The Friction & Wear Property of DAELIM PLAVIS

1. Friction Properties

The all grade of PLAVIS ® provides an excellent friction behavior in none-lubricating condition.
Temperature, pressure and running velocity all affect the friction coefficient of PLAVIS®.
Typical friction coefficient of various PLAVIS ® composition is shown as table below.

Table 1. Typical friction coefficient and wear rate of PLAVIS ® -MP

Grade	Friction Coefficient	Wear loss(㎛)
Un-filled	0.24	100
15wt% Graphite filled	0.20	8
40wt% Graphite filled	0.14	4

PV= 35.0 kgf/cm^2.1.3m/sec[P(Pressure) ; 27 kgf/cm^2, V(Velocity) ; 1.3 m/sec,
Counter parts material ; S45C
Condition ; None Lubricant

The friction coefficient and wear rate of all PLAVIS ® provide almost the same or superior value compare with temporally predominant commercial POLYIMIDE.
Therefore, PLAVIS ® can be recommended as suitable alternative used none-lubricating condition as example of bushing, bearing, etc.

The friction coefficient of PLAVIS® is affected by load applied, application temperature and velocity. Especially, PLAVIS-G15 ®, which is our representative wear resistance grade shows rapid decline of friction coefficient between 150℃ to 200℃.
And the friction coefficient shows almost same value over 200℃ irrespective of temperature (figure 1). This phenomenon is natural characteristic of materials, which is unrelated wear properties.

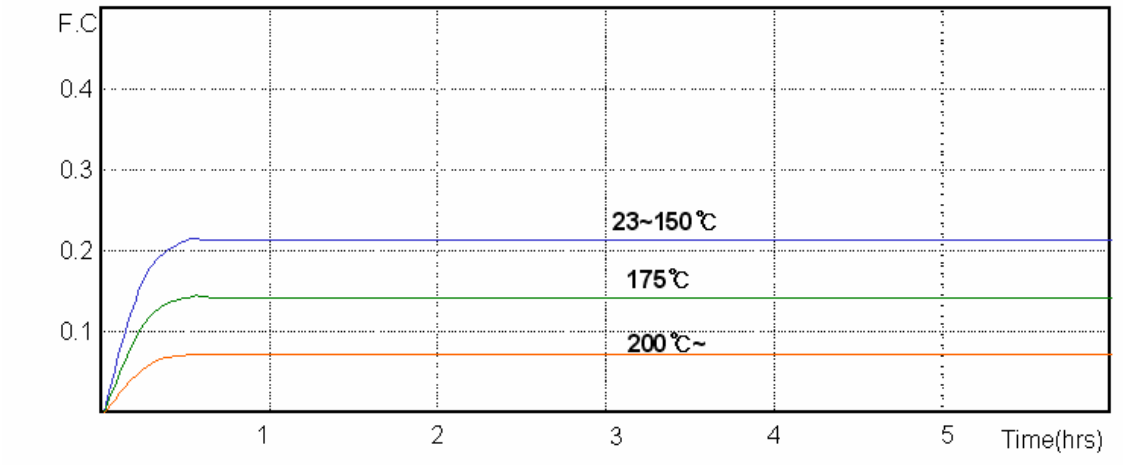


Figure 1. The representative wear pattern of PLAVIS(counter parts ; Carbon steel S45C)

2. Wear Properties

As shown figure below(Figure 3) , PLAVIS achieves primary wear to counter parts materials in a shot time.
After certain time, wear progress shows small changes.
The wear rate depends on the temperature, counter parts materials, surface hardness, roughness and lubricating Condition.

