

Tribology characteristics of KEPITAL

R&D Center

1. Friction & Wear – the definition of the word 'Tribology'

(1) Etymology : The word tribology derives from the Greek root τριβ- of the verb τριβω, tribo, "I rub" in classic Greek; and the suffix -logy from -λογία, -logia "study of", "knowledge of". It was coined by the British physicist David Tabor,[1] and also by Peter Jost in 1964, a lubrication expert who noticed the problems with increasing friction on machines, and started the new discipline of the tribology.

(2) What is tribology?

Tribology is the science and engineering of interacting surfaces in relative motion. It includes the study and application of the principles of friction, lubrication, and wear. Tribology is a branch of mechanical engineering and material science.

2. The three elements of tribology



(1) Friction

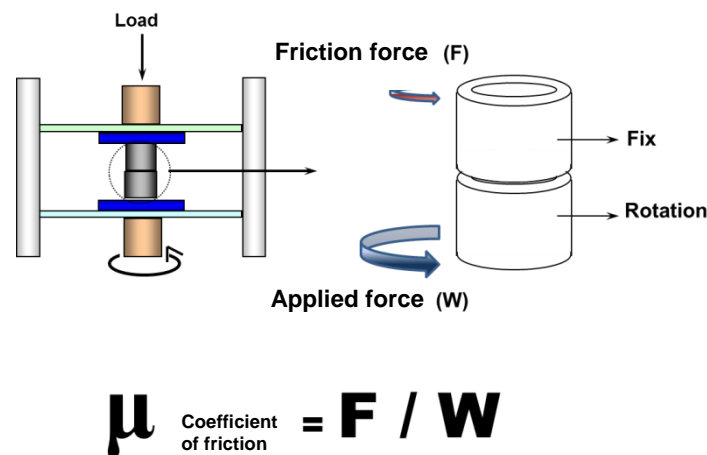
1) Definition : Friction is the force resisting the relative motion of solid surfaces, fluid layers, and material elements sliding against each other.

2) Types of friction

① Classification depends on the situation:

- Static friction : friction between objects that are not moving relative to each other

- Dynamic friction : friction between solids that are moving relative to each other
footnote) 1. The friction in field of plastics is included in dynamic friction.
 - ② Classification depends on the condition of the friction surface
 - Dry friction : the resistive force between solid surfaces in contact which resists their relative tangential motion
 - Boundary friction : the friction between surfaces that are neither completely dry nor completely lubricated
 - ex) friction between cylinder and piston ring when setting an automotive engine
- 3) Friction force : the force that opposes the motion of an object
- 4) Coefficient of friction
- The coefficient of friction is a value which describes the ratio of the force of friction between two bodies and the force pressing them together. Therefore, if the coefficient of friction is higher, the force of friction is also higher.
- $F = \mu W$ (F : friction force, μ (mu) : coefficient of friction, W : applied force)
- ※ The coefficient of friction depends on the materials, existence of lubricants, and types of lubricants.



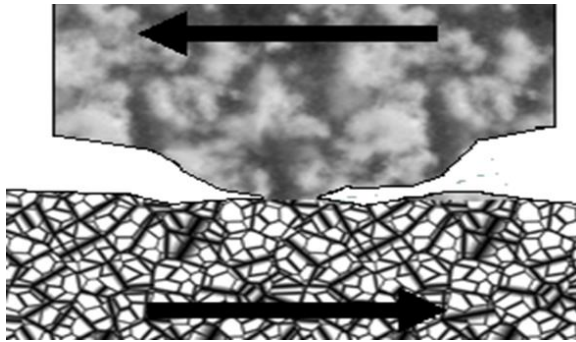
Picture 1. Definition of the coefficient of friction

(2) Wear

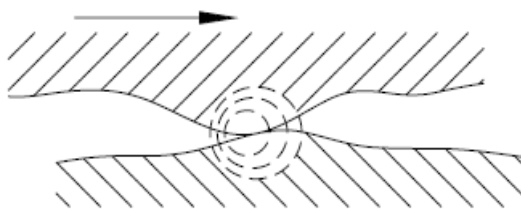
- 1) Definition : the loss of dimension that originates at the interface between two sliding surfaces
 - 2) Causes : adhesion, corrosion, abrasion, fatigue, fracturing chemical reactions, etc.
- ※ "Industrial Wear" is commonly described as incidence of multiple wear mechanisms.

3) Types of wear

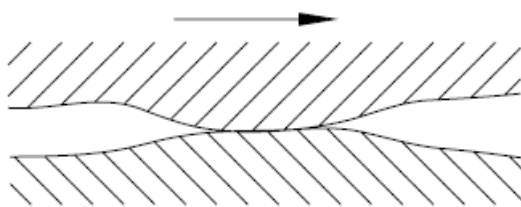
- ① Adhesive wear : Adhesive wear can be found between surfaces during frictional contact and generally refers to unwanted displacement and attachment of wear debris and material compounds from one surface to another.



