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FOAMING CAN REDUCE LUBRICATION OF LUBRICANTS SO CAUSING WEAR

PEMBUSAAN DAPAT MENURUNKAN LUBRIKASI MINYAK LUMAS SEHINGGA MENYEBABKAN KEAUSAN

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ABSTRAK

Pembusaan pada minyak lumas mempunyai efek yang sangat tidak diinginkan yang dapat menyebabkan peningkatan oksidasi oleh campuran intensif dengan udara, kerusakan kavitasi, dan transportasi minyak tidak cukup dalam sistem sirkulasi pelumasan yang dapat menyebabkan miskin pelumasan. Penambahan aditif antifoam yang sesuai adalah salah satu cara untuk menghindari adanya pembusaan. Untuk mengetahui kecenderungan pembentukan pembusaan yang berdampak pada kestabilan kinerja minyak lumas, sehingga terjadi keausan dilakukan penelitian di laboratorium dengan cara; 6 jenis minyak lumas yang diambil dari pasaran diuji viskositas, index viskositas, flash point, pour point dan color. Serta untuk mengetahui pengaruh pembentukan busa diuji foaming tendency/stability dan keausannya sebelum dan sesudah ditambahkan antifoam dari 6 (enam) jenis minyak lumas yang didapat dari pasaran. Hasilnya setelah ditambahkan aditif antifoam, tiga jenis (GB, SH, dan MH) dari enam jenis minyak lumas yang diuji, nilai kecenderungan pembusaan dan keausan hasilnya memenuhi batasan yang dipersyaratkan yaitu 0/50/0 ml unuk foaming tendency dan maksimum 0.5 mm untuk keausan, sedangkan untuk 3 (tiga) minyak lumas hasilnya tidak memenuhi batasan yang dipersyaratkan.

Kata Kunci: *pembusaan, antifoam polydimethylsiloxane, keausan*

ABSTRACT

Foaming on oil has a very undesirable effect which can cause an increase in oxidation by intensive mixture with air, damage to cavitation, and insufficient oil transportation in the lubrication circulation system which can cause poor lubrication. Adding the appropriate antifoam additives is one way to avoid foaming. To determine the tendency of foaming formation which has an impact on the stability of the performance of lubricating oil, so that there is wear and tear in research in the laboratory by means of; 6 types of lubricating oil taken from the market are tested for viscosity, index viscosity, flash point, pour point and color. As well as to determine the effect of foam formation tested foaming tendency / stability and wear before and after antifoam added from 6 (six) types of lubricated oil obtained from the market. The result after adding antifoam additives, three types (GB, SH, and MH) of six types of lubricated oil were tested, the tendency of foaming and the wear results met the required limits, namely 0/50/0 ml for foaming tendency and maximum 0.5 mm for wear, while for 3 (three) oils, the results are not satisfying the required limits.

Keywords: *foaming, antifoam polydimethylsiloxane, wear*

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I. INTRODUCTION

Foaming on oil is divided into two types: surface foam and inner foam. Surface foam refers to foam on the surface of lubricating oil which is usually noticeable. This foam can be controlled by additives as foam inhibitors. Effective inhibitors have a lower surface tension compared to base oil, which is usually insoluble in base oil, and therefore must be well dispersed to be sufficiently stable even after long-term storage or use. The size of the dispersed antifoam particles for foam surfaces must be smaller than 100 μm. For improved performance, particle size must be smaller than 10 μm (Chandran et al. 2016).

Foaming on lubricating oil is a small bubble agglomeration, where each bubble has the same strength in all directions. The ability of the bubble to solve is related to surface tension and surface homogeneity, depending on the nature of the bubble-surface interface (Lantz S. et al. 2017). If the liquid has a strong surface tension interface, bubbles will become strong and tend to not break or fuse. Thus, the stability of the foam will last long. If the surface liquid lacks homogeneity, it will affect the bubble surface. So the forces towards the wall of the bubble will become unequal and damage, weaken and destroy the bubble wall. As shown in Figure 1. Scheme of Marangoni bubble stabilization mechanism (Serpetsi and Yiantsios 2012). Therefore, to avoid the occurrence of foam in lubricating oil by modifying the interface in breaking bubbles, that is by adding antifoaming additives.

