Heat Resistant Acrylic Rubber L6070

1. Introduction

For automobiles, many rubber products are used as important functional parts, such as oil seals, belts, hoses, packing, O-rings, and diaphragms. This is because of the unique properties of rubber materials that cannot be replaced by other materials, such as ①large deformation capability, ②flexibility and ③good damping characteristics[1].

In recent years, the demand for sealing materials has been increasingly growing for applications used in the engine periphery of automobiles as they are used in ever harsher environments. Such environments include not only oil and fluid resistance but also maintenance-free long-life characteristics, space saving in the engine compartment, heat resistance required by higher performance and higher output, and others. Table1 shows the seal parts and materials used in various types of oil.

Table1 Oil and fluid resistant rubber parts for automobiles[2]

Oil classification	Part name	Material used
Engine oil	Crank oil seal	VMQ、FKM
	Cam oil seal	VMQ
	Valve stem seal	FKM
	Oil pan packing	NBR、ACM
	Head cover packing	NBR、ACM
	Oil cooler hose	NBR、ACM
	O-rings	NBR、ACM
ATF mission Oil	Transmission oil seal	ACM、VMQ
	Oil cooler hose	NBR、ACM
	O-ring and packing	NBR、ACM
PSF	Power stay hose	NBR
	Rack end seal	U、NBR
	Oil pump oil seal	NBR
	O-ring and packing	NBR
Fuel	Fuel hose	NBR
	Evapo hose	NBR
	Fuel pump diaphragm	NBR
	Check valves	NBR、FKM
	High pressure fuel hose	NBR、FKM
	Regulator diaphragm	NBR、FKM
	Injector seal	FKM
	O-ring and packing	NBR、FKM
Coolant	Radiator hose	EPDM
Brake fluid	Heater hose	EPDM
Etc.	Brake hose	NR、SBR、CR
	Master cylinder cup	SBR
	Wheel cylinder cup	SBR
	Caliper seal	EPDM

Acrylic rubber is positioned as the third rubber material following fluororubber and silicone rubber for applications that require both oil resistance and heat resistance. Figure1 shows the positioning of oil resistance and heat resistance of various rubber materials.

Acrylonitrile butadiene rubber, which has been widely used as an oil-resistant rubber, lacks heat resistance for automotive applications which are becoming increasingly sophisticated in performance. Also, fluororubber has been increasingly replaced by acrylic rubber due to price issues balancing performance and costs.

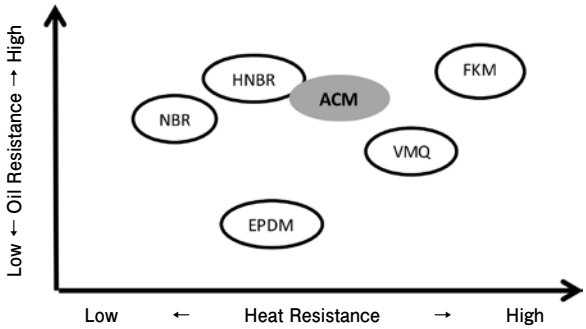


Figure1 Oil resistance and heat resistance of various rubber materials

2. Characteristics of L6070

Acrylic rubber is a copolymer composed mainly of acrylic acid ester, and its ASTM abbreviation is ACM. The chemical structure of acrylic rubber is shown in Figure2.

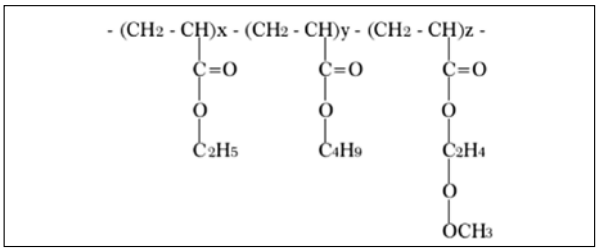
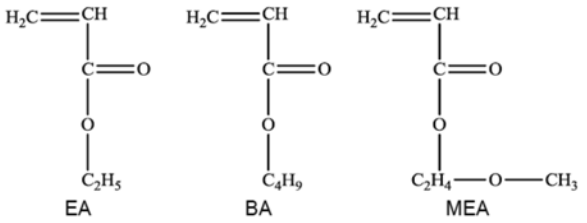


Figure2 Chemical structure of acrylic rubber

The characteristics of acrylic rubber differs depending on the combination of three types of monomers with different side chains (ethyl acrylate: EA, butyl acrylate: BA, and 2-methoxyethyl acrylate: MEA). The chemical structures of the main component monomer species and their characteristics are shown in Figure3[3].



