



Development of a PAG type Base Material for Water-soluble Metalworking Oils

Which Achieves Both Lubricity and Low Foaming Property

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Introduction

“Metalworking oil” is a product that is indispensable for machining of metal parts in the automotive industry and in the machine manufacturing industry. It has long been used to improve the accuracy of processed products, reduce tool damage, improve productivity, etc., and has played a major role in the development of the industry. As the necessity for advances in required performance and environmental measures became prominent, the demand for high-function and high-value-added products has increased. This article provides an outline of metalworking and metalworking oils, and introduces our company’s existing product family as well as “UTILIOL GA-15P,” a newly developed water-soluble polyalkylene glycol (PAG) type base material for lubricant oils with both lubricity and low foaming property.

1. Metalworking and metalworking oils

1-1 Lubricating function and its importance in metalworking
Metalworking refers to the technology to work metallic materials into the desired shapes. Metalworking is roughly divided into “cutting,” “grinding” and “plastic working.” Strong friction occurs in metalworking due to contact between the metal and tool, and causes heat generation

and damage. One of the approaches for reducing this friction is through the lubricating function (lubricity). It is an essential function in metalworking during manufacture of components and parts of automobiles, machines, etc. Its advantages include improving the lifetime of tools through damage prevention and reducing the defect ratio in products, in addition to suppressing heat generation through addition of lubricity. Metalworking oils also have other features such as cooling property, permeability, rust prevention, degradation resistance, emulsification/dispersibility, and viscosity index improving property, and are selected according to the type of metal to be processed and the method of metalworking.

1-2 Types and features of metalworking oils

Metalworking oils are roughly divided into water-insoluble types, which are mainly made of base oils such as mineral oil; and water-soluble types, which are made of water mixed with base material for lubricating oils. In general, the water-insoluble types excel in lubricity, while water-soluble types excel in cooling property. By itself, the “base oil,” which accounts for approximately 80% of a water-insoluble metalworking oil, has a poorer lubricity than

the PAG type base materials for lubricating oils. Lubricity is improved by adding “extreme pressure additives,” “friction reducers,” etc. Water-soluble metalworking oil consists of a “base material for lubricating oil” and “water,” which have the lubricating function; “surfactants” for expressing dispersibility solubilization, etc.; and “additives” such as antirust agents and preservatives. The concentrated solution comprising of these is diluted with water to approximately 10- to 50-fold at the metalworking manufacturer before use. Sanyo Chemical Industries offers a range of PAG type base materials for lubricating oils and additives for water-insoluble and water-soluble metalworking oils. [Table 1] and [Table 2] show their typical examples.

1-3 Trends in metalworking oils

While water-insoluble metalworking oils have been used for metal processing since long ago, water-soluble metalworking oils have become more popular in recent years, mainly in general cutting of non-ferrous metals, steel, etc. The increased popularity is due to various factors including environmental measures, improvement in working environments to prevent oil and mist generation, increased processing accuracy through more efficient cooling during high speed processing, and improvement in

efficiency of the washing process after metalworking. In particular, market demand for “solution types,” which are transparent metalworking oils that do not contain any base oil, is growing as it is easy to visually check the processed section in addition to environmental consideration.

2. PAGs used in metalworking oils

2-1 PAGs and their applications

A PAG is a compound made by addition polymerization of a compound containing active hydrogen such as a low grade alcohol (hereinafter referred to as the starting material) with an alkylene oxide (AO) such as ethylene oxide and propylene oxide.

PAGs with various performances can be synthesized to suit the

application by varying the structure of the starting material, the type of AO to be added, the degree of addition polymerization, and the ratio or method of addition in cases where two or more different types of AO are added. While PAGs are used as base materials for lubricating oils as they excel in lubricity, they are also used as additives to metalworking oils as they increase functionality such as emulsification, solubilization, and permeation when they function as surfactants. They are also used in a wide range of lubricating applications in addition to metalworking applications to utilize their features [Table 3].

