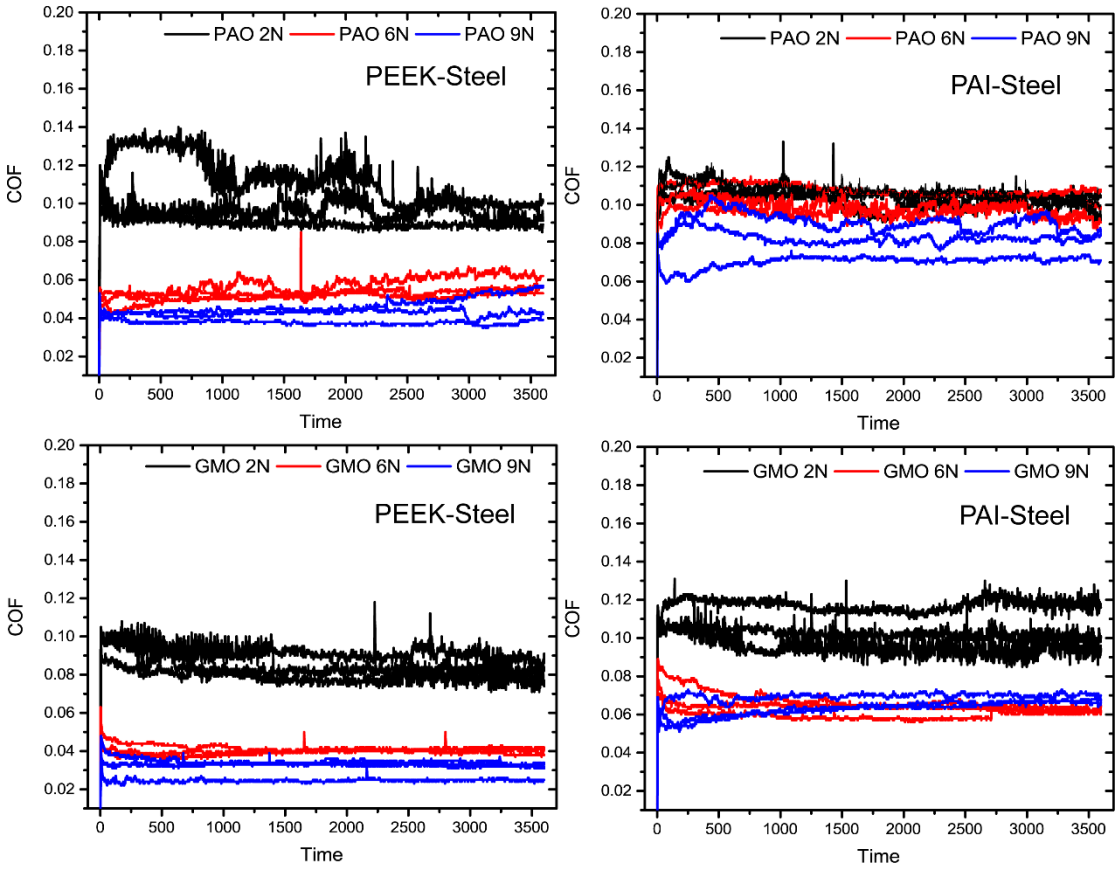

Figure S4-1: Evolution of friction coefficient of polymer-steel contacts: (a) PEEK-Steel (b) PAI–Steel under PAO4 lubrication and (c) PEEK-Steel, (d) PAI–Steel under GMO lubrication