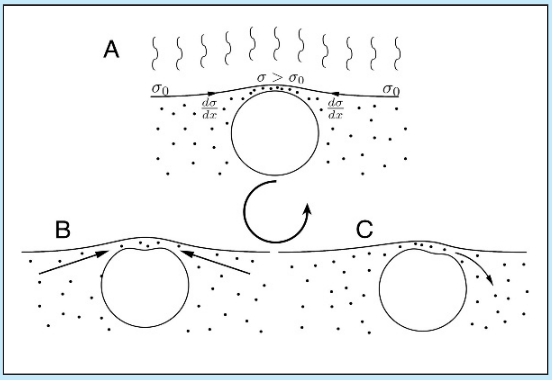

Figure 1
Schematic the mechanism of marangoni mediated bubble stabilization.
(A) Evaporation-driven enrichment of the less-volatile component (shown by the dots) in the thin liquid film making up the wall of the bubble- σ is the surface tension.
(B) The developed surface tension gradients drive flow into the apex of the bubble, leading to the growth of a dimple.
(C) Ambient disturbances destabilize the dimple, causing it to dissipate asymmetrically. At the end of this process the bubble wall returns to the state shown in A, and the process repeats.

Tribology in the lubrication system describes the physical contact between interacting surfaces or asperiti intersecting, so that the lubrication is not right, the friction force between the sliding surfaces will occur and will lose excessive energy, so the oil performance stability is disrupted due to formation of air bubbles and reduce viscosity (Wolak et al. 2018), so that wear occurs including adhesive wear, abrasive wear, surface fatigue wear and tribo chemical wear. The internal friction of the oil layer must be as low as possible, to allow the operation of the engine without obstacles, lubricating oil must have shear stability, good oxidation and thermal stability, corrosion protection and wear, good resistance to increased pressure, and good properties at low temperatures and foaming resistance.

Lubricating oil additives can be defined as compounds that can repair or prevent the formation of foam or break the foam that has been formed so that it can improve the specifications or characteristics of the base oil. In industrial processes, foam causes serious problems that can cause defects in the surface layer and prevent efficient filling of containers (Sheng 2014). Antifoam additives commonly used in industry can reduce and block the formation of foams are polydimethylsiloxanes (PDMS), known as dimethylpolysiloxane or dimethicone, a group of organosilicon polymer compounds commonly referred to as silicon (Marotrao 2012). PDMS is most widely used because it has unusual rheological (or flow) properties, and properties are generally very clear, inert, non-toxic, and non-flammable. Figure 2 is a chemical compound from antifoam PDMS additives.

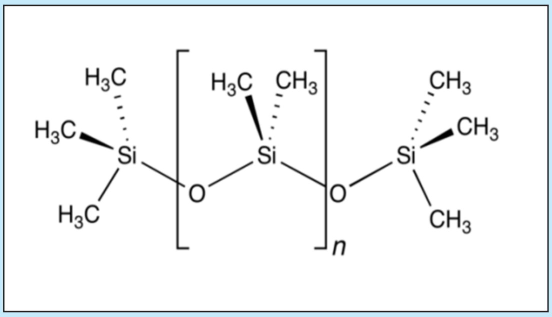

Figure 2
Additive antifoam polydimethylsiloxane (PDMS).

II. METHODOLOGY

The test materials used in this study were oils that have the ability to separate high water and not escape the stirring movement. It is naturally stirring stirring that will lead to aeration of lubricating oil, so it can cause air bubbles or foam formed. The foam does not only trigger oxidation of lubricating oil, but also reduces the effect of lubricating lubricating oil that will eventually wear wear. The lubricant used is neat metalworking (NM) lubricating oil, synthetical lubricating oil (GB), oil hydrodynamic oil (TH), Synthetic hydraulic (SH) lubricating oil, hydraulic oil lubricating oil (MH), Circulating Oil (CO). The additives used in this study are the most commonly used antifoam additives in the industry, namely silicon in the form of polydimethylpolysiloxane with an addition of 0.1% wt.

As preliminary data the oil is lubricated to be tested using the ASTM Method to determine the test of physical chemical characteristics, namely viscosity; viscosity index; flash point; pour point; and color. Whereas for the test of resistance to foaming is used ASTM D 892. There are two interesting variables in the foaming test method namely foaming tendency and foam stability. The tendency to foaming quantifies the amount of foam (in milliliters) made during air flow and still exists after cessation of air flow. Foam stability quantifies the extent to which bubbles do not join and break. In this test, the amount of foam remaining, in milliliters, after 10 minutes. from when the air flow is stopped.

