

# Shear Stability of Engine Oils

Presented by:

Dr. Tina Dasbach, Institute of Materials, Inc.

Co-Author:

Theodore Selby, Savant Group



**F+L Week 2016**

8-11 March 2016

Regent Hotel, Singapore



# Agenda

- Market outlook
- Significance of shear stability
- Comparison of mineral, synthetic, and synthetic-blend base oil formulations
- Summary



# Market Outlook

- According to a recent report from The Freedonia Group, Inc., world demand for lubricants is projected to rise 2.0% annually to 45.4 million metric tons in 2019 (Jan. 2016).
  - **Growth in Asia Pacific region**
    - According to Grand View Research, Asia Pacific along with being the largest market is also expected to be the fastest growing market for lubricants, at an estimated CAGR of 3.49% from 2014 to 2020.
    - Owing to favorable government policies, domestic demand and demographical advantages, APAC has also emerged as a leading lubricant manufacturer on the global scale. (Jan. 2016)
  - More mature markets of US, Western Europe and Japan are expected to stay fairly flat.
    - “Many of these developed countries enforce strict regulations on the use and disposal of lubricants, which will drive demand for non-conventional lubricants, such as more environmentally friendly bio-based lubricants and lubricants derived from re-refined base oils”. (Emily Park- Analyst)



## Market Outlook Cont.

- The motor vehicle aftermarket will remain the largest end use for lubricants; however, as drain intervals lengthen and as electric vehicle ownership rates increase in developed nations, growth will trail the other major markets for lubricants.
- Demand in the manufacturing market will post faster gains as manufacturing output expands, particularly in developing regions. In addition, **quality** will continue to improve as **manufacturers** increasingly demand lubricants that are effective in a wider range of operating conditions.



## Car Sales Outlook - China

- Car sales in China rose by 4.7% to 24.6\* million units in 2015 - the slowest pace in three years -- as a tax cut did little to revive sales amid the country's slowest economic expansion in 25 years. In comparison, auto sales grew 5.7% to 17.5 million units in the U.S. last year.
- Looking ahead, the China Association of Automobile Manufacturers (CAAM), are projecting the country's vehicle sales will grow 6% in 2016. Vehicle sales accelerated sharply in October after the Chinese government halved a 10% tax on vehicles with engines smaller than 1.6 liters in a bid to boost the world's largest car market.

China Car Sales Growth Drops To 3-Year Low In 2015  
BY ADITYA KONDALAMAHANTY ON 01/12/16 (INTERNATIONAL BUSINESS TIMES)



# Concern for Engine Oil Quality

- Dollar General Sued For 'Obsolete' Oils
  - A California resident filed a class action lawsuit against the owner of Dollar General discount stores, alleging that its house brand motor oils are obsolete and harmful to vehicles.
- Actions from American Petroleum Institute (API)
  - From 2009 to 2014, API found as high as 19% of bulk oils it tested failed to meet the claimed API Service category requirements. API said they were bulk samples purchased from oil-change locations where consumers likely believed they were receiving quality oils.
  - API plans to publish a list of nonconforming oils and regularly update the API unlicensed list.
  - More enforcement actions needed against nonconforming oils.

BY GEORGE GILL • JANUARY 20, 2016



## Information from the Institute of Materials, Inc.

- The Institute of Materials (IOM) was formed in 1984.
  - It was formed to provide an unbiased source of information on marketed engine oils by publishing test data.
  - 650 **new** oils are collected annually from the world's market place including the Americas, Europe & South Africa and Asia Pacific.
  - Over 18,000 engine oils have been tested over 30 years.
  - It is the world's largest unbiased collection of such data.
- The IOM Database reveals the availability of well-formulated engine oils present on the world's markets, as well as those of questionable quality.
- Of the more than 30 bench tests used by IOM to test each marketed engine oil, three are presented here to show the variation of viscosity among the oils collected across the globe.



## Multigrade Engine Oils and Viscosity Modifiers

- Viscosity Modifiers (PVMs) are used in lubricants to decrease the oil's viscosity dependence on temperature and allow the formulation of multigrade, non-Newtonian oils that meet both the high and low temperature requirements of SAE J300.
- As a consequence of their macromolecular nature, VMs are subject to two forms of viscosity loss.
- It was found that the engine would cause breakage of some of the VM macromolecules and, thus, some viscosity loss. This response of the multigrade engine oil was **irreversible** and was called Permanent Viscosity Loss (PVL).
- Additional high shear rate viscometric studies of VMs revealed another form of viscosity loss that was **reversible** and was termed Temporary Viscosity Loss (TVL).