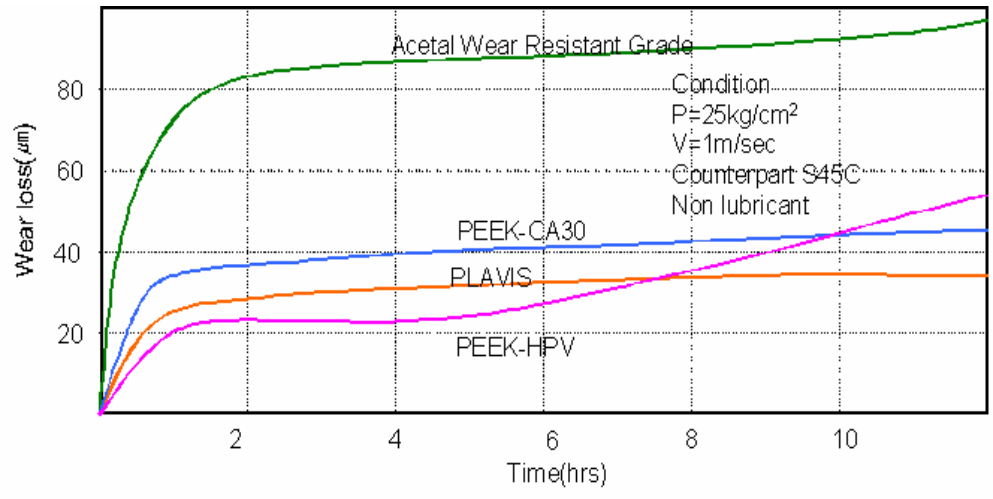


Figure 3. The representative wear pattern of PLAVIS
(counter parts ; Carbon steel S45C)

As the mentioned previous slide, PLAVIS® have typical properties, which would achieve primary wear to counter parts materials in shot time, then shows with very slow wear progress.
Therefore, use of grease at initial running could be effective method for reducing total wear rate.

Wear factor could be expressed following equation.

$K = X / PVT$

K : Wear factor(cm^3·sec/kg·m·hr)
X : the height of wear
P : Pressure(kg/cm2)
V : Operation velocity(m/sec)
T : Time(hr)

Although wear factor K is shown almost same value within a limiting PV, it can be changed by different running condition for example of temperature, kinds of counter parts materials, surface hardness & roughness and etc.
Generally, in case of counter parts are carbon steel, wear rates could be reduced by increasing the hardness and decreasing the roughness of counter parts material surface.
Following figure 4 illustrates the effect of counter part material hardness and finish on wear performance.

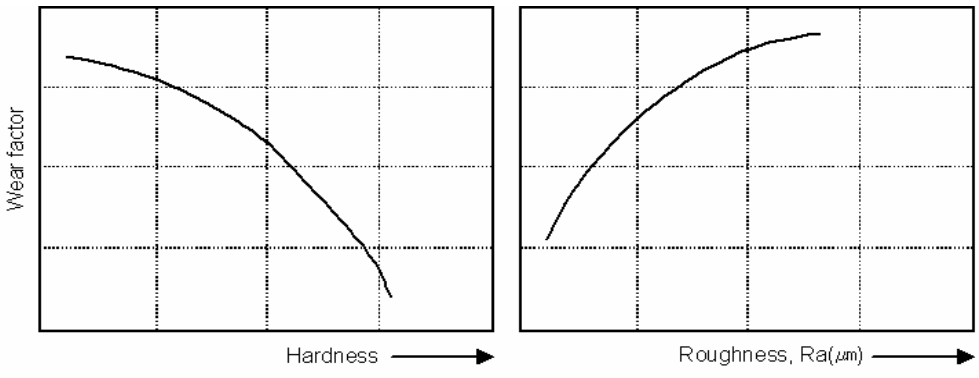


Figure 4. Effect of counter part material hardness, roughness on wear rate.

All grades of PLAVIS ®-MP are shown the smaller wear rate than other's in none-lubricating condition.
Especially, all PLAVIS ® G-grades, which are reinforced with various filler are shown superior Wear resistance to competitor's(figure 5).