SI 5 Friction curves of polymer-polymer

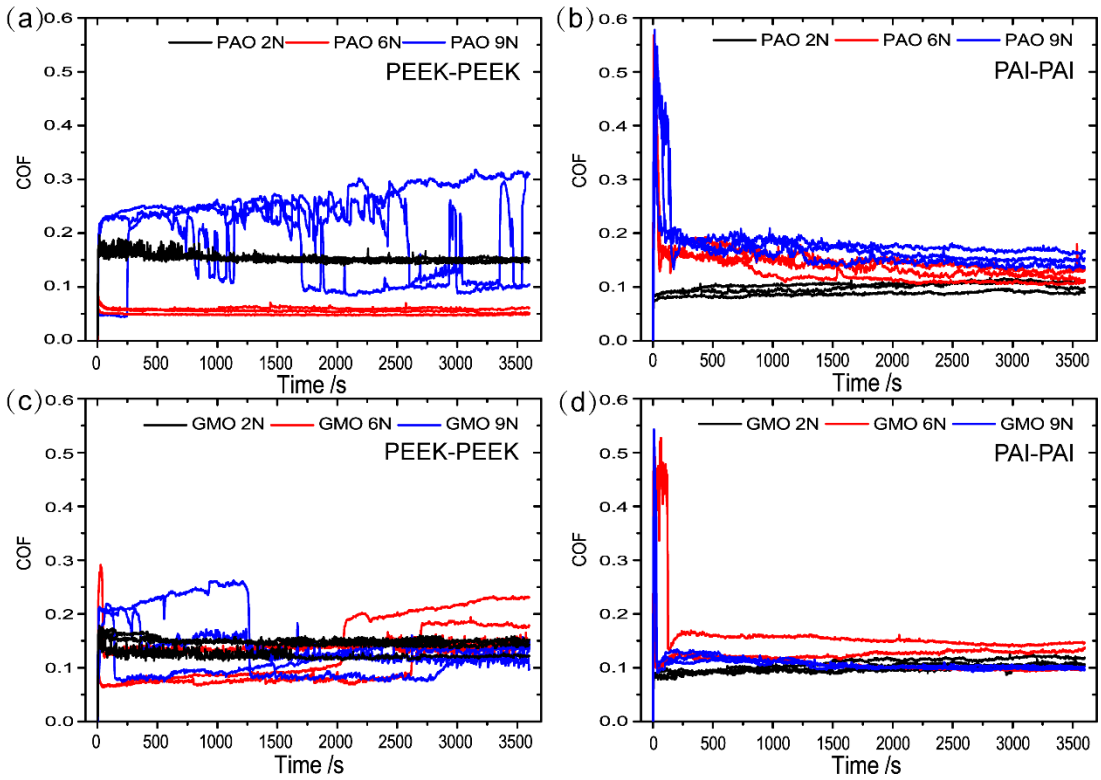

Figure S5-1: Evolution of friction coefficients of polymer-polymer contacts: in PAO4 with (a) PEEK-PEEK and (b) PAI–PAI contacts; and in PAO+GMO with (c) PEEK-PEEK and (d) PAI–PAI contacts.

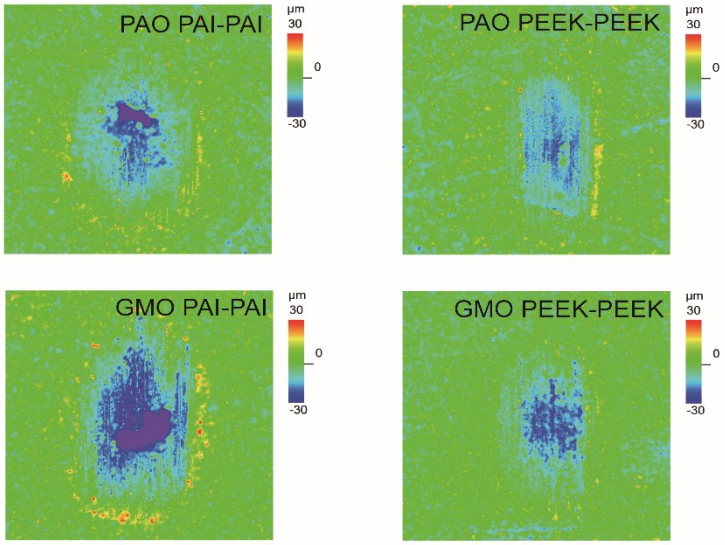

Figure S5-2: 3D images (2500 × 2500 μm) of wear scars on polymer discs from polymer-polymer contacts at an applied load of 9 N.