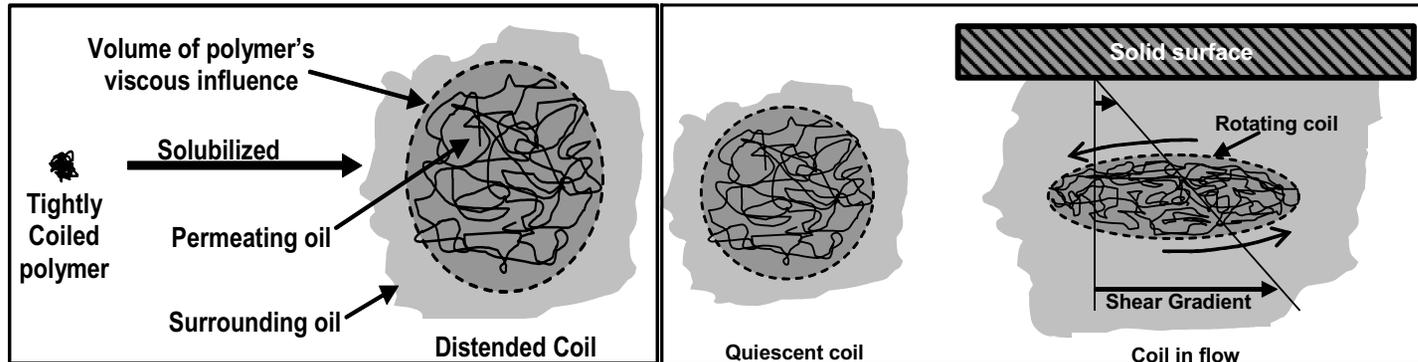


## Temporary Viscosity Loss

- Temporary viscosity loss (TVL) of multi-grade engine oil has been a matter of interest, question and measurement since shortly after polymeric viscosity modifiers (PVMs) began to be used in the early 1950s.
- At higher shear forces and related high shear rates, these PVMs deform and temporarily lose a considerable portion of their viscosity contribution to the engine oil.
- Accordingly, resistance to viscosity loss was found to be of value and engine and bench test methods for determining such resistance were developed by the ASTM and CEC.



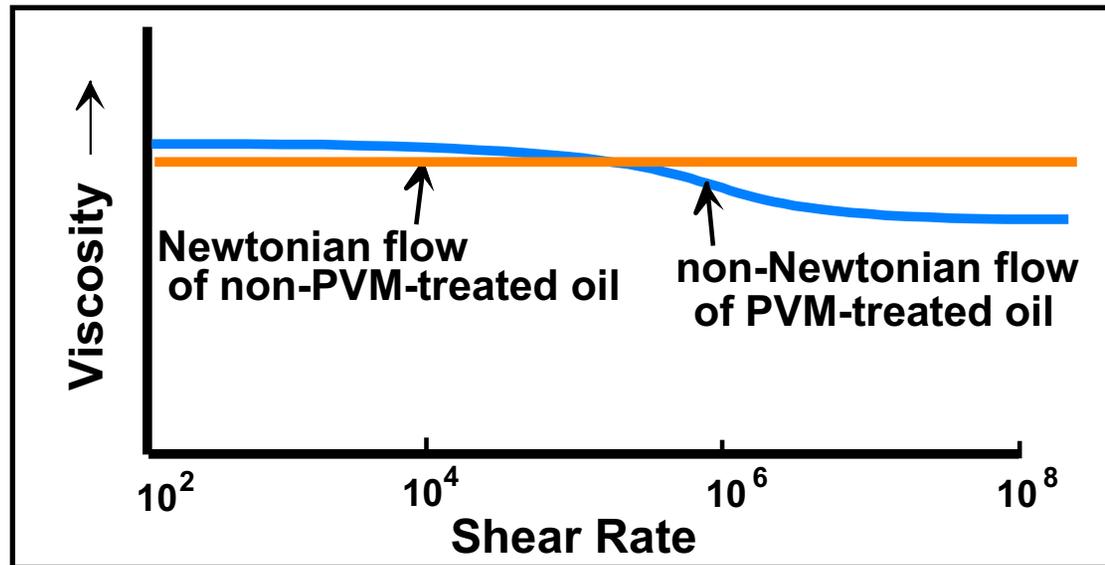
# Nature of Multigrade Engine Oils at High Shear Rates



- The expanded polymer coil is quite flexible and at increasing shear rates it is progressively deformed and oriented by the 'viscous grip' of the oil molecules. As the coil deforms, its contribution to the viscosity of the oil becomes less. This response is referred to as Temporary Viscosity Loss (TVL) since the viscosity lost returns to its original state when shear is reduced.



## Temporary Viscosity Loss



- Compared to a Newtonian oil at any constant temperature, a VM containing engine oil showing TVL is non-Newtonian between the two “Newtonian” shear rate zones.
- That is, with increasing shear forces, the VM containing engine oil reversibly passes through the “shear thinning” phase.
- Concern with viscosity losses of PVL and TVL on wear led to the development of dynamic viscometers and minimum viscosities in engine oil specifications.