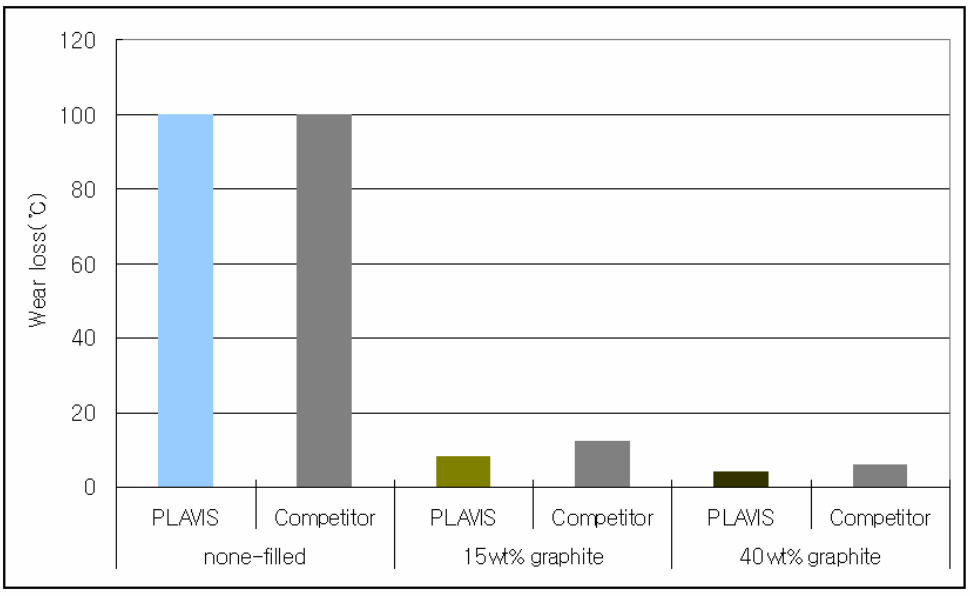


Figure 5. Wear rate of PLAVIS®-MP

PLAVIS ®-DF parts are molded from good powder produced by own unique technology and are molded with hot molding temperature.
Thus, all grades of PLAVIS ®-DF are shown the smaller wear rate than other's in none-lubricating condition (figure 6, figure 7).

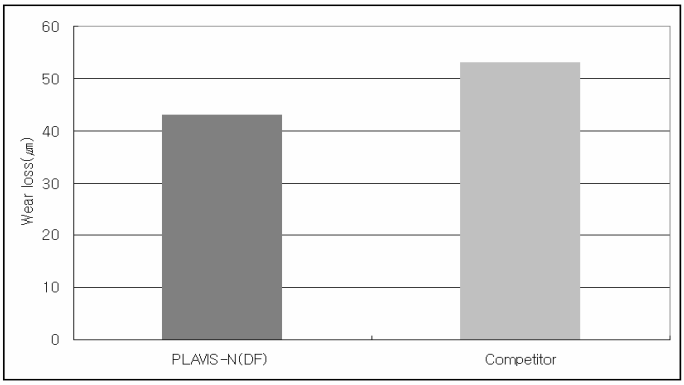


Figure 6. Wear loss DF-parts(un-filled)
- Standard pin on disc method
- PV=13kg/cm^2.m/sec
- Testing time ; 40min
- Counter part ; S45C

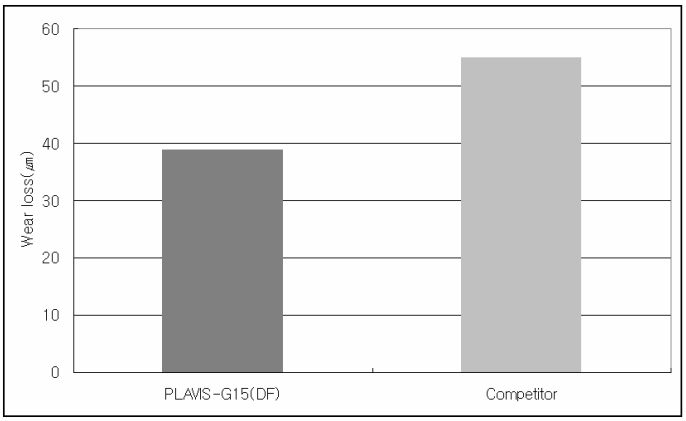
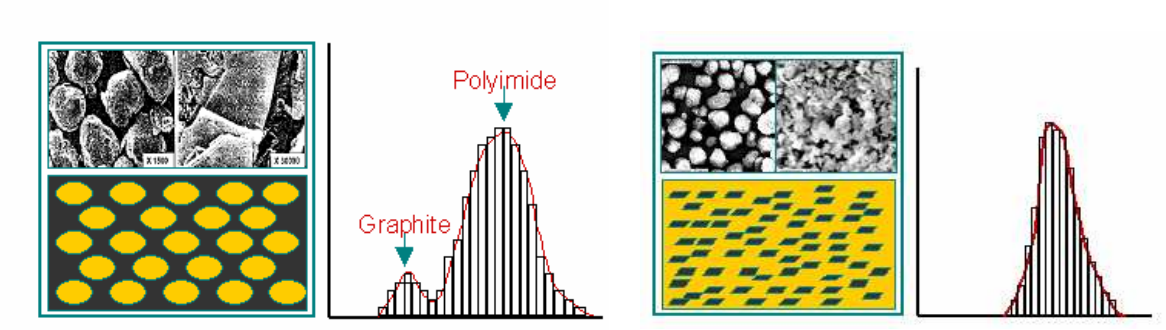


Figure 7. Wear loss DF-parts
(15wt% graphite filed)
- Standard Thrust washer method
- PV=25kg/cm^2.m/sec
- Testing time ; 30min
- Counter part ; S45C

Why do PLAVIS-G grade have excellent friction & wear Properties ?.