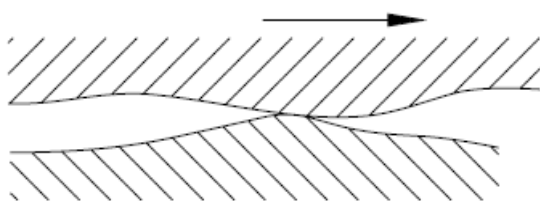
Picture 2. Example of adhesive wear



1 step : Elastic and plastic deformation, pitting



2 step : Adhesion

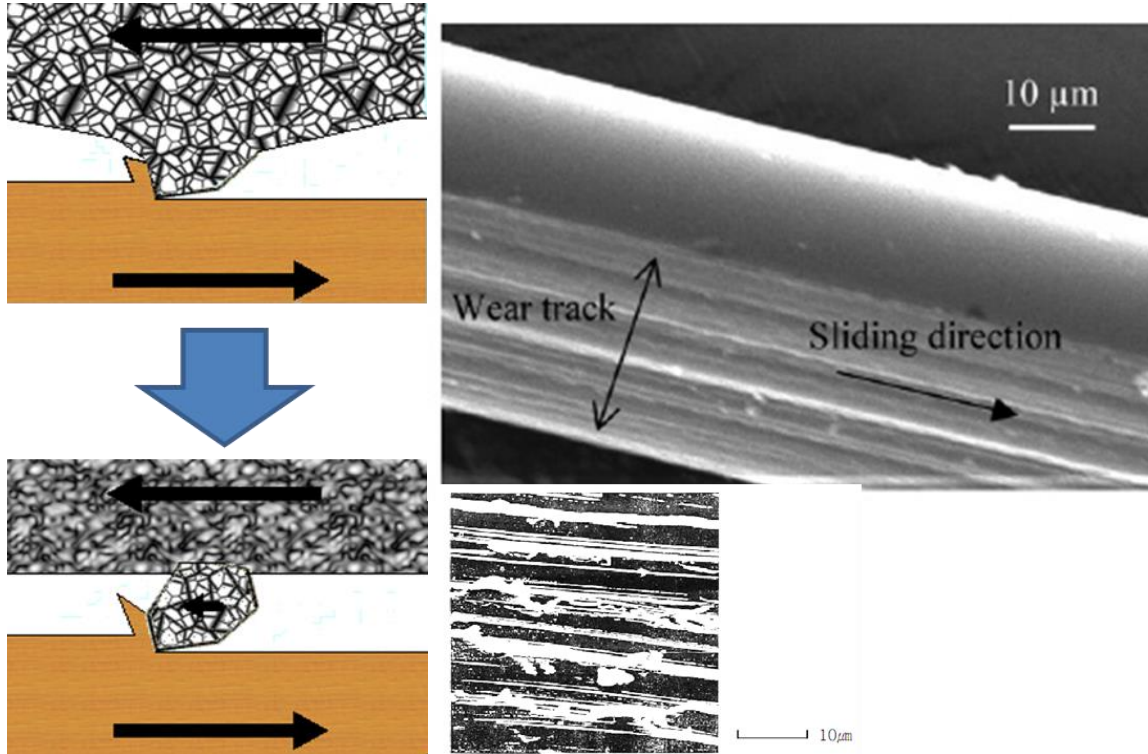


3 step : Shear on the adhesive point

Picture 3. The steps of the adhesive wear

{Reference : Know-how of wear test(TN-05-14), pp. 10 (2007)}

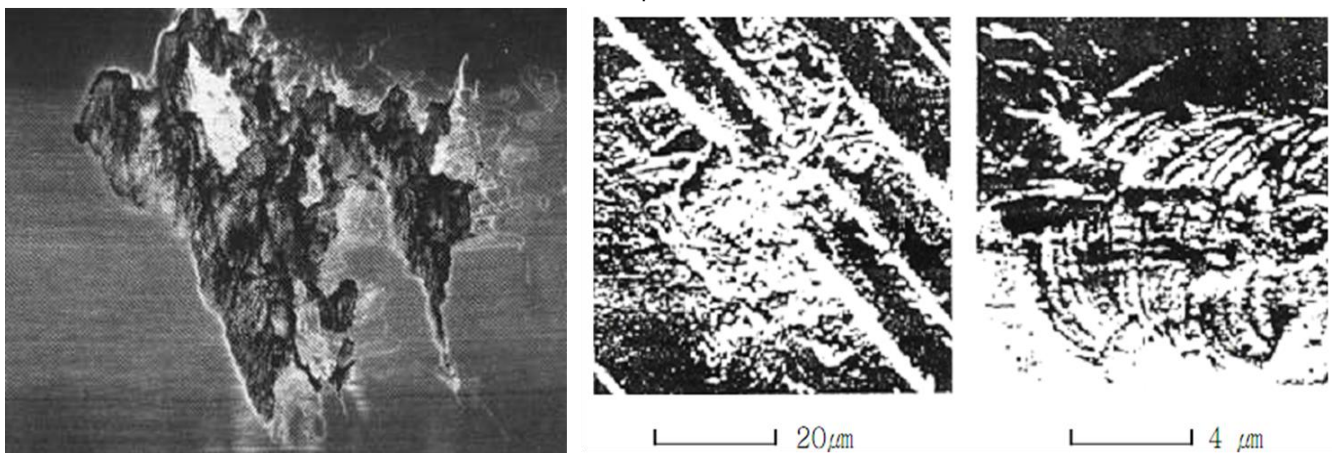
- ② Abrasive wear : Abrasive wear occurs when a hard, rough surface slides across a softer surface. ASTM International defines it as the loss of material due to hard particles or protuberances that are forced against and move along a solid surface.



Picture 4. Example of abrasive wear

(Reference : Polymer 45 (2004) 2729~2736)

- ③ Surface fatigue wear : Surface fatigue is a process by which the surface of a material is weakened by cyclic loading, which is one type of general material fatigue. Fatigue wear is produced when the wear particles are detached by cyclic crack growth of micro-cracks on the surface. These micro-cracks are either superficial cracks or subsurface cracks.