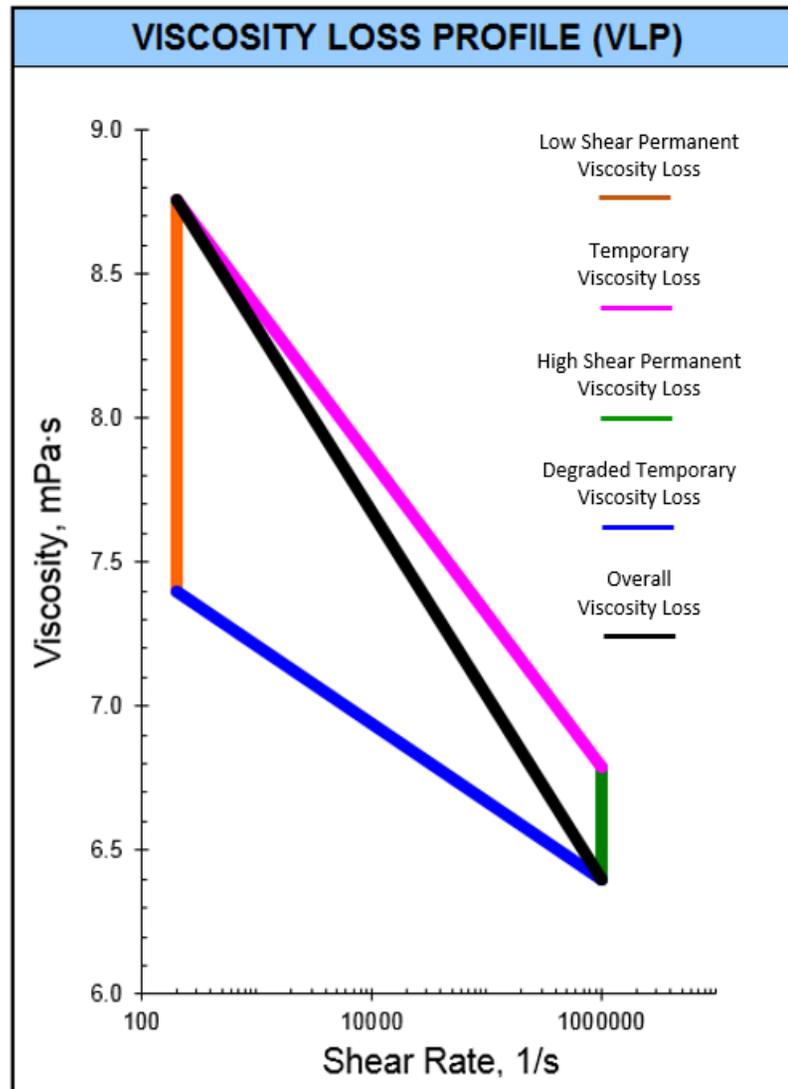


## SAE J300 Viscosity Grades for Engine Oils

SAE Viscosity Grade	Low Shear Rate KV (mm <sup>2</sup> /s) 100°C Min	Low Shear Rate KV (mm <sup>2</sup> /s) 100°C Max	High-Shear-Rate Viscosity (mPa·s) at 150 °C Min
8	4.0	<6.1	1.7
12	5.0	<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,and 10W-40)
40	12.5	<16.3	3.7 (15W-40,20W-40,and 25W-40, and 40 grades)
50	16.3	<21.9	3.7
60	21.9	<26.1	3.7



# Traditional Viscosity Loss Profile





## Multigrade Engine Oil Viscosity and TVL

- TVL has been associated with the presence of a relatively low concentration of soluble large molecules (PVMs) in the engine oil temporarily deforming and orienting under the forces producing high shear rate flow.
- One might think that without the presence of such PVMs neither TVL or PVL would occur – but this is not so.....
- It was found that the myriad of smaller linear synthetic base oil molecules may also impart TVL.
- Our analysis included the variation of temporary viscosity losses of fresh multi-grade engine oils collected around the world and their cavitation-degraded counterparts at high shear rates (FISST).