2-2 PAG type base materials for lubricating oils
While the shift to water-soluble

metalworking oils advances, base materials that function as the lubricant in lubricating oils which are becoming more essential to the water-soluble metalworking oils; a representative example of these is the “PAG type base materials for lubricating oils.” Their features include [1] Excellent lubricity, [2] Viscosity characteristics (high viscosity index, easy molecular weight control), [3] Control of solubility in water (ability to adjust the hydrophilicity-hydrophobicity ratio), and [4] Excellent low temperature fluidity. Contrariwise, their disadvantages include [1] Poor solubility in hydrocarbons such as mineral oil, [2] Poor oxidation and heat stability, [3] Hygroscopic property, and [4] Possibility of causing

Table 1 PAG type base materials for lubricating oils that are used in metalworking oils

Application	Name of product	Property	Composition, etc.	Features
PAG type base materials for lubricating oils	[Developed product] UTILIOL GA-15P	Water-soluble	•Not disclosed	Water-soluble base material for metalworking oils which achieves both lubricity and low foaming property. Expectations are high for life elongation of tools with excellent last non-seizure load (lubricity). For example, it is expected to realize tap machining on aluminum with solution type.
	BLEMBER Series	Water-soluble	•Not disclosed	BLEMBER LUB-90 is a water-soluble base material for metalworking oils with excellent lubricity. BLEMBER LUB-65 and LUB-82 have excellent low foaming property.
	NEWPOL 75H-90000	Water-soluble	•Polyoxyethylene polyoxypropylene hexylene glycol ether	Water-soluble base material for metalworking oils with high molecular weight. Also possible to impart mold release properties.
	NEWPOL 50HB Series	Water-soluble	•Polyoxyethylene polyoxypropylene butyl ether	General-purpose water-soluble base material for metalworking oils.
	NEWPOL LB Series	Water-insoluble	•Polyoxypropylene butyl ether	It can impart defoaming and mold release properties. It can also be used in water-insoluble metalworking oils.
	NEWPOL PE Series	Water-soluble - water-insoluble	•Polyoxyethylene polyoxypropylene glycol	A general-purpose pluronic surfactant with a lineup of variety of products depending on the hydrophilic-hydrophobic balance and molecular weight. Suited as a base material for metalworking oils and cleaning agents for machines and metal parts.

Table 2 Additives used in metalworking oils

Application	Name of product	Property	Composition, etc.	Features
Antirust agent	SANHIBITOR Series	Water-soluble/oil-soluble	•Anionic surfactant •Alkenyl succinic acid type	An adsorption coating type organic antirust agent.
Emulsifier Dispersant Degreasing agent	IONET Series	Water-soluble/oil-soluble	•Sorbitan fatty acid ester •Polyoxyethylene sorbitan fatty acid ester	Suited as an emulsifier and dispersant. IONET S Series also has defoaming properties.
	EMULMIN Series NAROACTY Series	Water-soluble	•Polyoxyalkylene alkyl ether	Suited as an emulsifier and dispersant. It is also suited as a base material for cleaning agents.
	SEDORAN Series	Water-soluble	•Polyoxyalkylene alkyl ether	Suited for degreasing treatment before coating, and as a cleaning agent for machines and metal parts. High cleansing power and excellent low foaming property.

Please contact our company's sales representative when handling our company products. Also be sure to read the “Safety Data Sheet” (SDS) before use. It is the responsibility of the user to determine the suitability and safety of the product for the intended application.

paint, etc. to peel (surface active performance and permeability), and necessary measures must be taken before using based on these properties.

3. Water-soluble PAG type base material for metalworking oils which achieves both lubricity and low foaming property

3-1 Concept for new development Water-soluble metalworking oils pose a low risk of fire and have excellent cooling properties; demands are growing due to perspectives on work environment improvements and reduction of environmental loads. There is increasing demand for higher lubricity in water-soluble metalworking oils as further speedup, higher precision, and

longer lives of tools are desired in metalworking in concurrence with the evolution of metalworking technology. Additionally, the target metals for processing include not only iron-based materials but also high-hardness materials that are difficult to process and materials with high ductility. It is essential to improve the lubricity in order to process these hard-to-cut materials with high precision and high productivity. On the other hand, foaming tends to occur more easily in metalworking oils with the conventional PAG type base materials for lubricating oils when the lubricity is improved. This leads to concerns about defects such as decrease in cooling property and lubricity at the high speed processing parts