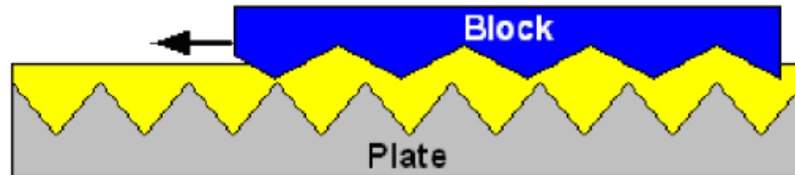


Picture 5. Example of the surface fatigue wear

Reference : <http://www.acta.nl/dentalmaterials/research/wear>

(3) Lubrication

- 1) Definition : Lubrication is the process or technique employed to reduce friction between, and wear of one or both, surfaces in close proximity and moving relative to each other, by interposing a substance called a lubricant between them.



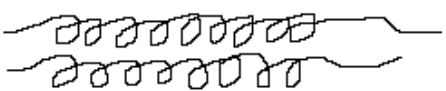
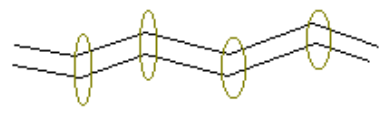
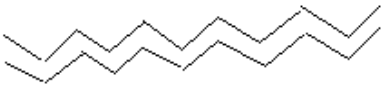
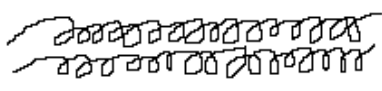
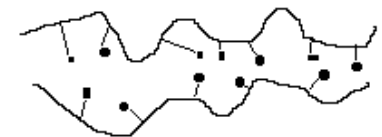

(Reference : Annual Report of the KNIT, Vol. 12, pp 53~65, 1991)

- Fluid lubrication : The lubrication regime in which through viscous forces the load is fully supported by the lubricant within the space or gap between the parts in motion relative to each other (the lubricated conjunction) and solid-solid contact is avoided. Therefore, the wear of contact surface is hardly observed. (Minimum depth of lubricant : 0.008 – 0.020 mm)
- Mixed lubrication : Occurs when fluid lubrication is partially applied between the protuberance on the surface
- Boundary lubrication : Chemically reactive constituents of the lubricant react with the contact surface forming a highly resistant tenacious layer, or film, on the moving solid surfaces (boundary film) which is capable of supporting the load and major wear or breakdown is avoided.

3. Main factors influencing a tribology characteristic

(1) Material

- 1) Surface characteristic : the less surface roughness and surface tension,
the less coefficient of friction
- 2) Molecular structure : the less molecular force or symmetric molecular structure,
the less coefficient of friction
- 3) Molecular weight : low molecular weight has better tribology characteristics than higher
molecular weights
- 4) Crystallinity : semi-crystalline polymers have a lower coefficient of friction than amorphous
ones; the higher the crystallinity, the lower the coefficient of friction

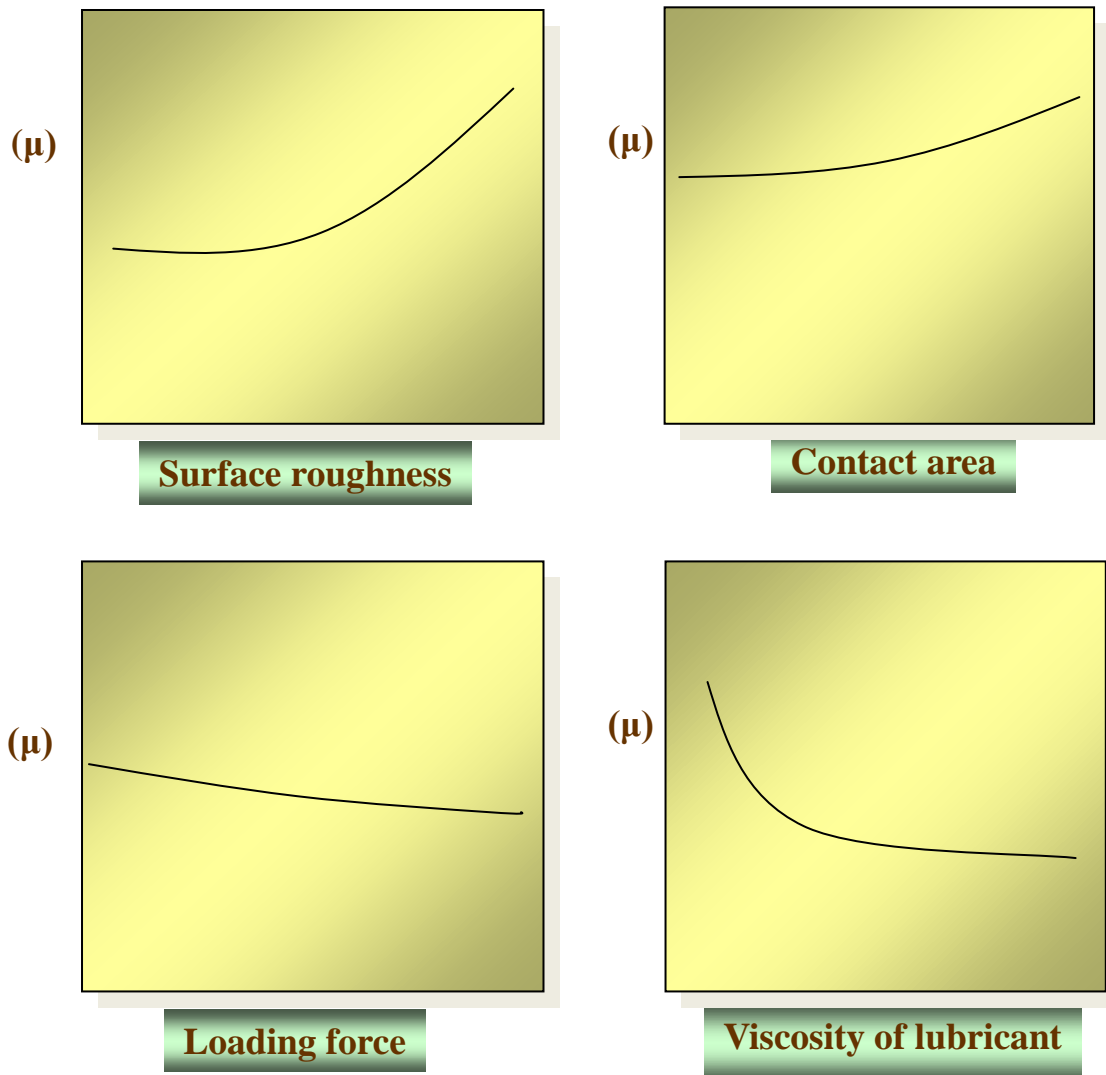
	Polymer	molecular structure	rotating form
crystalline	Polyacetal		Helical
	Nylon		zig-zag
	Polyethylene		Fully extended zig-zag
	PTFE		Compacted Helical
amorphous	Polystyrene		Amorphous
	Polycarbonate		Amorphous