	Heat resistance	Oil resistance	Cold resistance
EA	◎	○	△
BA	○	△	◎
MEA	△	◎	○

◎ : Excellent ○ : Good △ : Inferior

Figure3 Chemical structures and characteristics of acrylic rubber monomers

Since the main chain of acrylic rubber consists only of saturated bonds, it is necessary to introduce functional groups with crosslinking points. Table2 summarizes the characteristics of acrylic rubber according to the differences in cure sites.

Table2 Types and characteristics of functional groups at various cure sites[3]

Cure site	Cure rate	Processability	Storage stability	Compression set	Heat resistance
active chlorine group	○	×	△	○	○
Epoxy group	×	○	○	○	○
Carboxyl group	○	○	○	○	○

Due to its characteristics, acrylic rubber has been used for oil seals and hoses in the engine periphery of automobiles. Our existing acrylic rubber L1270 has also been used as oil seals and gaskets in many engine periphery applications, but it is becoming more difficult for it to meet specifications under the high temperature environment near the engine in recent years.

By utilizing our unique compound design technology that we have cultivated over the years, we have developed L6070 acrylic rubber, which has improved heat resistance while maintaining the oil resistance of acrylic rubber. The various characteristics of the developed material L6070 and the conventional material L1270 are described below.

2-1) Compression set properties

As an index of the heat resistance of sealing materials, the compression set is used. Under the same environment, the lower the compression set is, the longer the use you can expect as a quality sealing material.

The method of measuring and calculating the compression set is shown in Figure4[4].

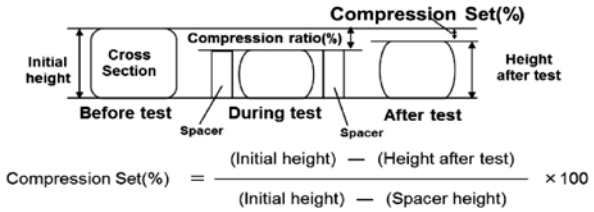


Figure4 Method of measuring and calculating compression set

In general, the compression set of 80% is used as the life expectancy of materials used for sealing materials [5].

In this report, in order to calculate the seal life and the time to reach the compression set of 80% under the environment of 150 ℃ which is required for seals used in the engine periphery, the compression sets of L6070 and L1270 are plotted to calculate the time to reach the compression set of 80% from the approximate equation.

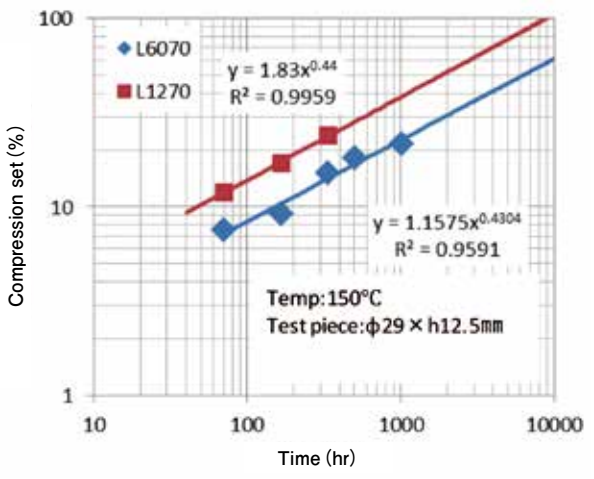


Figure5 Compression set at 150℃ in Air

Table3 Time at compression set of 80% at 150℃

Rubber Code	Approximate expression	Time at compression set of 80%
L6070	$y=1.1575x^{0.4304}$	1.88×10^{4}
L1270	$y=1.83x^{0.44}$	5.35×10^{3}

Calculated from an approximate equation, the time to reach the compression set of 80% in air at 150 ℃ is 1.88×10^{4} hours for L6070 and 5.35×10^{3} hours for L1270. This indicates that the life of L6070 is expected to be more than 3.5 times longer.