and overflow from a circulating tank. In other words, low foaming property is also considered to be an important feature of the base materials. “Lubricity” and “low foaming property” are generally in a trade-off relationship in terms of the structural design. To achieve both, we used our proprietary interface control technology and the molecular design and manufacturing technology for PAGs to develop “UTILIOL GA-15P.” Since the developed product is readily soluble in water and has a high clouding point, the metalworking oil diluted with water is highly transparent and exhibits not only low foaming property but also excellent lubricity. Although it is a solution type base material, “UTILIOL GA-15P” can be used to process lightweight metal “aluminum,” whose market is expected to grow markedly in the future, and it is expected to contribute to a wide range of metal species and processing methods [Table 4].

3-2 Last non-seizure load and foam breaking rate The feature of “UTILIOL GA-15P” is that it achieves both “lubricity” and “low foam property.” The results of the expression of each function that was evaluated using a simple model composition for metalworking oil are described below.

While there are various reports on how to assess lubricity in metalworking oils, we used an oscillation friction and wear testing system (manufactured by Optimal Instruments Prueftechnik) to measure the last non-seizure load when the load between the oscillating test steel balls was gradually increased. A higher value indicates better lubricity. It was shown that the tolerance range while adjusting the mixed amount to suit the processing precision is wide, as it was indicated that “UTILIOL GA-15P” was superior to our company’s conventional

Table 3 Functions of PAG and application examples

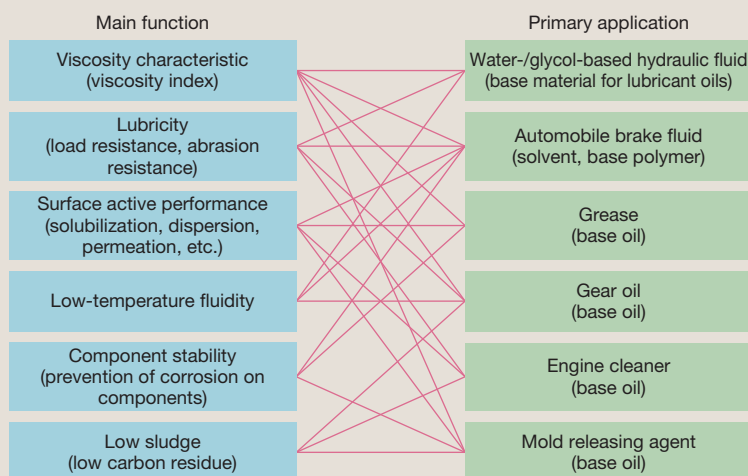
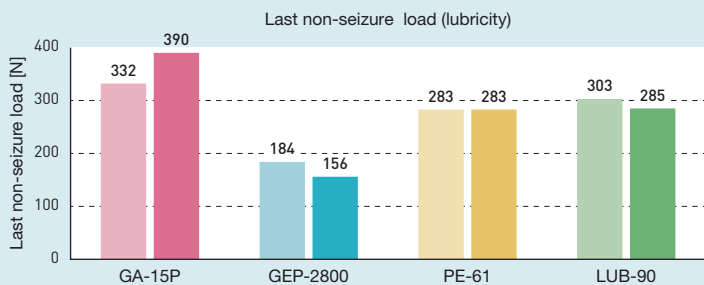


Table 4 Properties of “UTILIOL GA-15P” and conventional PAG type base material for lubricating oils

Item [Unit]	[Developed product] UTILIOL GA-15P	NEWPOL GEP-2800	NEWPOL PE-61	BLEMBER LUB-90
Kinematic viscosity (40°C) [mm ² /s]	263	198	144	461
Flash point [°C]	255	240	210	230
Fire Service Act	Designated combustible (flammable liquids)	Hazardous material (Class IV petroleum)	Hazardous material (Class IV petroleum)	Hazardous material (Class IV petroleum)
Appearance (20°C)*	Clear liquid	Clear liquid	Clear liquid	Slightly turbid liquid
Clouding point* [°C]	52	>75	26	18

(*) The appearance (20°C) and clouding point of the cutting fluid model “each PAG type base material for lubricant oils: 0.50 wt%, medium chain fatty acid amine salt: 2.40 wt%, ion exchanged water: 97.10 wt%.”