Picture 6. Molecular structure influence on tribology

(2) Moving conditions

- 1) Lubricative condition : The tribology characteristic will be changed according to existence of
the lubrication.
- 2) (Real)contact area : The coefficient of friction tends to increase with increasing (real) contact
area.
- 3) Load & linear velocity :

- ① The coefficient of friction is slightly decreased when a loading force is increased.
- ② The coefficient of friction has a tendency to change according to increased linear velocity.
- ③ The effect of contact load and linear velocity for the coefficient of friction will be different depending on a material's characteristics.



Picture 7. The main factors influencing the coefficient of friction

- (3) Noise : Noise is classified with a vibration sound and a sympathetic sound. The vibration sound is a main noise to be made by moving materials. Shear stress, surface roughness, and dimensional accuracy can affect the vibration sound.

1) How to decrease noise

- Decreasing some noise from friction and impact by using soft material.
- Minimize differences surface roughness by decreasing moisture during injection molding.
- Improve the surface roughness by using an MTC machine and modified design.

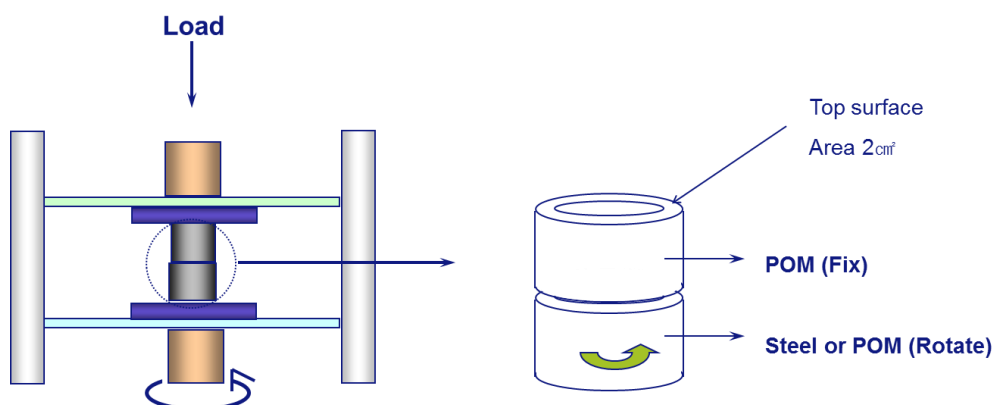
4. Test method and results for tribology characteristic

(1) Properties for tribology characteristic

- 1) The dynamic friction coefficient : The value of resistance to made by moving two materials contacting each other.
- 2) Specific wear rate : Measured using an amount of material loss by mechanical movement.
- 3) PV limit : The heat buildup caused by friction and adhesive wear makes materials wear down under extreme operating conditions. All materials have limits in their ability to sustain a given loading at a particular speed. This is known as the pressure times velocity or PV limit.