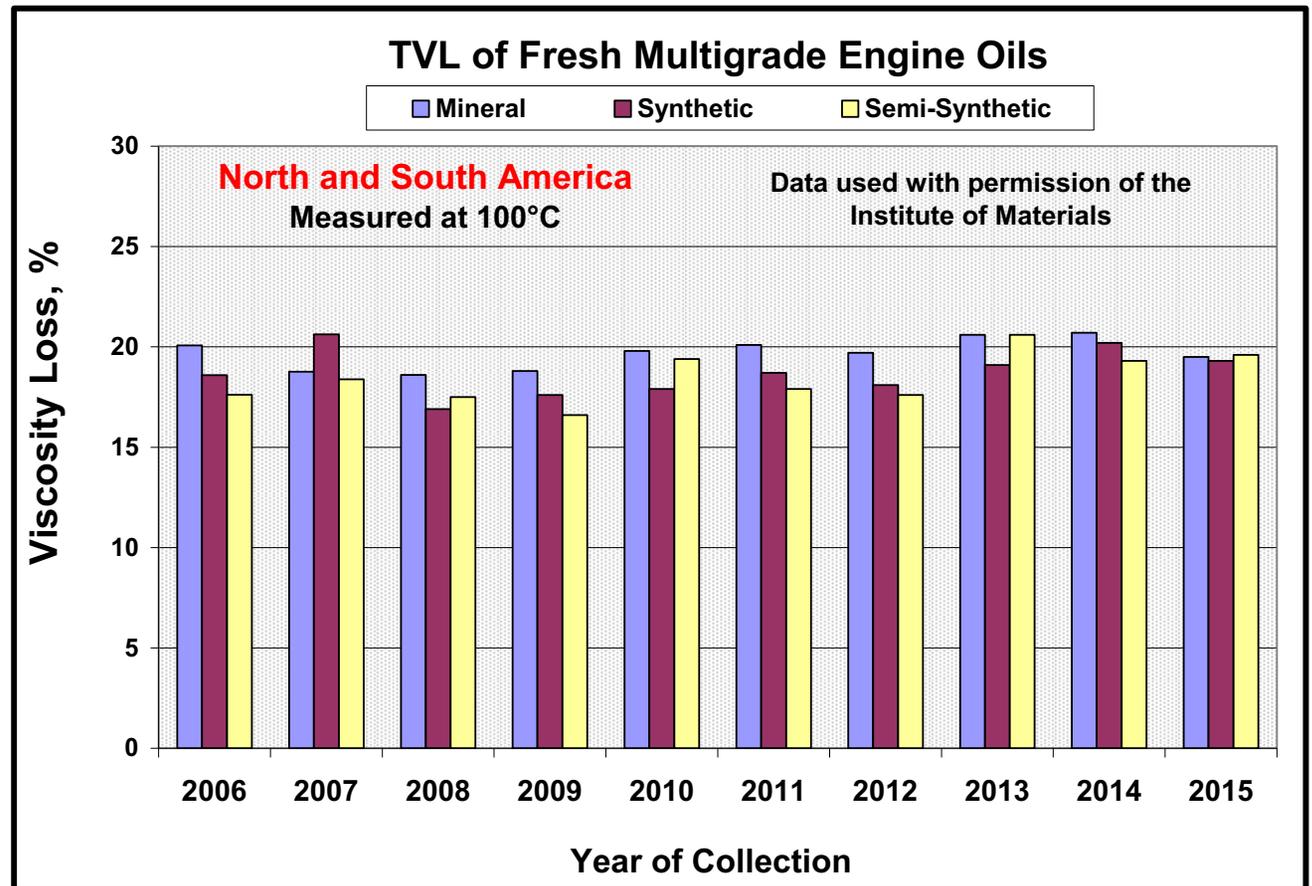


## Temporary Viscosity Loss

- Regarding engine oil quality, temporary viscosity loss (TVL) of multi-grade engine oils – which may range from less than 10% to more than 30% – has been an interesting and important property of these oils.
- Among IOM's thorough analyses are the measurement of TVL at both 100°C and 150°C, and these data are presented for mineral, synthetic, and semi-synthetic multi-grade oils.
- Today's presentation compares the Institute of Materials' (IOM's) TVL engine oil data collected in Asia and the Pacific Rim, Europe and the Americas over the last 10 years at 100°C.
- Particularly relevant are the comparisons between the mineral, semi-synthetics, and the synthetics given their formulation differences.

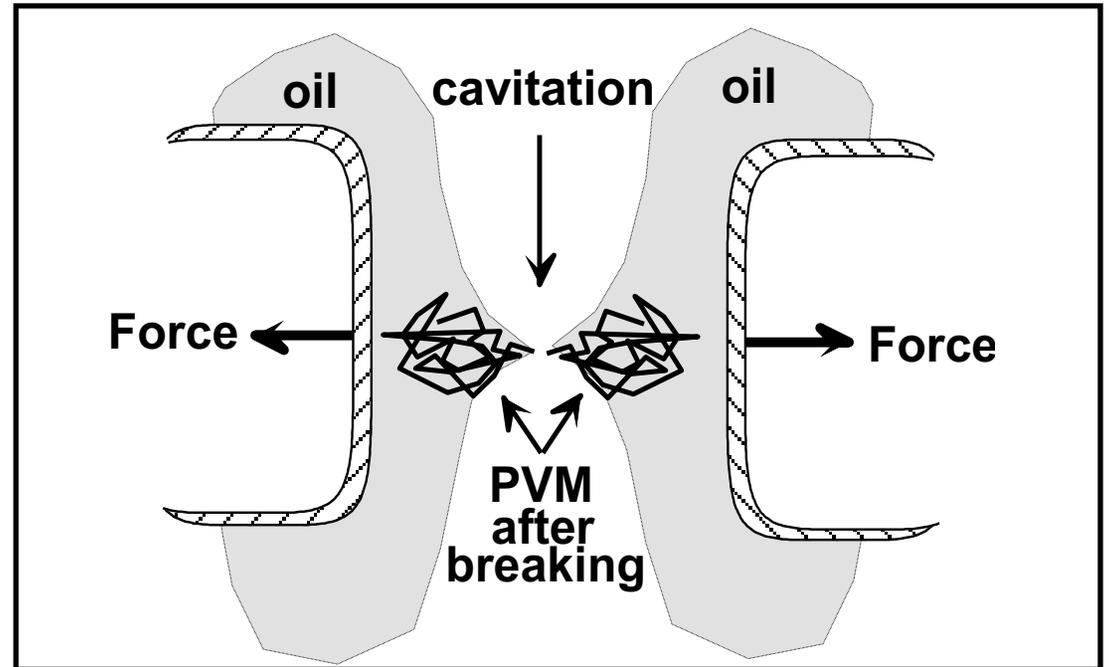
# TVL of Fresh Oils from the Americas

- Over the last 10 years, the mineral and synthetic based engine oils collected from North and South America have had somewhat similar levels of 17% to 20% TVL.
- However, as the sketch shows in the following slide, the PVM in multigrade engine oils can also be degraded by cavitation.
- This results in permanent viscosity loss (PVL) which also affects the TVL response.