L6070 has good compression set properties even in a high temperature environment of 150 ℃ or higher. When evaluated under the same test time, the compression set of L6070 and that of L1270 are equivalent, respectively 170 ℃ and 150 ℃, which means that an increase in service temperature can be expected. The results of the compression set test under high temperature environments are shown in Figure6.

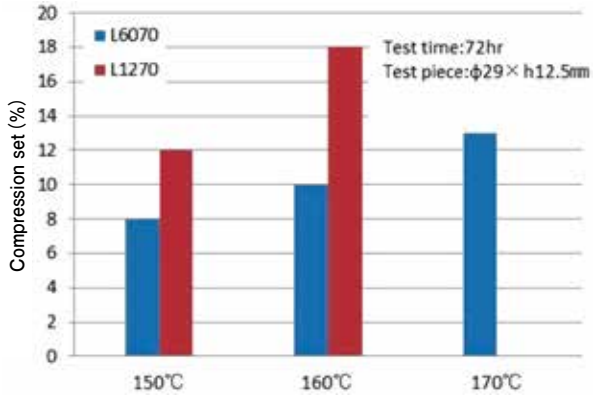


Figure6 Temperature dependency of compression set

2-2) Engine oil resistance properties

Automotive engine oil is classified by standards each for its quality and viscosity. Each standard is shown in Table4.

Table4 Classification of engine oil

Type of standard	Standard name	Description
Quality standard	API : American Petroleum Institute	Performance classification standards for internationally used engine oils
	ILSAC : International Lubricant Standardization and Approval Committee	Standards that require more fuel-efficient performance than API
Viscosity standard	SAE:Society of Automotive Engineers	Standards for classifying oil viscosity

The API standard is a standard to classify quality, setting the fuel efficiency, heat resistance, and wear resistance of engine oil. It had classifications from SA to SP, but some of them have been abolished by 2020. ILSAC is a standard that requires additional fuel efficiency and classifies the SH to SP classifications of API into GF-1 to GF-6. Table5 shows the quality classification of automotive engine oil [6), 7)].

Table5 API standard and ILSAC standard

API standard	ILSAC standard	Performance
SA		Low ↑ Performance ↓ High
SB		
SC		
SD		
SE		
SF		
SG		
SH	GF-1	
SJ	GF-2	
SL	GF-3	
SM	GF-4	
SN	GF-5	
SNPlus		
SP	GF-6	

As for the SAE standard for classifying viscosity, the SAE J300 standard established by SAE is used. For example, in the case that it is noted as 5W-30, the notation on the left side indicates viscosity at low temperatures while the notation on the right side indicates viscosity at high temperatures. Both indicate that the higher the number is, the harder the engine oil becomes. Table6 shows the viscosity classification of automotive engine oil[8)].

For the evaluation of engine oil resistance properties, the following standards were used from the viewpoint of availability: API: SN/CF (for simultaneous use of both gasoline and diesel vehicles), ILSAC: GF-5 (fuel efficiency, exhaust gas purification, oil degradation prevention, heat resistance and wear resistance) and SAE: 5W-30 (usable even at −30℃ outside temperature + medium viscosity at high temperature).

The change of volume of both L6070 and L1270 after the immersion test at 150℃ for 70 hours was small (less than 10%), confirming that both materials were resistant. Figure7 shows the change of volume of both materials after the immersion test.