As we could see the previous data, PLAVIS® filled with various fillers (PLAVIS® -G grades) have superior friction and wear properties to temporally predominant commercial POLYIMIDE.
Because PLAVIS® -G grades are produced by our unique technology named micro-composition method, PLAVIS® -G grades have excellent friction and wear performance compare with equivalent PI produced by others.
Conventional process to mix PI powder and filler adopted many PI producers. However, with this method, Graphite covers the surface of PI particles that interrupt effective contacting each other (figure 8-a). thus, molded parts show low friction coefficient, but resulted in poor wear resistance and mechanical strength. but, in the micro-composition by in-situ reaction, due to no interruption on PI particles, it brings excellent wear property, and high mechanical strength on molded parts (figure 8-b).



a) **Conventional mixing method**
Graphite covers the surface of PI particle that interrupt effective contacting each other

b) **Micro composition by in-situ reaction**
can't show graphite particles on surface of PI-particles.

Figure 8. Morphologies of POLYIMIDE powder using different mixing method

Generally, POLYIMIDE becomes to reduce their mechanical strength in proportion to be added filler.
PLAVIS® G-grades, which are produced by Daelim's own in-situ micro composition technology shows smaller mechanical properties decline than other's.
So, PLAVIS® G-grades have higher tensile strength compared to the others in the normal and high temperature as we can see the bellow(figure 8).

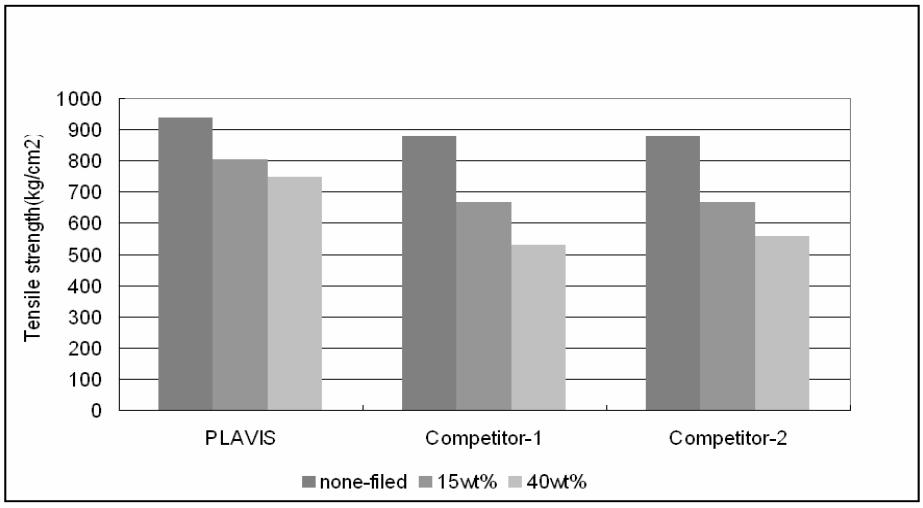
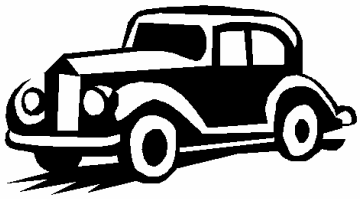


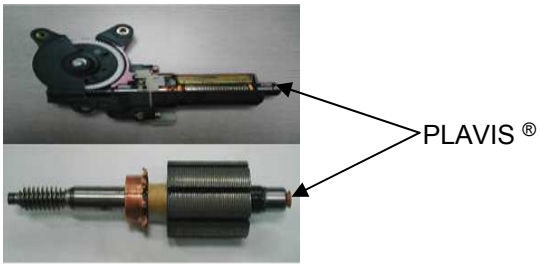
Figure 8. Tensile strength of several POLYIMIDE.

Application Data – the evidence of superior wear resistance

Electrical Motors ;

The excellent wear and friction performance of PLAVIS® have helped electrical motor manufactures to simplify their design while improving performance and life-time.
For example, Parts such as Thrust Plug working in electrical motor have to withstand axial and rotational load coupled with speed.
Because of excellent wear and friction performance of PLAVIS®, many electrical motor companies have adopted our PLAVIS® Thrust Plugs already.