(2) Test machine and method

1) Ring-on-Ring (rotation type)



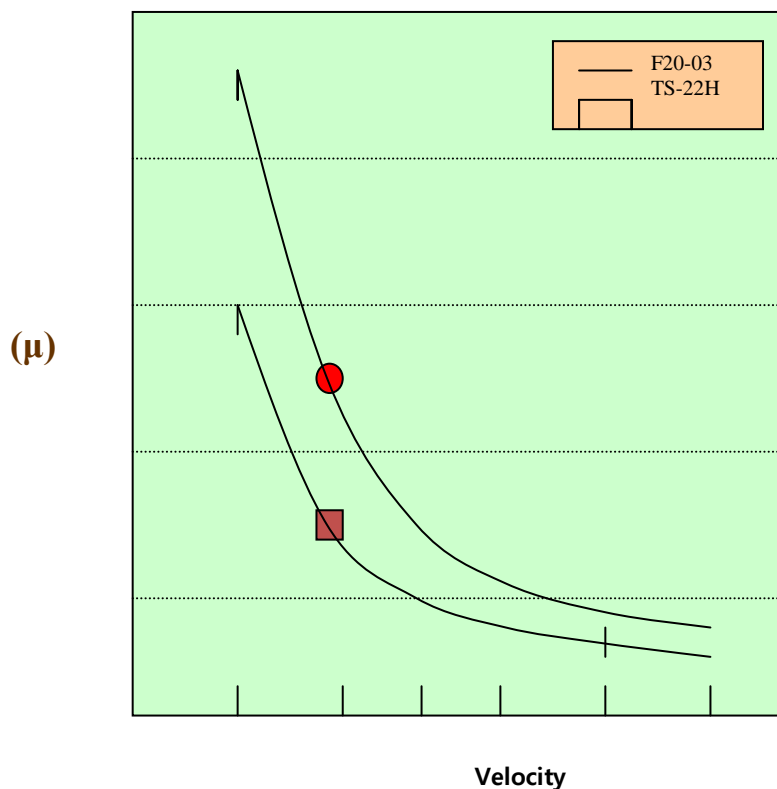
Picture 8. Ring-on-Ring Test Machine

- Two ring-type specimens are contacting each other. Then, one specimen is fixed and another specimen is rotating. The dynamic coefficient, specific wear rate, PV limit, and noise

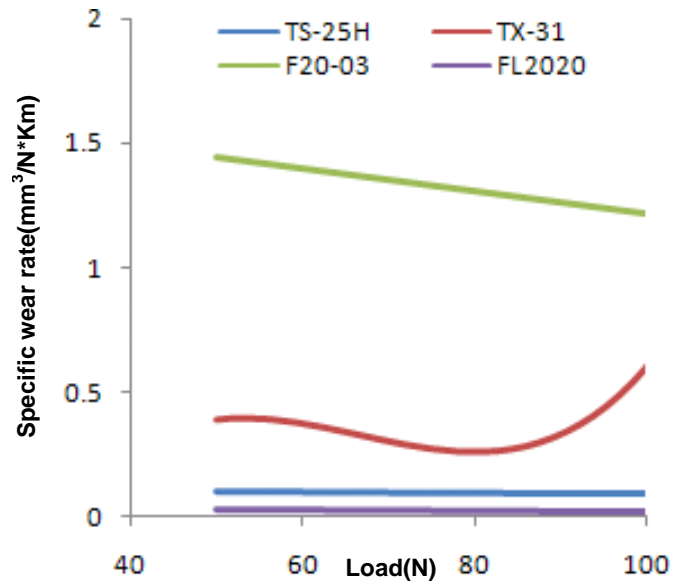
are measured on the contact surface.

- This method derives from the JIS method. It is possible for comparison evaluation by changing a load, speed, and test time.
- Same resin, different resins, and metal can be used for counterpart materials. There are several types of metals such as S45C (Steel), SUS (Stainless-steel), brass, etc.

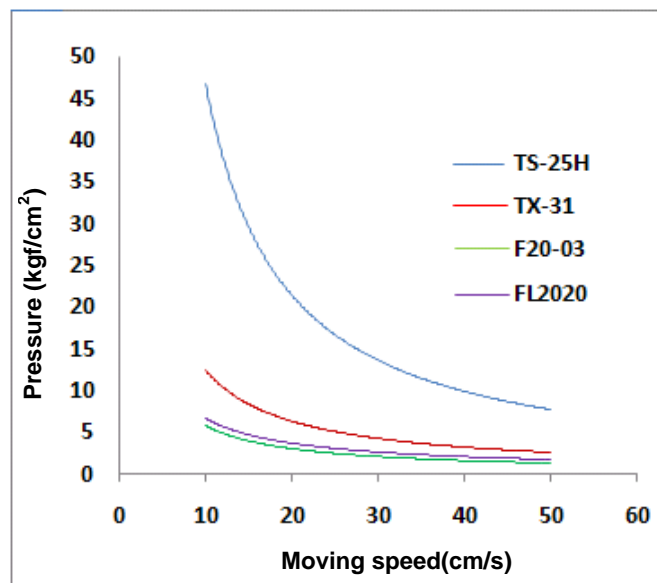
Generally, the tribology characteristic of plastics is influenced by contact load, moving speed, temperature, and humidity. There is a the dynamic friction coefficient, specific wear rate, and PV limit of KEPITAL according to moving conditions on Pictures 9 to 11.