<Test method>

Translatory Oscillating Tribometer (SRV) was used to evaluate the lubricity (last non-seizure load).

Sample (left on bar graph): A mixture solution of each PAG type base material for lubricant oils (0.50 wt%), medium chain fatty acid amine salt (2.40 wt%), and water (97.10 wt%)

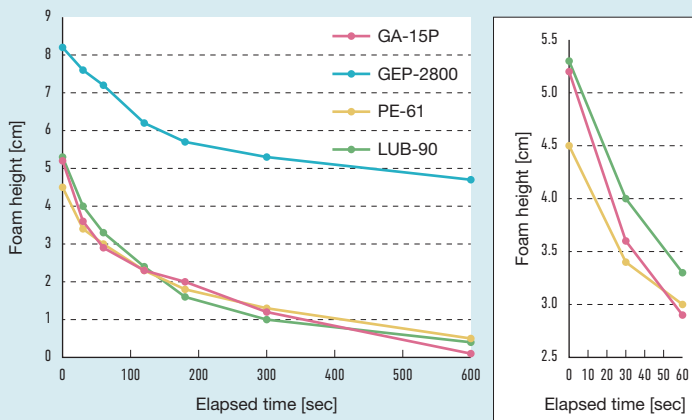
(right on bar graph): A mixture solution of each PAG type base material for lubricant oils (0.75 wt%), medium chain fatty acid amine salt (2.40 wt%), and water (96.85 wt%)

Test specimen: Steel balls (SUJ-2, ϕ 10 mm), steel discs (SUJ-2)

Test conditions: Load 50 → 500 N, oscillation frequency 50 Hz, range of oscillation 1.0 mm, temperature 30°C, with use of an immersion jig

Fig. 1 Lubricity evaluation for “UTILIOL GA-15P” and conventional PAG type base material for lubricating oils

Results of low foaming property evaluation (biomixer method)



<Evaluation method (biomixer method)>

150 mL of the sample was weighed into a 300 mL tall beaker and evaluated for low foaming property (changes over time in foam height after stirring) using a biomixer.

Sample: A mixture solution of each PAG type base material for lubricant oils (0.50 wt%), medium chain fatty acid amine salt (2.40 wt%), and water (97.10 wt%)

Test conditions: Number of revolutions 11500 rpm, stirring period 40 seconds, temperature 23°C

Measurement period: Immediately after stirring, 30 seconds after settling, 1 minute, 2 minutes, 3 minutes, 5 minutes, and 10 minutes

Fig. 2 Low foaming property evaluation for “UTILIOL GA-15P” and conventional PAG type base material for lubricating oils

product in terms of lubricity and that there was a concentration effect of increasing lubricity at higher concentration of base material [Figure 1]. In addition, no significant difference was observed in the coefficient of friction compared to the conventional product. On the other hand, we compared the initial foaming property generated by the turbulent flow of the biomixer and the defoaming property after the settling time

(over time) with the conventional product, although there were various reports on evaluation methods for low foaming property of metalworking oils. We used the initial foam height, low foam height over time, and the large inclination when they plotted on a graph as the points of focus for the low foaming and foam breaking properties. “UTILIOL GA-15P” with high total performance showed a better foam breaking rate than

the conventional product, while showing a low foaming property equivalent to it [Figure 2]. Based on the above, it was indicated that “UTILIOL GA-15P” has achieved both lubricity (last non-seizure load) and low foaming property (low foaming and foam breaking property).

3-3 Further leap in developed products

It is expected that the developed product “UTILIOL GA-15P” will be applied in various different fields in addition to its use as a base material for lubricating oils for application as metalworking oils that require lubricity and low foaming property including cutting and grinding. Being a surfactant, it is expected to deliver functions such as dispersion and solubilization and has features such as low sludge properties being a PAG. We hope that it will be a performance chemical that will play an important role all over the world in the future. We would like to continue the development of more high-function performance chemicals that meet the needs of the world and help build a better society.

[Contact (about the product)]

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