1. The Endurance Test Result by ***customer- "A"***

Test Method ;

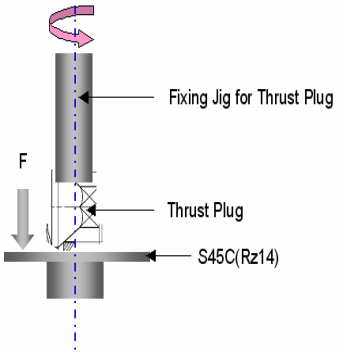
- Test Sample Quantity : 3 pcs/each test
- Test 1 : 5 Cycles with below
  * 1-Cycle = 5Kgf(F) × 1,200rpm × 90min → Pause(10 min) → 10Kgf × 1,200rpm × 60 min → Pause(10 min)
- Test 2 : 5 Cycles with below
  * 1-Cycle = 20Kgf(F) × 300rpm × 30min with temp.100℃ (Steel Plate Temp.) → Pause(10 min)

Requirement ;

1) Check the weight loss after each test
2) Check the length wear loss after each test

Test Result ;

PLAVIS®-N thrust plug shown the superior performance to competitor's currently used by Customer A (figure 9).



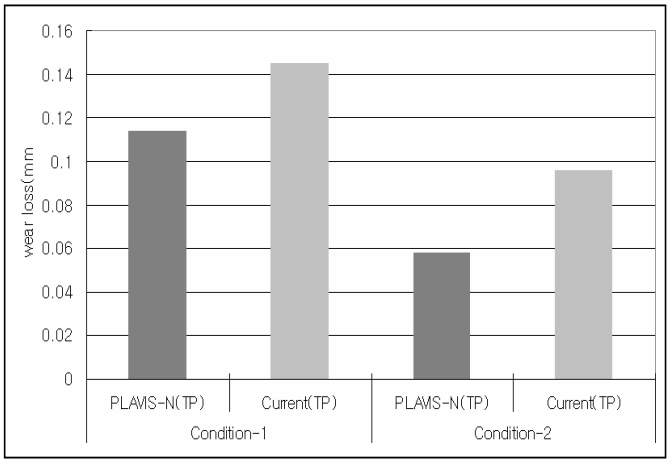


Figure 9. Specimen installation & wear loss for each test.

2. The Endurance Test Result by ***Customer – "B"***

There are several kinds of motor in auto-mobile. Window shift motor, wiper motor and sear adjust motor etc.This test carried out to evaluate thrust plug performance for seat adjust motor used more severe condition than other.
PLAVIS Thrust plug passed three kinds of testing method
(figure10, figure 11, figure 12).

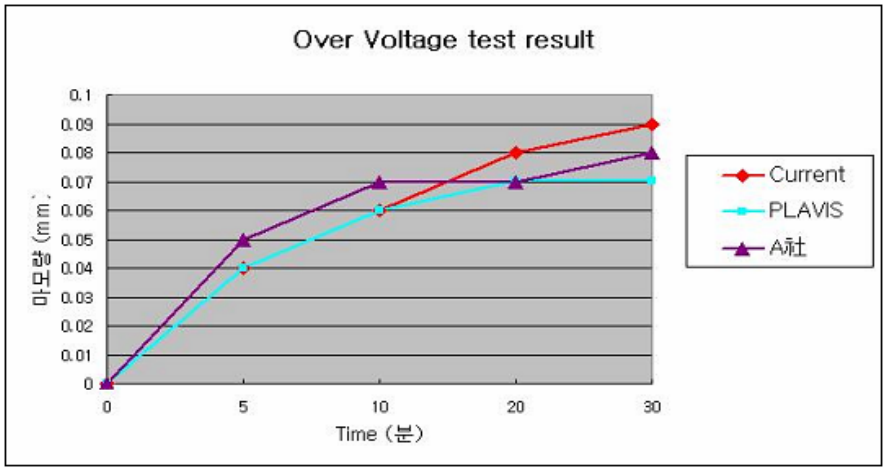


Figure 10. Over voltage test result.