Picture 9. The dynamic friction coefficient of KEPITAL at various moving speeds (Ring-on-Ring)

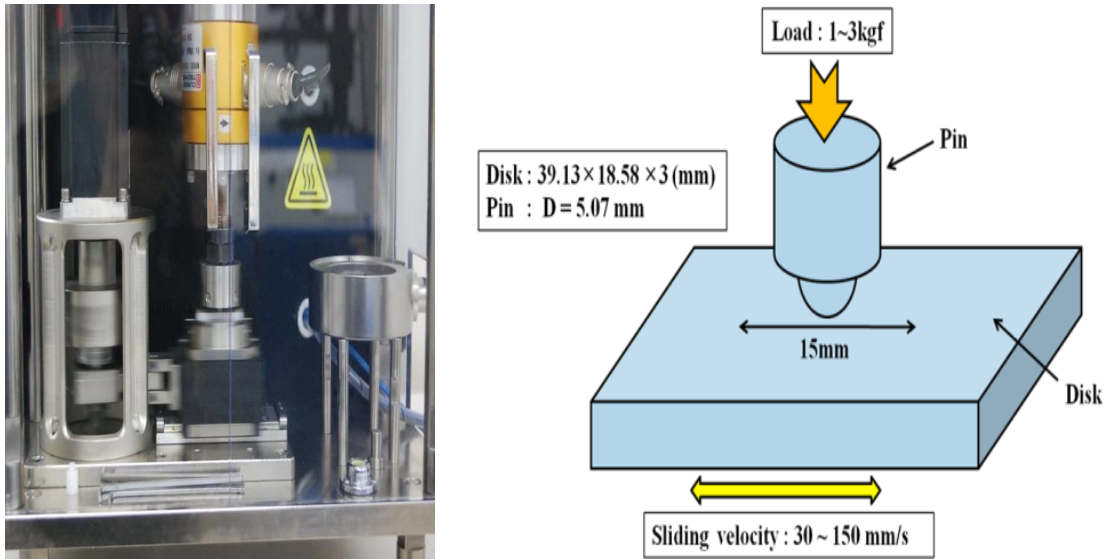


Picture 10. The specific wear rate of KEPITAL on various contact loads (Ring-on-Ring)



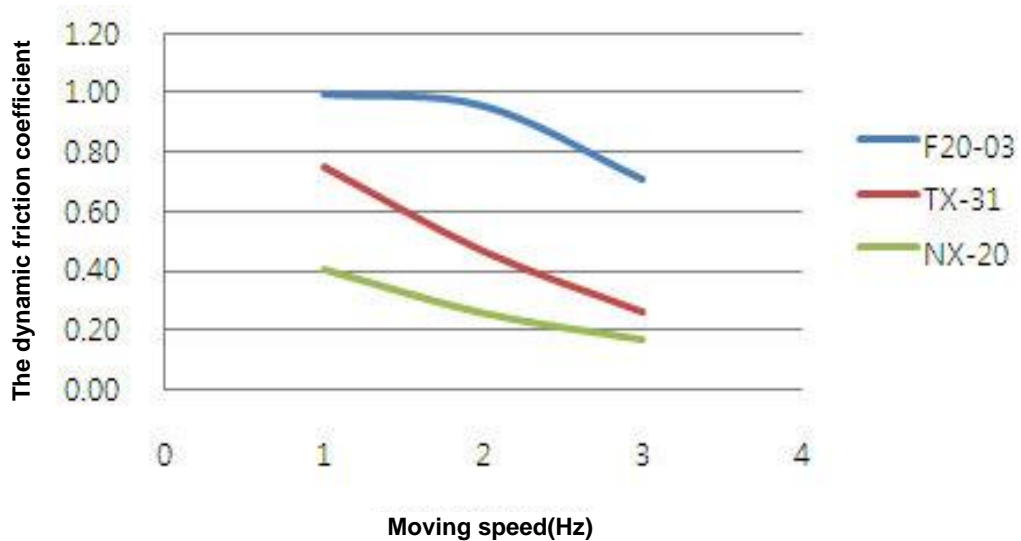
Picture 11. The PV limit of KEPITAL(Ring-on-Ring)

2) Pin-on-Disk(reciprocating motion)

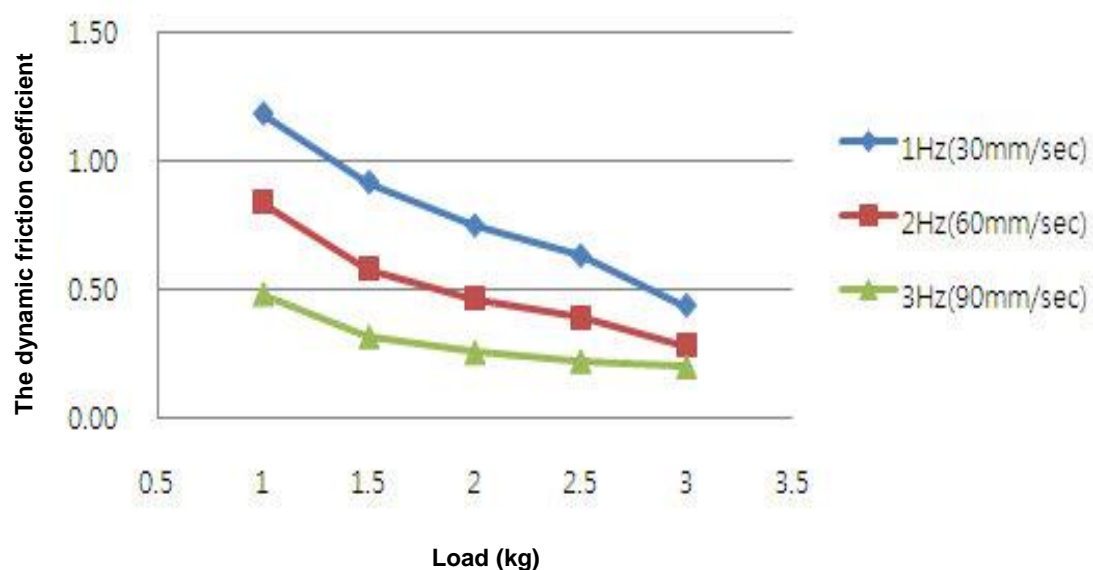


Picture 12. Pin-on-Disk Test Machine

This type machine is useful to measure the tribology characteristic of reciprocating motion application. You can see the dynamic friction coefficient of KEPITAL at various moving speeds and contact loads in Pictures 13 to 14.