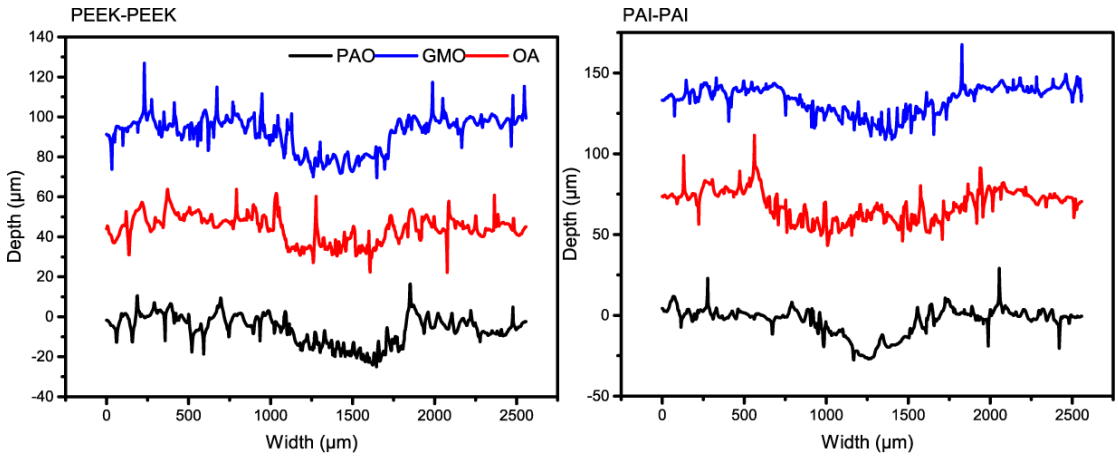

Figure S5-3: Profiles of wear tracks on polymer discs for (a) PEEK-PEEK and (b) PAI-PAI contacts at 9N.

SI 6 Flash Temperature Rise Calculation

Calculations for the average flash temperature T_f are based on Jaegers model for a uniform circular source. The below equations and data listed in Table S. 1 are used for calculations.

$T_f = \frac{0.903\dot{q}a}{1.064K_{ball}+0.849K_{disc}\sqrt{Pe}}$ and $\alpha = \frac{0.849K_{disc}\sqrt{Pe}}{1.064K_{ball}+0.849K_{disc}\sqrt{Pe}}$

Definitions for variables used in calculations and discussion of the flash temperature and temperature measurements are given below:

T_f Average flash temperature rise $[°C]$

α Heat partition coefficient

μ Coefficient of friction

W Normal Load $[N]$

U Relative sliding velocity $[m/s]$

a Contact radius $[m]$

$A = \pi a^2$ Contact area

$p = W/A$ Average contact pressure $[Pa]$

$\dot{q} = \mu pU$ Heat flux per unit area $[W/m^2]$

K Thermal conductivity $[W/mK]$

ρ Density $[kg/m^3]$

σ Specific heat $[J/kgK]$

$\chi = K/\rho\sigma$ Thermal diffusivity $[m^2/s]$

$Pe = 2Ua/\chi$ Peclet number

Table S6-1: Material properties for flash temperature calculations.

Materials	*X [m²/s]*	*K [W/mK]*	*ρ[kg/m³]*	*σ[J/kgK°C]*
PEEK	*0.000000141*	*0.25*	*1320*	*1340*
PAI	*0.000000176*	*0.26*	*1183*	*1248*
Steel	*0.000013*	*46*	*7700*	*461*

Table S6-2: Calculated average flash temperature rise in °C based on maximum friction coefficient obtained.

	2N	*6N*	*9N*
PAO/PAI-PAI	*15.94*	*40.38*	*61.22*
PAO/PEEK-PEEK	*22.81*	*14.28*	*83.44*
PAO/PAI-Steel	*1.36*	*2.53*	*2.67*
PAO/PEEK-Steel	*1.07*	*1.22*	*1.25*
PAO+GMO/ PAI-PAI	*16.71*	*37.88*	*38.51*
PAO+GMO/ PEEK-PEEK	*20.79*	*33.24*	*43.41*
PAO+GMO/ PAI-Steel	*1.21*	*1.53*	*2.01*
PAO+GMO/ PEEK-Steel	*0.91*	*0.89*	*1.09*