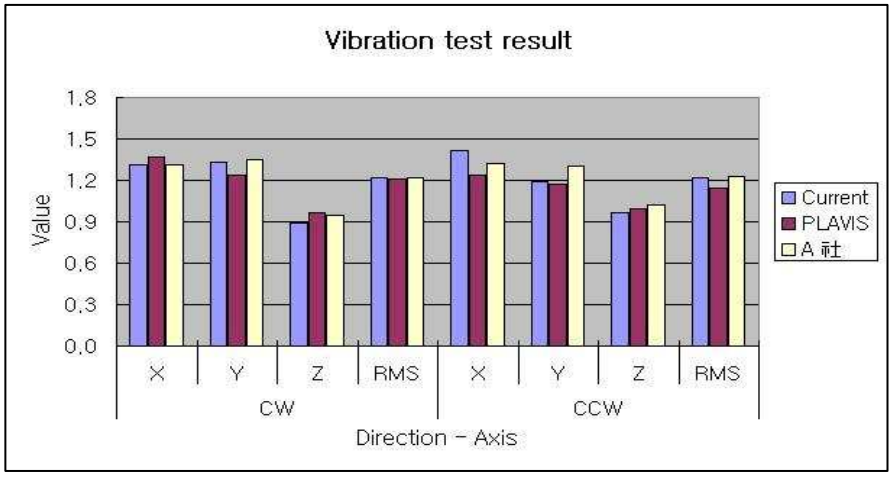


Figure 11. Vibration test result

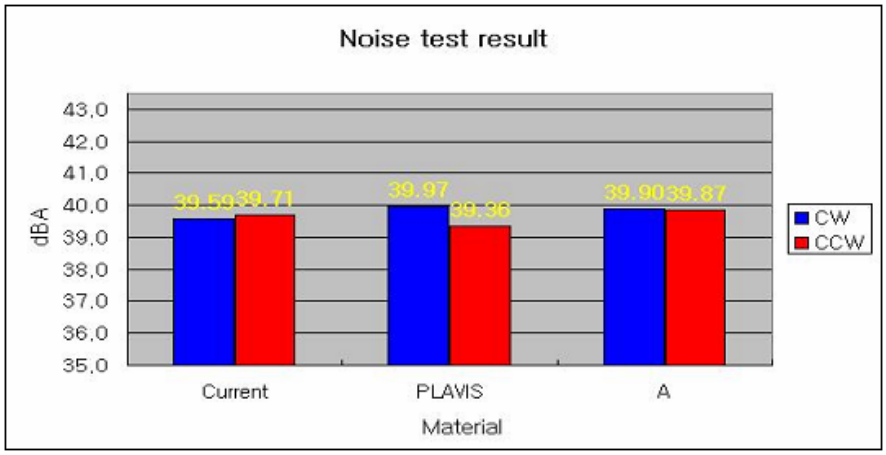
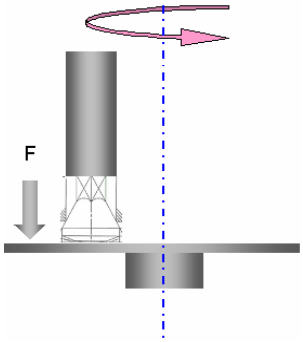
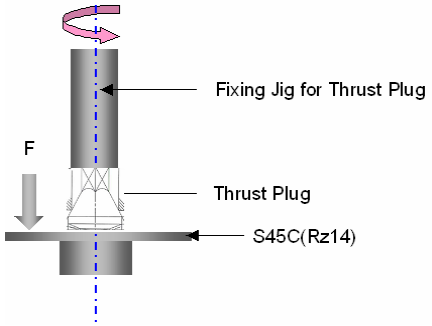


Figure 12. Noise test result

3. The Endurance Test Result by *Customer – "C"*





Test Condition of TEST-1
Test Type : Pin-on-Disc(One-Pin) Type
Load : 3 Kg
Velocity : 1.0 m/sec
Test Duration : 30min
Track Diameter : 23mm(rpm 1,246)
Test Temperature : 25℃
Condition : Non-lubricant

Test Condition of TEST-2
Load : 10kg ~ 40kg(Hold for 5min at each load)
Rotation Speed : 1,000 rpm
Test Duration : 20min (Hold for 5min at each load)
Test Temperature : 25℃
Condition : Non-lubricant

DAELIM Thrust Plug show the same performance at the low and high testing load(table 2). Friction and Wear properties are exactly the same at the low testing load condition but, at the high DAELIM TP was slightly superior to current TP of Customer-"C" (table 3, figure 13). From this point of view, we come to the conclusion that DAELIM TP is more stable than current TP of Customer-"C" at the severe operating condition.