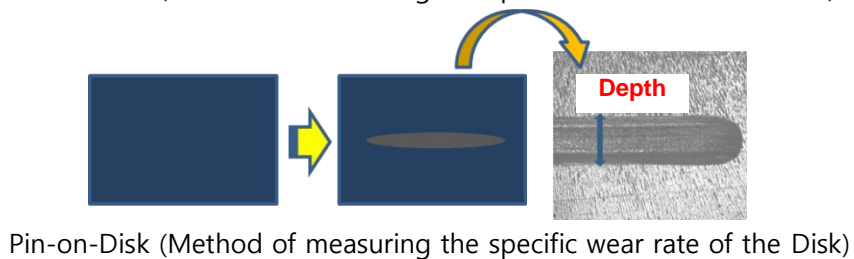
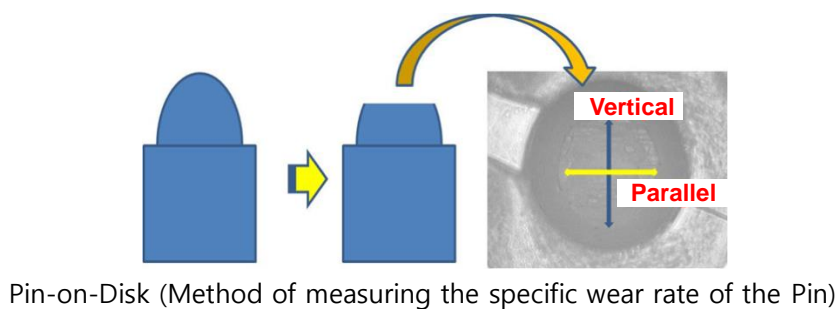


Picture 13. The dynamic friction coefficient of KEPITAL at various moving speeds



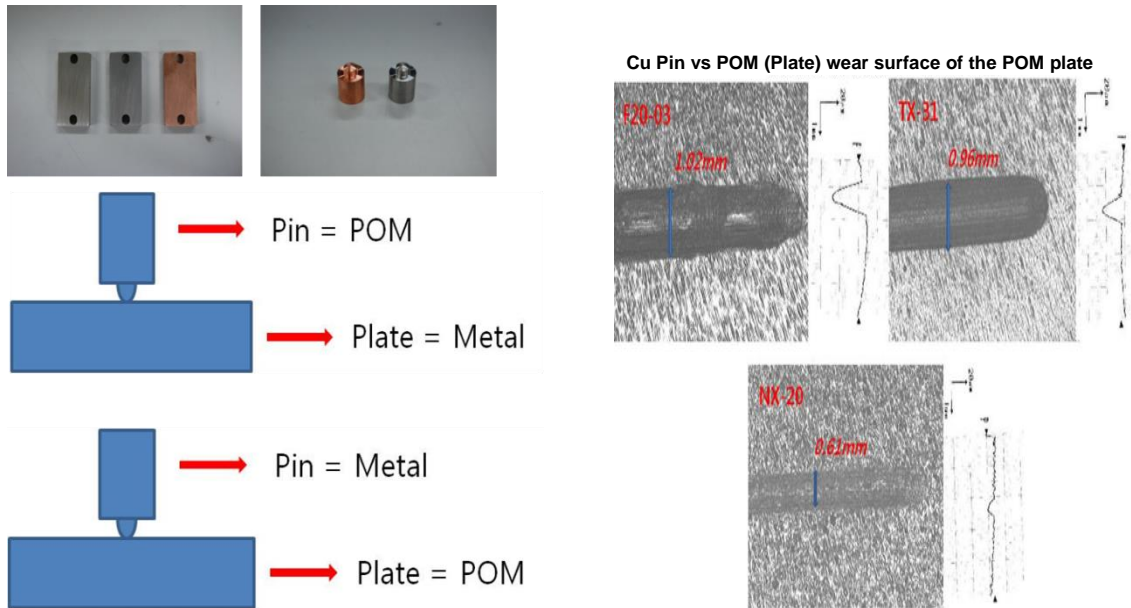
Picture 14. The dynamic friction coefficient of KEPITAL TX-31 at various contact loads

- ① How to measure the specific wear rate (counterpart material : resin)