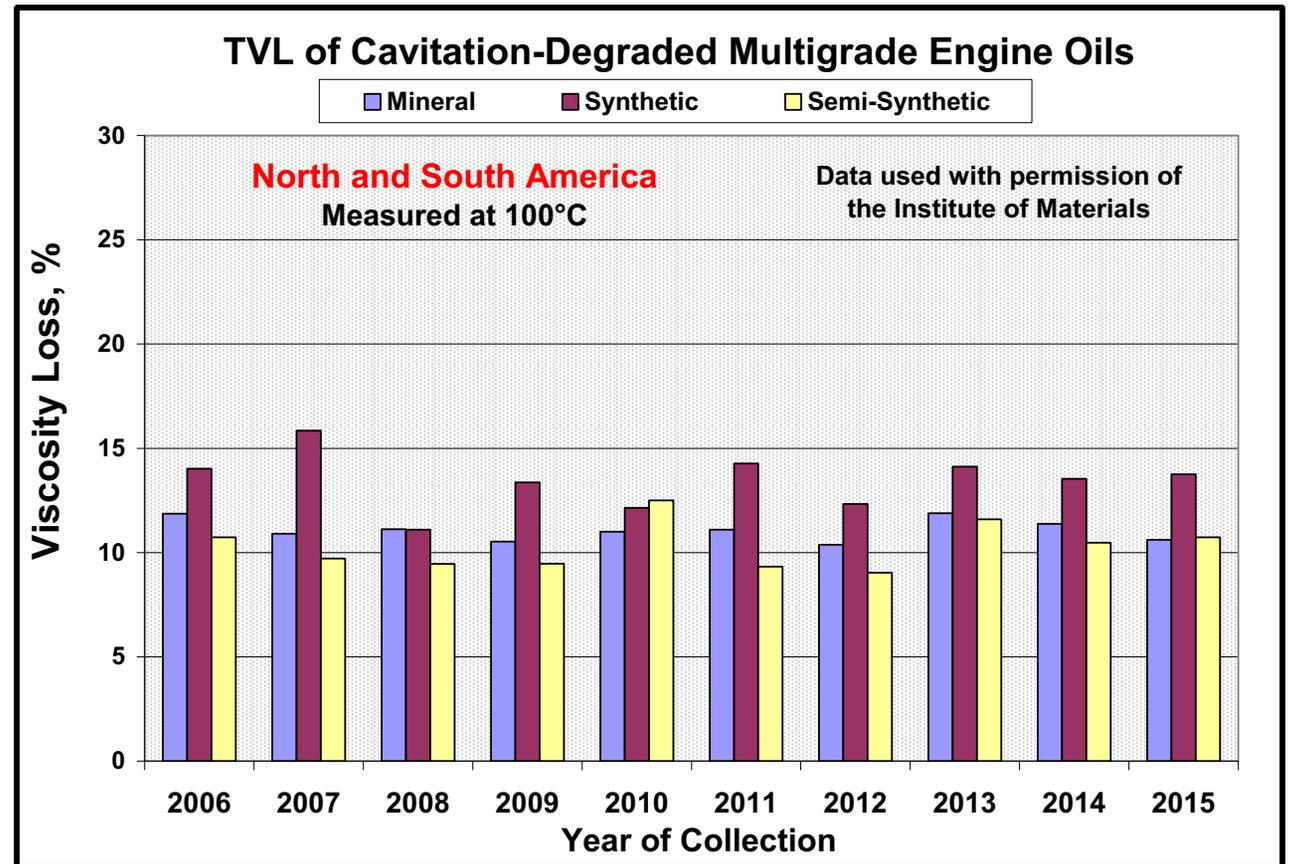
# Permanent Viscosity Loss and Its Influence on Temporary Viscosity Loss

- Cavitation of the engine oil is believed to pull apart the larger molecules of PVM contained in the oil (i.e., separation of the pump gear teeth during rotation).
- As previously mentioned, this not only reduces the PVM's viscosity contribution to the multigrade oil but also reduces the amount of TVL.
- That is, since PVL reduces the size of the molecules of the PVM and its viscosity contribution, it also reduces the amount of orientation and, thus, the degree of its temporary viscosity loss (TVL).