Whereas, to determine the sliding contact properties of relative lubricant protection under certain test conditions using the ASTM D 4172 test method using 1200 rpm, 1800 rpm, and 2200 rpm speeds.

The four-ball test mechanism (Figure 8) is three steel balls with a diameter of 12.7 mm (½ inch) clamped together and given lubricating oil to test. A fourth steel ball with a diameter of 12.7 mm (½ inch) is mounted on top, pressing down on the three balls with a compressive force of 147 or 392 N (15 or 40 kgf). The temperature of the lubricated oil to be tested is conditioned at 75oC (167oF), and then the ball of the upper rpm is rotated at a speed of 1200 rpm, 1800 rpm, and 2200 rpm for 60 minutes. Oil is comparatively compared using the average size of scar diameters produced on the three test balls.

III. RESULTS AND DISCUSSION

Lubricating oil as a protective layer serves to separate components that move together. Without direct touch or friction, wear and tear may not occur. But when a heavy load exceeds the ability of lubricating oil to separate between components, the layer will tear and cause friction (direct contact)

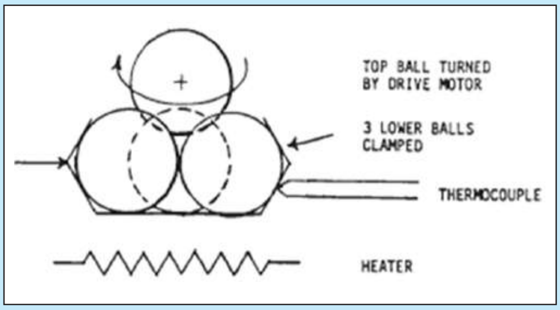

Figure 3
Schematic of a four-ball wear test machine.

Table 1
Physical Characteristics Test Results

No.	Characteristics	Test Method	NM	GB	TH	SH	MH	CO
1.	Kinematic viscosity at 40°C, mm2/s	ASTM D445	32.09	102.35	33.97	48.7	71.39	102.2
2.	Kinematic viscosity at 100°C, mm2/s	ASTM D445	5.67	15.21	5.7	8.7	9.95	10.97
3.	Viscosity index	ASTM D2270	117	156	107	160	121	90
4.	Pourpoint, °C	ASTM D97	-12	-54	-36	-58	-27	-12
5.	Flash point, °C	ASTM D92	220	210	230	256	238	243
6.	Appearance and color	Visual Clear	brown	brown Clear	red Clear	brown Clear	brown Clear	brown Clear

between metals (Malam et al. 2016). The following is the analysis of 6 types of lubricating oil carried out in the 2016 lubricating laboratory.

A. Physical Characteristics Test Results

Table 1. shows the characteristic test results of various types of lubricating oil used in a variety of industrial equipment, which has the potential for its use to cause foaming in machine tools. The results of the viscosity characteristic test at 400C above are in accordance with the VG ISO classification required for use in any type of lubricating oil. While the viscosity index is tested to determine changes in viscosity at various high temperatures or low temperatures.

B. Foaming Tendency Test Results

Reflux of lubricating oil is a very undesirable effect that can cause increased oxidation by intensive mixture with air, damage to cavitation and inadequate

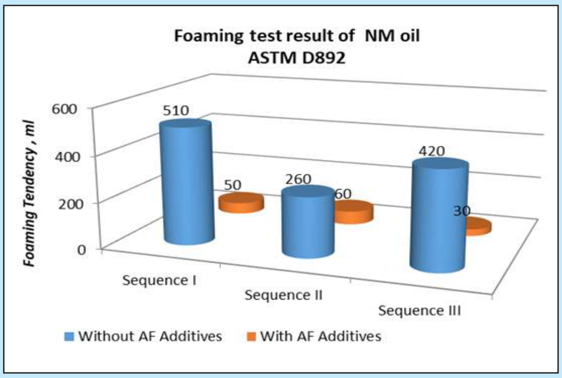

Figure 4
Foaming test of NM oil.