Table6 SAE J300

SAE viscosity grade	Low temperature viscosity		High temperature viscosity		
	CCS viscosity (cP) / temperature (℃)	Pumping viscosity (cP) /temperature (℃)	Kinematic viscosity (cSt) (100℃)		Viscosity at high shear (cP) (150℃、106S-1min.)
			Minimum	Maximun	
0W	6,200/−35	60,000/−40	3.8	—	—
5W	6,600/−30	60,000/−35	3.8	—	—
10W	7,000/−25	60,000/−30	4.1	—	—
15W	7,000/−20	60,000/−25	5.6	—	—
20W	9,500/−15	60,000/−20	5.6	—	—
25W	13,000/−10	60,000/−15	9.3	—	—
8	—	—	4	<6.1	1.7
12	—	—	5	<7.1	2.0
16	—	—	6.1	<8.2	2.3
20	—	—	6.9	<9.3	2.6
30	—	—	9.3	<12.5	2.9
40	—	—	12.5	<16.3	3.5 (0W-40, 5W-40, 10W-40)
40	—	—	12.5	<16.3	3.7 (15W-40, 20W-40, 25W-40, 40monograde)
50	—	—	16.3	<21.9	3.7
60	—	—	21.9	<26.1	3.7

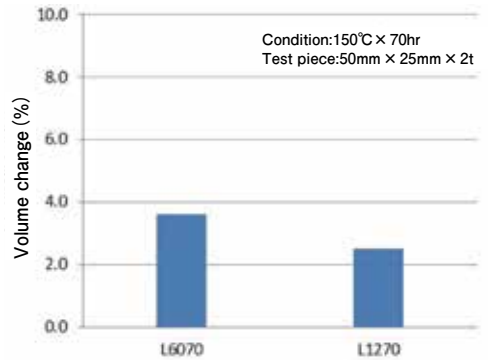


Figure7 Change of volume after gasoline oil immersion test

2-3) Low temperature properties

The low-temperature properties were confirmed by the temperature restraction test (TR test). L6070 showed the same TR10 value as L1270, and it was confirmed to have the low-temperature properties that can be used as a sealing material in the engine periphery. Table7 shows the TR values for L6070 and L1270.

Table7 Comparison of TR values

	L6070	L1270
TR10 (℃)	−21.5	−20.7
TR30 (℃)	−16.5	−16.1
TR50 (℃)	−12.9	−12.9
TR70 (℃)	−8.7	−9.3

2-4) Product shape

Since acrylic rubber L6070 has the same level of processability as that of general synthetic rubber, it can be used to manufacture various cross-sectional shapes and large-diameter products such as O-ring (VALQUA No. 640), V-packing (VALQUA No. 2631), and X-ring (VALQUA No. 641).

2-5) Mechanical properties

The results of physical properties and various durability tests of L6070 and L1270 are shown in Table8.

Table8 Comparison of physical properties

Characteristic		Test method	Unit	L6070	L1270
Hardness		JIS K 6253	SHORE A	71	72
Tensile strength		JIS K 6251	MPa	11.8	11.0
Elongation			%	250	190
Heat resistance	Compression set factor 25% compression φ29×h12.5	JIS K 6262 150℃ x70h	%	7	12
	Change of hardness	JIS K 6257 150℃ x70h	POINT	+1	+2
	Change of tensile strength		%	−3	+3
	Change of elongation		%	−6	−3
Oil resistance	Change of hardness	JIS K 6258 SN/CF, GF−5 5W−30 oil 150℃ x70h	POINT	−4	±0
	Change of tensile strength		%	+1	−6
	Change of elongation		%	−6	−12
	Change of volume		%	+3.6	+2.5
Low-temperature properties	TR10 value	JIS K 6261	℃	−21.5	−20.7

※These are measured values, not standard values

3. Applications

The newly developed acrylic rubber L6070 is expected to be applied to the automotive market (especially engine periphery).

※Oil filter gaskets (automobiles, construction machinery, agricultural machinery, etc.) head cover gaskets, oil seals, oil pump gaskets, etc.

4. Conclusion

The acrylic rubber L6070 introduced here is a material with upgraded heat resistance properties while maintaining the same level of oil resistance as that of conventional materials. In automotive applications, there is a trend where the operating environment is becoming hotter and hotter and thus seal materials are required to have high heat resistance. We believe that this new material can handle the environment adequately. In addition, the quality standard for engine oil was revised in October 2020. Since this revision has introduced stricter standards for the environment and oil performance has been improved, it is expected that the requirements for sealing products are also going to change. We, as a seal manufacturer, will continue to strive to develop new materials and improve existing materials by quickly capturing the latest trends in the market in order to meet the demands of our users.

5. References

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