Table 2. Result of Test-1

Test Sample	Friction Coefficient	Wear loss-1(㎛)	Wear Loss(㎎)
DAELIM	0.18(0.175)	0.3	50
Current used	0.18(0.181)	0.3	50

Table 3. Result of Test-2

Load(KG)	PLAVIS	Current
10	0.020	0.026
20	0.067	0.075
30	0.140	0.153
40	0.221	0.242
Wear Loss(㎎)	0.67	0.76
Wear Loss(㎛)	76	87

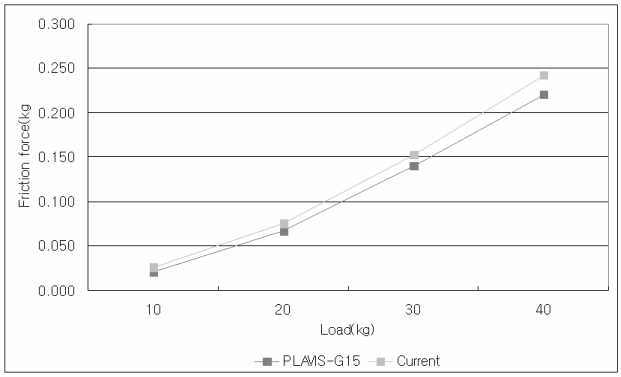


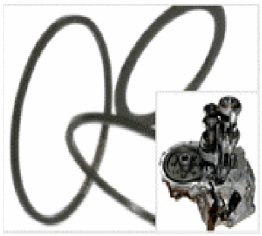
Figure 13. Change of friction force at high load

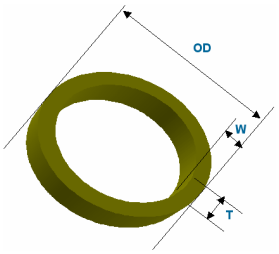
Application Data – the evidence of excellent Limiting PV-Value

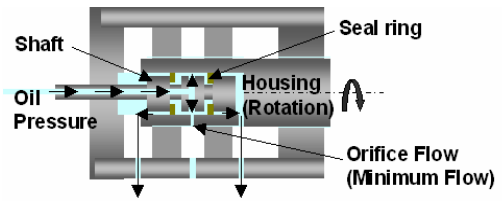
Seal ring for Hydraulic unit such as automatic gear box, oil pump, etc.:

In the last few decade automatic transmission have rapidly replacement manual gear box in car. Fuel saving, smooth shift quality related comfort driving, etc are important issues in the automotive Industry.
There are important considerations such as oil leakage control, sealing, vibration, high load and rotating speed, high temperatures generated by friction, durability in design of hydraulic unit such as auto-transmission gear box.

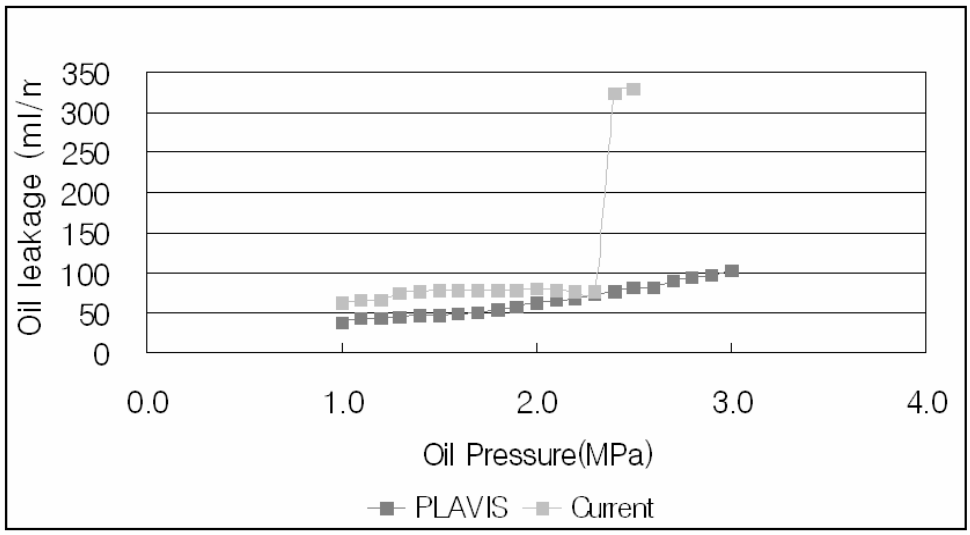
So, PLAVIS® Seal ring having high performance friction and wear resistance in addition excellent mechanical properties and thermal resistance will be powerful alternative.