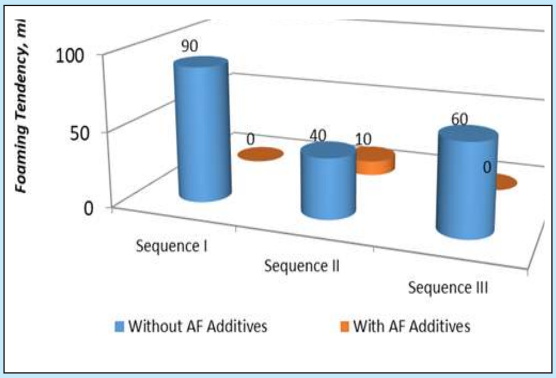

Figure 7.
Foaming test of SH oil.

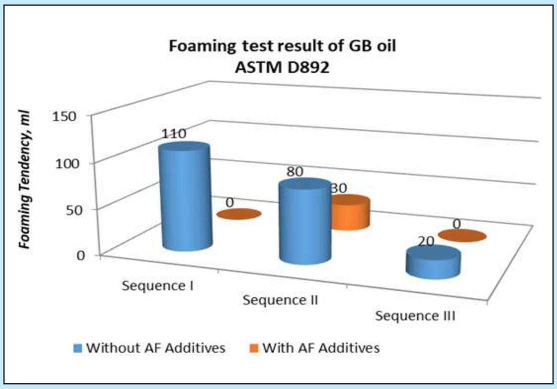

Figure 5
Foaming test of GB oil.

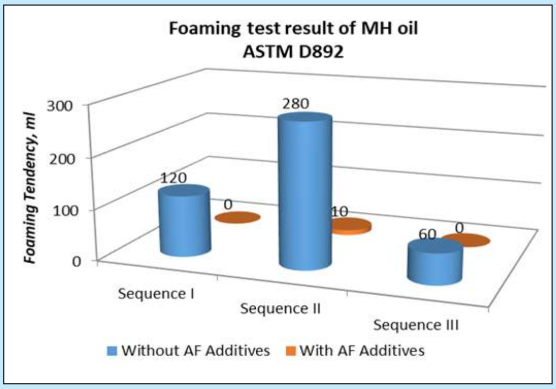

Figure 8
Foaming test of MH oil.

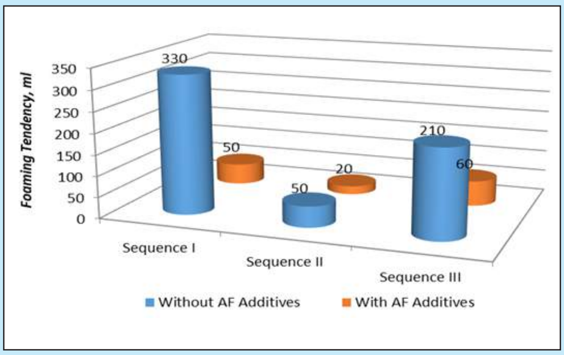

Figure 6
Foaming test of TH oil.

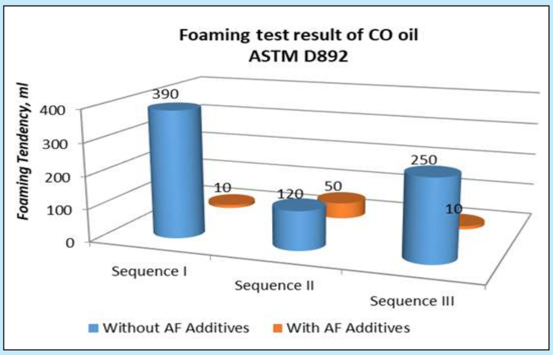

Figure 9
Foaming test of CO oil.

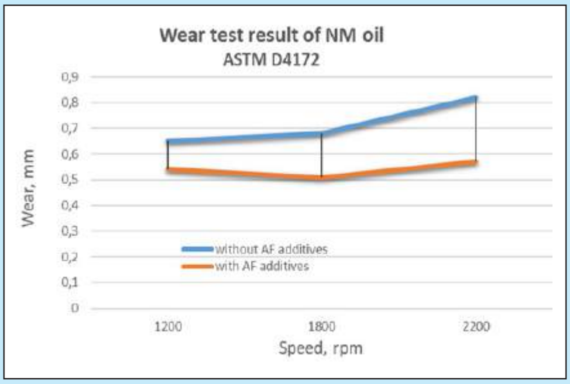

Figure 10
Wear test of NM oil.