# TVL of Degraded Engine Oils from the Americas

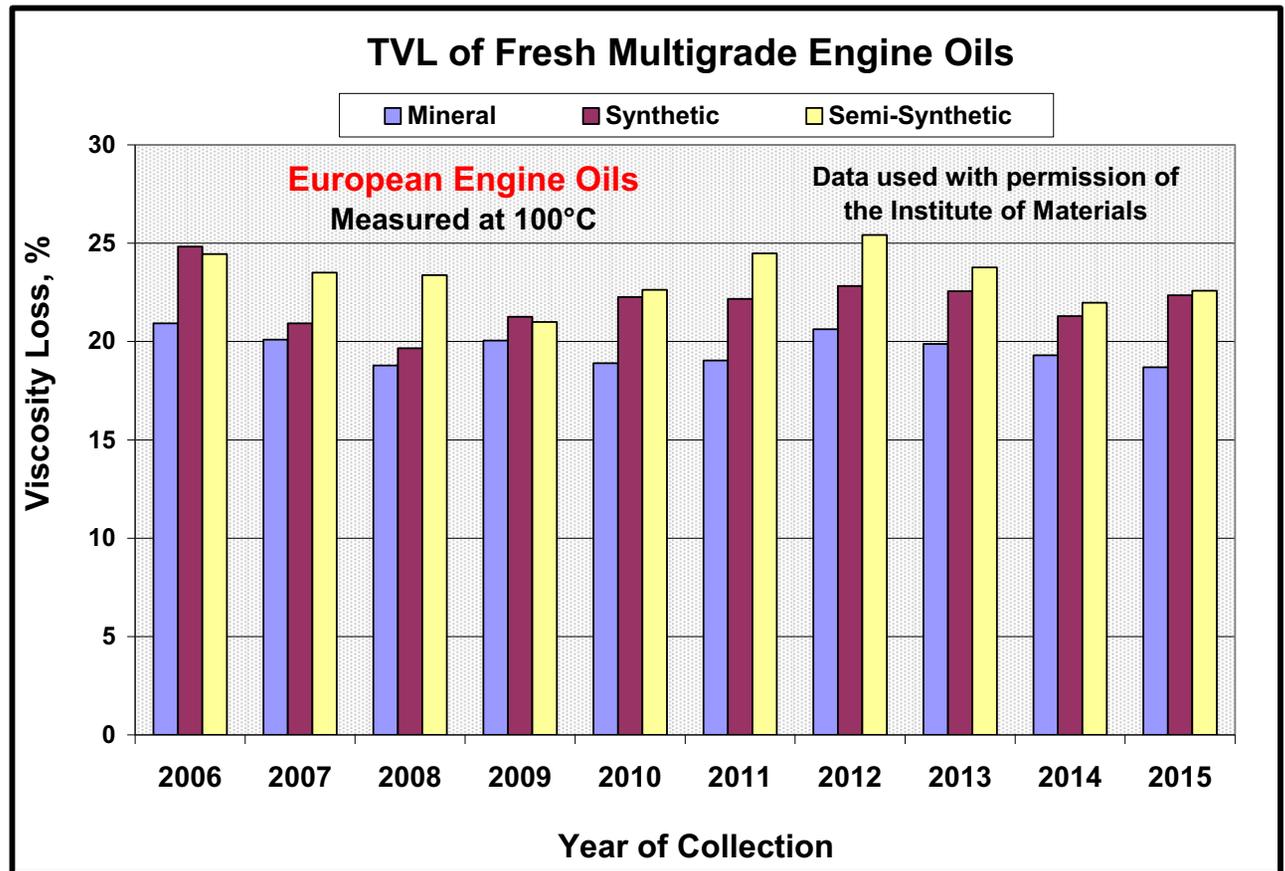
- For the same reason, synthetic oils with less PVM would be expected to retain more of their level of TVL than mineral and semi-synthetic oils containing more PVM.
- The degraded semi-synthetic oils of the Americas, show comparable TVL performance as the mineral oils.
- This suggests they may contain similar PVM content.



# TVL of Fresh Oils from Europe

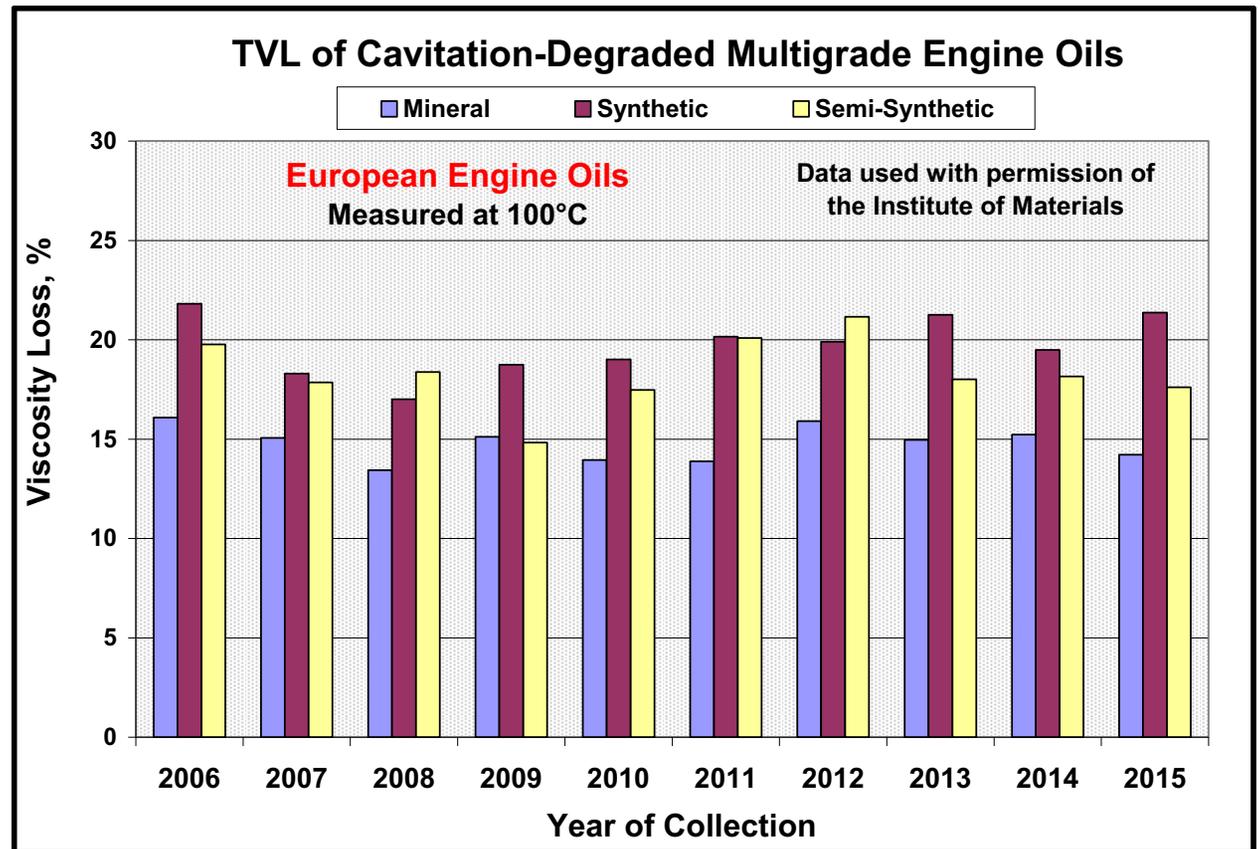
- It is evident that the performance of the European mineral engine oils is similar to that of the Americas, but different as shown by the TVL of the synthetics and, particularly, the semi-synthetics.