SI 7: FTIR spectra of steel ball wear scars formed by steel-PAI contacts

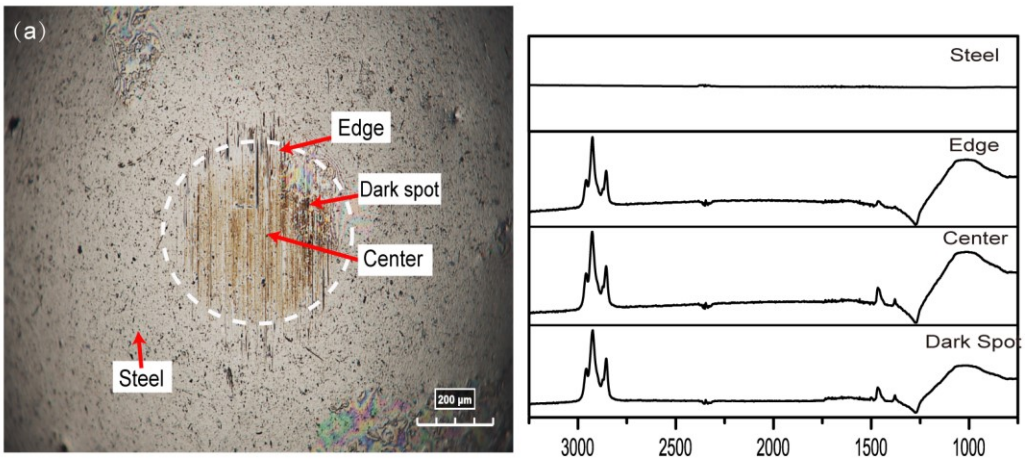

Figure S6-1 Left: an optical image of a steel ball wear scar formed by rubbing against PAI in PAO at 9 N; and Right: FTIR spectra taken at different locations on the wear scar shown on the LefT

SI 8: Raman spectra of steel ball wear scars formed by steel-steel contacts

Raman spectra of steel ball wear scars formed by steel-steel contacts (Figure S8-1) lubricated with PAO (dotted line) and PAO+OA (solid line) are similar. Peaks that can be assigned to α-Fe_2O_3 (dashed rectangles), including clear phonon lines for A_{1g} modes (222, 496 cm^{-1}) and E_g modes (293, 409, 614 cm^{-1}), and the peak at 1322 cm^{-1} for its two-magnon scattering caused by the interaction of two magnons created on antiparallel close spin sites, are clearly observed.[52] Peaks in the region between 1200-1600 cm^{-1} are assigned to α-Fe_2O_3 and γ-Fe_2O_3.[46] The peak at 667 cm^{-1} is for γ-Fe_2O_3 .[53] When lubricated with PAO+GMO (dashed line), Fe_3O_4, suggested by the peak at 673 cm^{-1}, is the only oxidation product of iron that can be clearly identified. Additionally, peaks of D- and G- bands of amorphous carbon appear at 1350 cm^{-1} and 1551 cm^{-1},[54] which however might be due to the laser excitation.

Generally, Fe_3O_4 undergoes a phase transition as temperature increases: [46,55]

$$Fe_3O_4 \xrightarrow{200℃} \gamma - Fe_2O_3 \xrightarrow{400℃} \alpha - Fe_2O_3$$

Our results suggest that the local temperature caused by frictional hearing in steel-steel contacts lubricated by PAO and PAO+OA may be higher than that of PAO+GMO. This is consistent with their friction coefficients being 0.14 (PAO), 0.135 (PAO+OA), 0.1 (PAO+GMO). Note that lower friction coefficient leads to lower frictional heating.

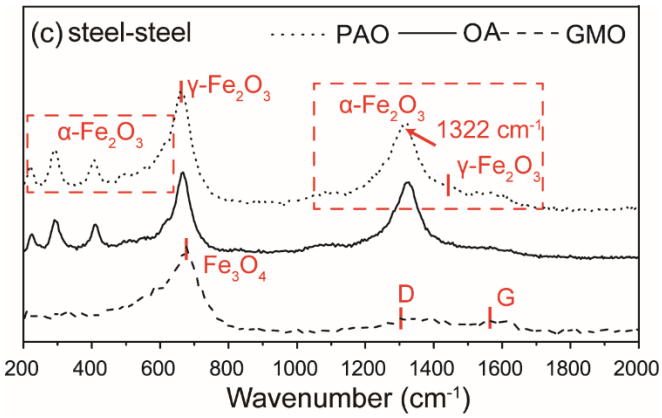

Figure. S8-1 Raman spectra obtained at center area on steel ball wear scar formed by steel-steel contacts at 2N.