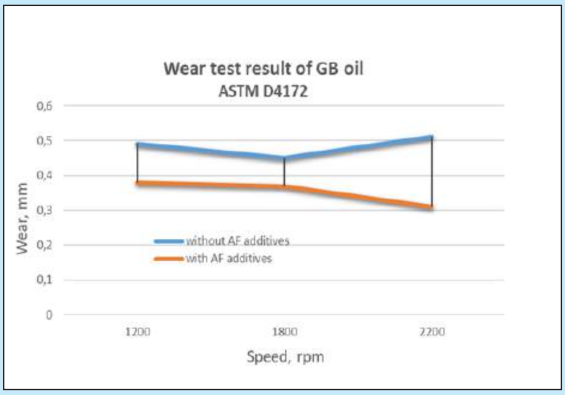

Figure 11
Wear test of GB oil.

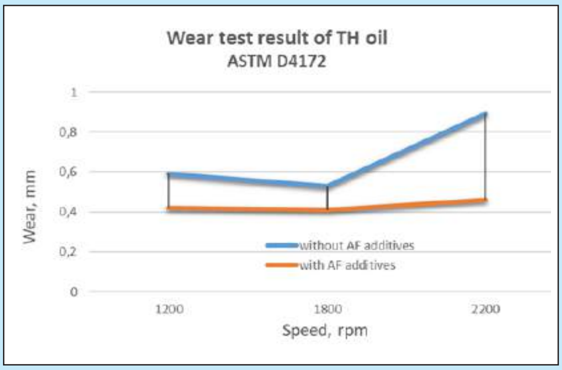

Figure 12
Wear test of TH oil.

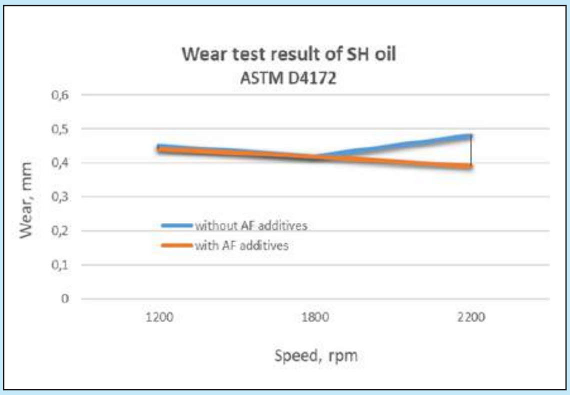

Figure 13
Wear test of SH oil.

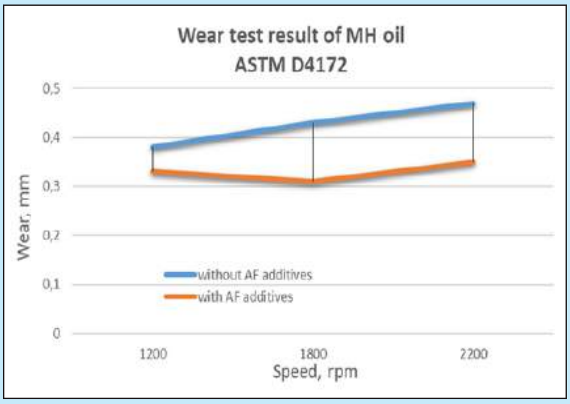

Figure 14
Wear test of MH oil.

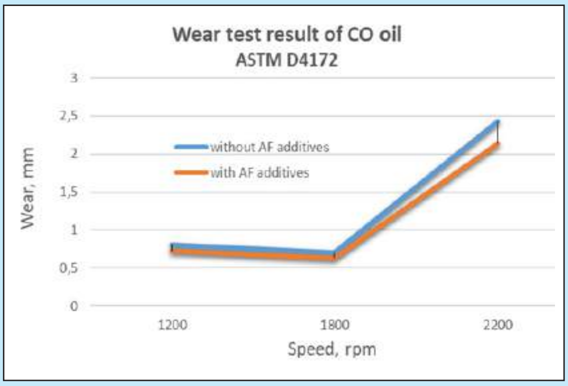

Figure 15
Wear test of CO oil.

oil transportation in the circulatory system (Serpetsi and Yiantsios 2012) which can cause a lack of lubrication.