- The synthetic and semi-synthetic engine oils show TVL values from 21% to 25%.
- Comparison of the degraded oils was interesting...



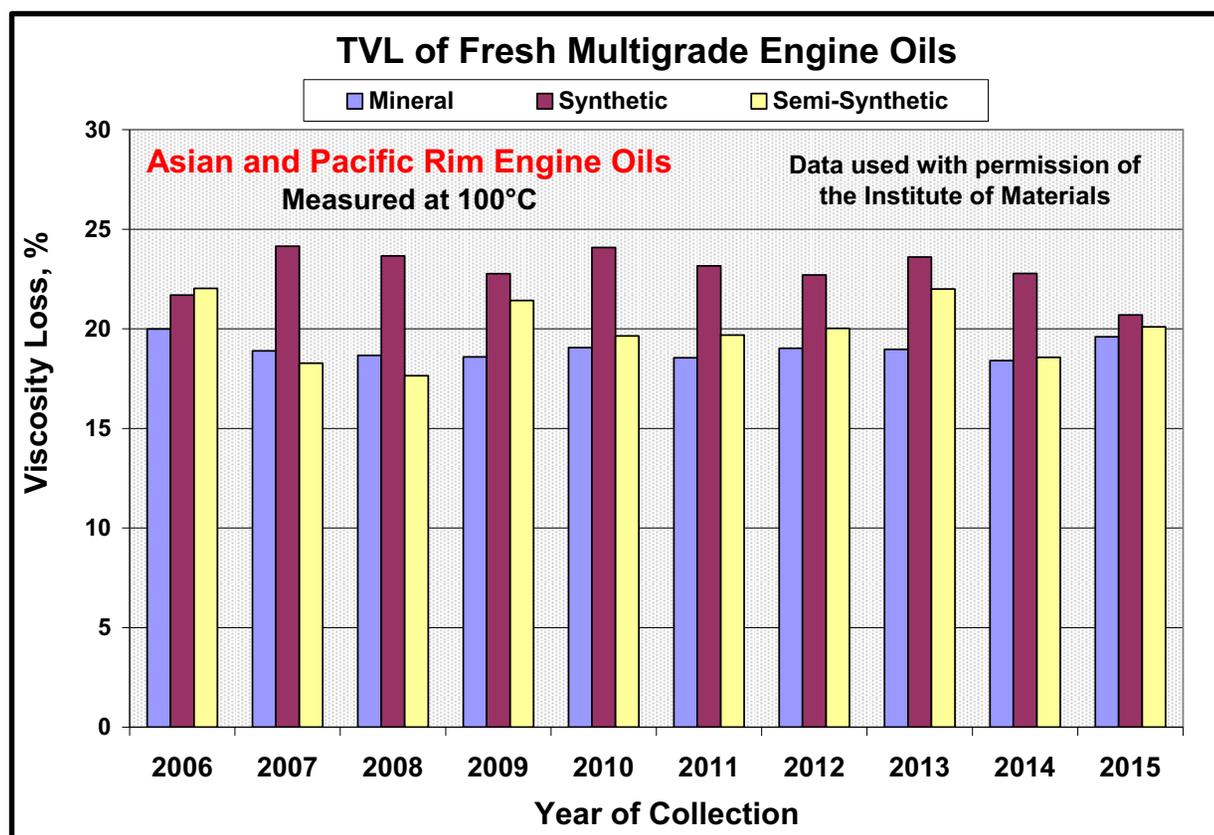
# TVL of Degraded Oils from Europe

- It is evident that permanent viscosity loss (PVL) has had its effect on reducing the susceptibility of the oils to temporary viscosity loss.
- However, it is also evident from the levels of TVL, that synthetic oils appear to be less impacted by degradation.
- In comparison to the Americas, the magnitude of the TVL after degradation is greater for the majority of the oils.