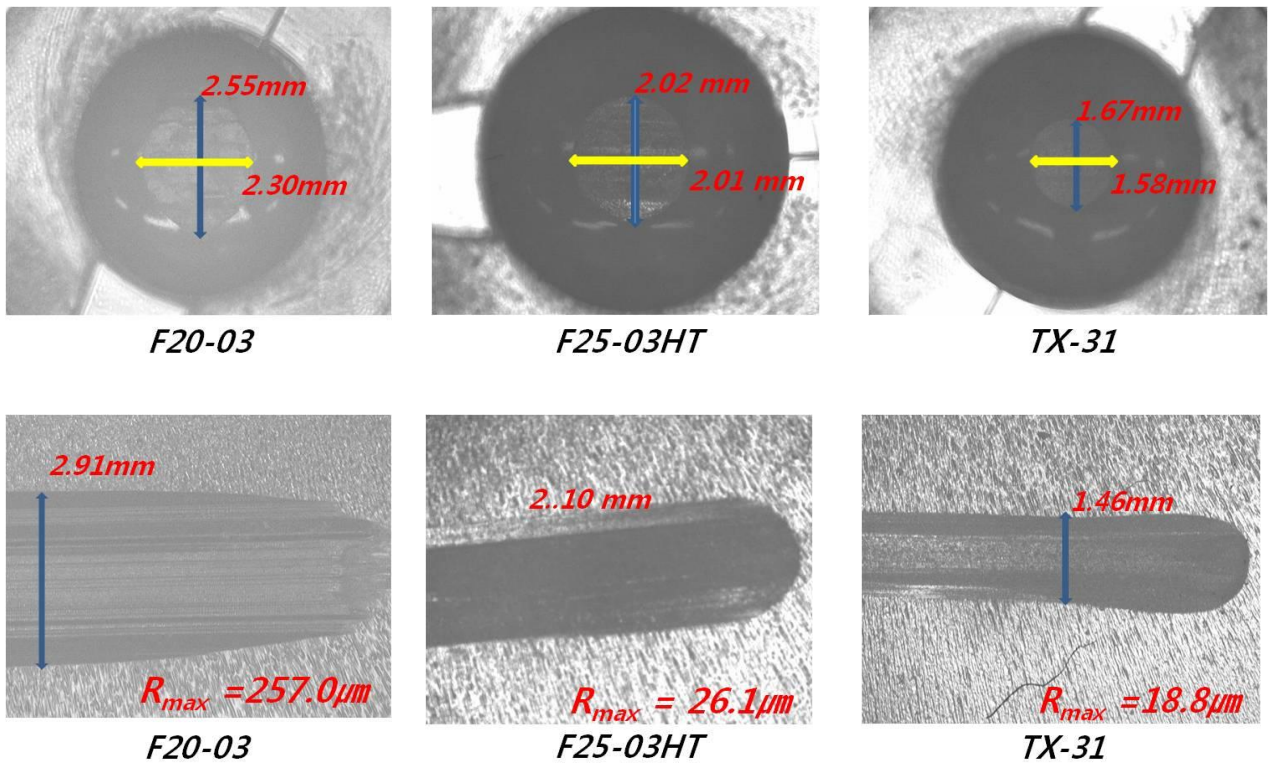
Picture 15. Method of measuring the specific wear rate against resin (Pin-on-Disk)

- ② How to measure the specific wear rate (counterpart material : metal)



Picture 16. Method of measuring the specific wear rate against metal (Pin-on-Disk)

- Metal specimen => Plate : S45C(Steel), SUS(Stainless), Cu(Copper)
Pin : S45C(Steel), Cu(Copper)



Picture 17. The specific wear rate of KEPITAL against resin

Table 1 is a chart that shows tribology characteristics of KEPITAL resistance to friction and wear grades against resin. It is important to select the correct grade with consideration to moving conditions.

Table 1. Tribology characteristics of KEPITAL (counterpart material : resin)

	20 N	40 N	60 N	100 N
100 mm/s	<p>TS-25H(20)</p> <p>TS-25A구(16)</p> <p>NK-20(12) FL2020(12)</p> <p>TX-31(10)</p> <p>CK-20(8)</p> <p>TS-25A산(8)</p> <p>FM2520S(4)</p> <p>F25-03HT(9) TX-11H(3)</p>	<p>TS-25A구(20)</p> <p>TS-25H(16)</p> <p>NK-20(12) CK-20(12) FL2020(12)</p> <p>TX-31(8)</p> <p>TX-11H(6) FM2520S(4)</p> <p>TS-25A산(3)</p> <p>F25-03HT(2)</p>	<p>FL2020(15)</p> <p>TS-25A구(12) TS-25H(12) CK-20(12)</p> <p>NK-20(10)</p> <p>TS-25A산(8) TX-31(8)</p> <p>TX-11H(4)</p> <p>FM2520S(3)</p> <p>F25-03HT(2)</p>	<p>TS-25H(20)</p> <p>NK-20(15)</p> <p>CK-20(12)</p> <p>TX-31(8)</p> <p>FL2020(8)</p> <p>TS-25A산(6)</p> <p>F25-03HT(4) FM2520S(4)</p> <p>TX-11H(2)</p>
300 mm/s	<p>TS-25H(16)</p> <p>TS-25A구(12) NK-20(12)</p> <p>TX-31(8)</p> <p>TS-25A산(8) CK-20(8)</p> <p>FL2020(4)</p> <p>FM2520S(3)</p> <p>F25-03HT(2)</p> <p>TX-11H(1)</p>	<p>TS-25H(20)</p> <p>TS-25A구(12)</p> <p>FM2520S(8)</p> <p>CK-20(8) TX-31(8)</p> <p>FL2020(4)</p> <p>TS-25A산(2) NK-20(2)</p> <p>F25-03HT(1) TX-11H(1)</p>	<p>TS-25H(20)</p> <p>TS-25A구(8) TX-31(8) FM2520S(8)</p>	<p>TS-25H(25)</p>
500 mm/s	<p>TS-25H(12)</p> <p>TS-25A구(6) TX-31(8)</p> <p>CK-20(4) FM2520S(4)</p> <p>NK-20(2)</p> <p>TS-25A산(1) F25-03HT(1) TX-11H(1) FL2020(1)</p>	<p>TS-25H(16)</p> <p>FM2520S(8)</p>	<p>TS-25H(25)</p>	

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