In Figures 5, 7, 8 and 9, it can be seen that the foaming test results before adding foaming tendency to foam foam additives are very high, whereas after adding anti foam additives the tendency to form foam is very sharp and the results meet the specification requirements of 0/50/0 ml. While in Figure 4 and Figure 6 it can be seen that, the test results before the addition of antifoam additives, the tendency of foam formation is very high, whereas after adding anti foam additives the tendency of foam formation is very sharp, but the results are still above the specification requirements of 0/50/0 ml. This occurs because the tendency to foam is very dependent on the lubricant itself and is influenced by the surface tension of the base oil (Chandran et al. 2016) and mainly by the presence of surface active agents such as detergents, corrosion inhibitors and other ionic compounds (Lantz et al. 2017), as shown in Figure 5 (Gearbox lubricating oil) and Figure 7 (hydraulic lubricating oil), the lubricating oil formula uses synthetic base oil which has a high surface tension and shows a relatively low foaming tendency compared to base oil derived from petroleum hydrocarbons (Khan, et al. 2014) for 4 (four) other lubricating oil formulas.

The phenomenon of the behavior of antifoam additives in the liquid that occurs in each of the images above in the lubrication system exists as very small droplets on the surface of the liquid that are static and work on fluid / air interfaces and are not soluble in liquids, because the addition of anti-foaming additives in very small formulas is around 0.05-0.5% by weight for long chain silicon polymer types (Chandran S. V, et al. 2016), so that the use of antifoam additives needs to be controlled and the addition is carried out periodically, because of the additive properties that have a certain service life.

C. Wear Test Results

Based on the results of testing the four-ball engine obtained the test results shown in Figure 10, before adding antifoam additives, it was seen to increase with the addition of the speed of wear value of 0.65 mm - 0.82 mm, while after adding antifoam additives there was a significant decrease in wear value especially at speeds of 1800 rpm and speeds of 2200 rpm, but the value is still above the required limit of 0.5 mm. In Figure 11 it can be seen that before the addition of antifoam additives at a speed of 1200 rpm the wear value was 0.49 mm but at 1800 rpm there was a decrease of 0.43 and up again at rpm 2200 which was 0.51 mm, while after adding antifoam additives there was a decrease quite significant which is equal to 0.2 mm. This proves that the addition of antifoam additives can reduce wear, as in Carden et al. 2013, Changes in the stability of lubricant oil performance against wear can be seen from the phenomenon of antifoam additive behavior in the form of droplets that will stick to the bubble wall, so that it is unstable and tend to ‘punch’ on surface parts such as glass or metal parts and filter media or can damage the walls of machines or equipment. While in Figure 12 shows that before additives are added and the speed is increased to 2200 rpm the value is up to 0.89 mm, this has the potential to wear and tear, but after adding antifoam additives, the test value significantly decreases and is within the required value of 0.5 mm.

In Figure 13 and Figure 14, the results of a four-ball test before and after adding the antifoam additive, the value in the required limit is 0.5 mm. The nature of lubricating oil as expected is in the lubrication system, so that the internal friction of the oil layer can be avoided as easily as possible, so that the operation of the engine has no obstacles and will ultimately increase energy (Vasanthan et al. 2015). Whereas in Figure 15, the four-ball test results before and after adding the antifoam additive value above the required limit are 0.5 mm, in the formulation the cutting oil is not required for the addition of antifoam additives. In its use, added water cutting oil according to a comparison that is recommended to form a good emulsion and depends on the equipment or products produced.

IV. CONCLUSIONS

Of the 6 (six) types of lubricated oil added with antifoam additives of 0.1% yielding, 4 (four) formulas (GB, SH, MH and CO) the foaming tendency test results met the requirements, namely 0/50/0 ml and the other 2 still above the required limit. For the results of the wear test, it produces 3 (three) formulas (GB, SH and MH) whose values are below the maximum limit required, namely 0.5 mm while the 3 formulas (NM, TH and CO) result above the required maximum limit. This can be caused by:

1. Adding antifoaming additives can reduce wear
2. Formula using synthetic base oil, has a higher surface tension than base oil derived from mineral oil.
3. The nature of foaming is also influenced by viscosity, the more dilute the oil lubricates, the higher the foaming tendency.
4. Mixing antifoam additives requires significant high-speed mixing to spread as small particles, so that they must balance blending power, surface activity and dispersibility which means they must not dissolve in the liquid and can spread on the surface / air interface.

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