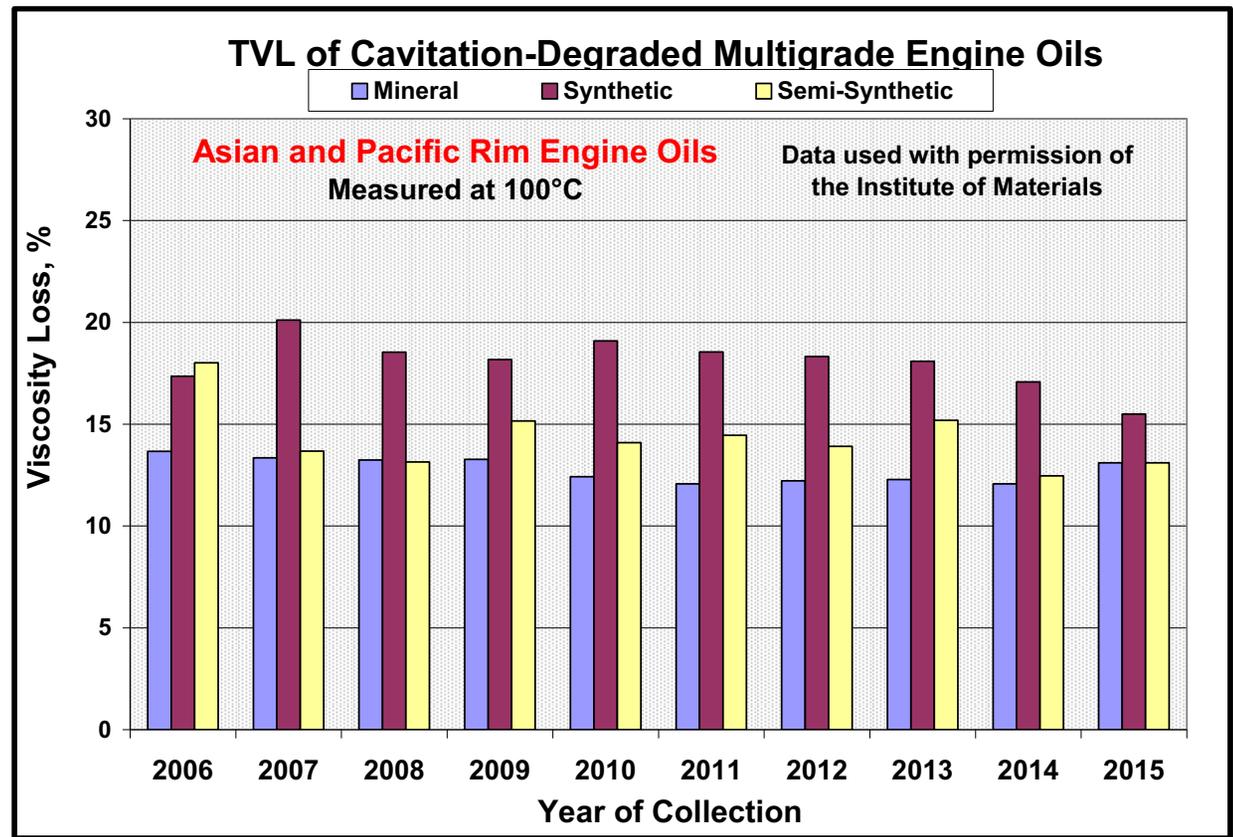
## TVL of Fresh Oils from Asia and Pacific Rim

- Formulation of engine oils in Asia and the Pacific Rim in regard to factors reflecting TVL seem interestingly different.
- For example, the average TVLs of the synthetic oils are predominantly greater than either the mineral or the semi-synthetic formulations (TVL > 20%).
- It was, thus, of interest to compare the engine oils after cavitation effects were imposed ....



# TVL of Degraded Oils from Asian and Pacific Rim

- The reduction in TVL after degradation is more prominent with the mineral and semi-synthetic oils.
- Consistent with the results from European oils, the synthetic oils appear to be less impacted by the degradation.
- Based on the oils collected in Asia Pacific, the data suggest fairly consistent TVL results over the last ten years for the mineral oils.





## Discussion and Summary

- The data obtained on TVL from the Institute of Materials Engine Oil Database has shown several interesting facts:
- The average TVL of the fresh synthetic-based engine oils is about the same as mineral-based oils collected in the Americas. In comparison with the other regions, the mineral oils tended to have less TVL compared than the synthetics or synthetic blends.
- In all three regions, the synthetic-based engine oils were less susceptible to degradation based on their TVL response.
- Analysis of all of the fresh engine oils collected in the three primary areas of the world shows that, on average, the oils show TVLs of about 20%.

**Thank you for your time and attention !**

**It has been a pleasure to present this study of some  
of the interesting information contained in the  
Institute of Materials  
Engine Oil Database**