Seal ring used oil hydraulic unit especially auto transmission have to pass relative severe performance test.
This strict test consist of 11-kinds of tests such as high pressure resistance test, rotating friction test, oil leakage test, contaminant test, limiting PV test, creep test, heat cycle test, dry test and so on.
In the above strict test items, Limiting PV Test related wear-resistance property play an important role to estimate durability of seal ring(figure 14).



Oil Pressure(MPa)	1.0 ~3Mpa
Speed(rpm)	7,500
Temperature(℃)	150
Oil	Dexlon III
# Sample	N=2

Figure 14. Oil leak during elevation of oil pressure.

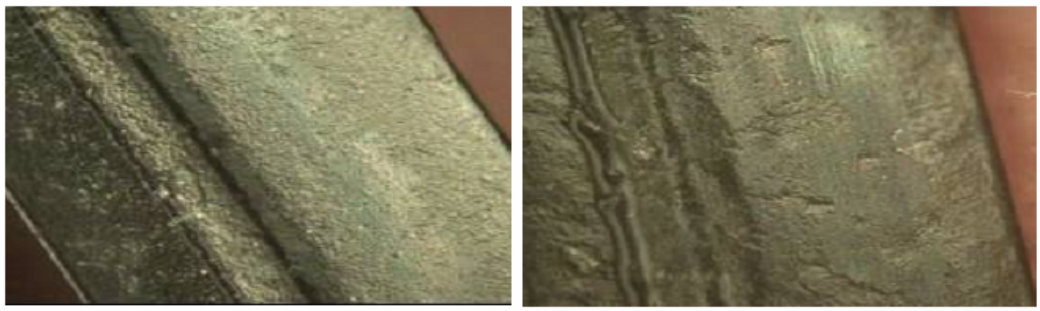


Figure 15. Sealing surface after limiting PV test.

At the high PV(about 2.3 Mpa), Current POLYIMIDE Seal ring shows rapid increase of oil leakage, and found a lot of defect on its surface(figure 15).

In case of PLAVIS® G-15 seal ring, there was no rapid increase of oil leakage and no defect of its surface.

Application Data – PLAVIS®-N is suitable for 10 CLASS.

Ball Transfer ;

Ball transfer used FPD industry such as LCD glass panel manufacturing need to be less than 10units of 0.3㎛ particle and mark as 10 CLASS.
The excellent friction & wear performance of PLAVIS® verified by actual test which was carried out ATEC.

Test Condition ;
Test speed : 300mm/sec
Time : 10 hrs
Running distance : 18km
Load : 1.5 kgf

Test Method ;

- Measuring particle count of 0.3㎛, 0.5㎛ in test chamber before running the test.
- Measure 0.3㎛, 0.5㎛ particle by each of 1hr(running with uniform speed)
- After measuring particles each hour, then remove all particles inside of vacuum.
- Re-measuring the particles by each hour.

Test Result ; PASS(figure 16)

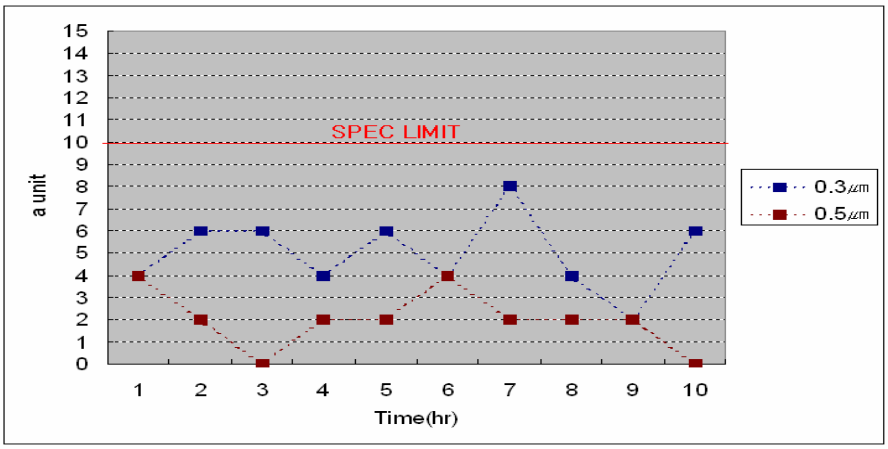


Figure 16. Particle count on running