

Influence of Low Viscosity Lubricating Oils on Fuel Economy and Durability of Passenger Car Diesel Engine

Ashok Permude
MARUTI SUZUKI INDIA LTD.

Mehul Pathak, Venkatesh Kumar, Sachleen Singh
SUZUKI POWERTRAIN INDIA LTD.

Copyright © 2012 SAE International

ABSTRACT

Continuously rising fuel prices and global concern on climate change have resulted in a need to deliver vehicles with increased fuel economy. This has to be achieved without compromising on performance, durability and cost.

Passenger car manufacturers are looking at various ways to maximize fuel economy. Major part of fuel saving can be tapped from engine itself. This can be done by activities on engine as below:

- Improving overall combustion efficiency and hence BSFC
- Efficient thermal management.
- Weight reduction of engine parts or complete downsizing
- Hybridization.
- Reducing engine losses i.e. parasitic losses from auxiliaries and frictional losses.

This paper is focused on the reduction of engine frictional losses (FMEP) through the use of low viscosity lubrication oils. Various factors in lubrication oil contribute to friction. Experimental approach to quantifying the effect of different parameters of lubrication oil on total engine friction is presented. Results of experiments on screening rigs, engine test bench and vehicle chassis dynamometer with lubricating oils having different properties are presented and discussed. In addition, for oil formulations that lead to significant friction reduction, their effect on engine component wear and durability are discussed.

INTRODUCTION

Typical system wise contribution towards total FMEP of a passenger car diesel engine is shown in figure 1 ^[Ref 1].

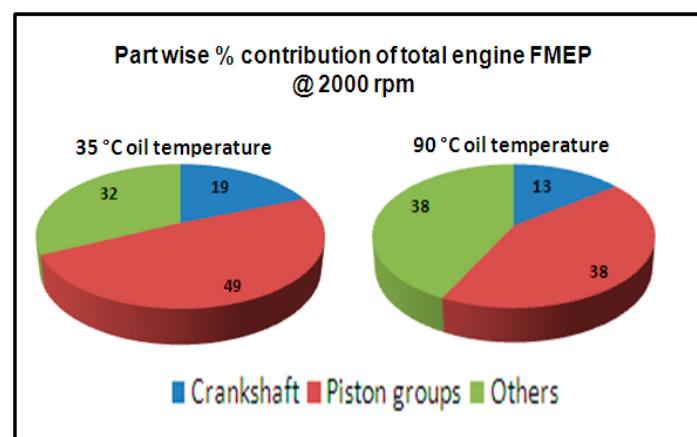


Fig 1 – Contribution of various engine parts in % FMEP

Reducing such losses is a very effective way of improving fuel economy. Such losses can be reduced by:

1. Design modification of base engine components.
2. Better process controls during production (eg. better surface finish/lower distortion of cylinder bore)
3. Modification of lubricating oil properties

This paper discusses in detail the effects of low viscosity lube oils on fuel economy and durability of passenger car diesel engine

LUBE OILS FOR FE IMPROVEMENT

Reduction in friction is a cheaper and easy to implement solution for increased fuel efficiency compared to other hardware changes. This has made OEMs and oil companies to formulate oils with enhanced base oil properties, introduction of friction modifiers and other additives.

Lubricating oil performs several key functions on PC diesel engines, of which friction reduction is in the scope of this paper.

Different engine systems experience different lubrication regimes which vary with operating condition. The frictional losses vary with the lubrication regime. These lubrication regimes are shown in below Stribeck Curve.

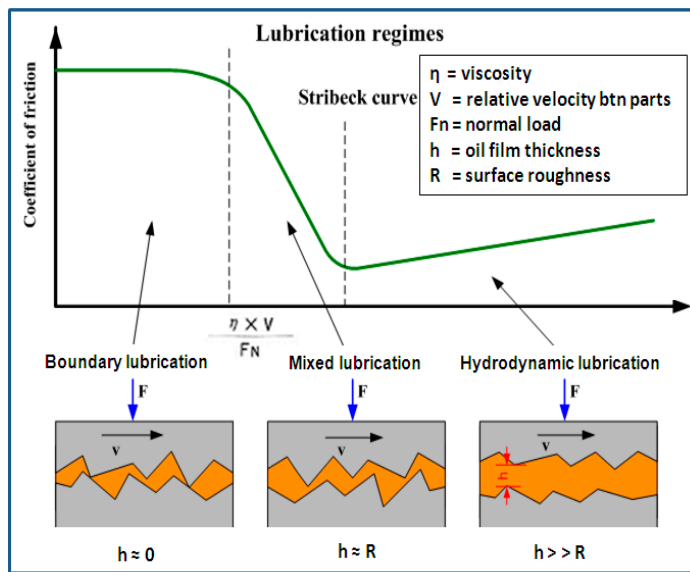


Fig 3 – Lubrication regimes

Main purpose of engine lubrication system is to ensure that all parts are under hydrodynamic lubrication regime for as much time as possible. This ensures minimum frictional losses and wear.

Lube oil characteristics play a very significant role in thickness of oil film and the viscous drag encountered in full hydrodynamic regime. Also they can significantly influence the friction in areas where lubrication regime remains in boundary or mixed regimes for most of the time (like in parts of piston ring/bore interface, cam-follower interface).

In table 1, the critical oil properties relevant to friction reduction are summarized:

Parameter	Influence
Kinematic viscosity	Influence on oil film thickness and viscous drag. Too high → higher viscous drag and higher friction. Too low → rupture of oil film and abnormal wear.
HTHS	Viscosity as seen by engine. Effective oil viscosity in high-shear rate components such as journal bearings and between piston rings and the cylinder liner under severe operating conditions with high oil temperatures and high engine speeds.
Friction modifiers	Molecules that adhere to surface and form a protective layer. Molecules have high compressive strength and low shear strength. Reduce friction between surfaces experiencing boundary and mixed lubrication. Acts at temperatures where antiwear additives are not yet active

Table 1 – Important properties of lube oil for friction reduction

The measurable advantage of each of these properties can be understood when different oils with variation in one or more properties are tested. Such formulations were tested for understanding friction reduction and fuel consumption improvement under several test regimes as mentioned below.

- 1) On HFRR – High Frequency Reciprocating Rig
- 2) On engine dynamometer: Motored engine
- 3) On vehicle chassis dyno: Emission cycle (MIDC)

FRICITION RIG TEST RESULTS

Various rig tests were done for initial screening of candidate oils. The details of oils screened on rig are as mentioned in table 2.

Oil	Kv at 100 deg C	HTHS viscosity	Friction modifier	SAE grade	Base oil
C1	14.6	4.1	None	15W40	GP1/GP2
C3	12.0	3.5	Organic	5W30	GP3
X3	12.1	3.5	None	5W30	GP3
C8	9.6	3.0	Organic	5W30	GP3
X1	9.6	3.0	Metallic	5W30	GP3
X2	9.7	3.0	None	5W30	GP3

Table 2 – List of candidate oils for rig test

HFRR (High Frequency Reciprocating Rig) test was done on all these oils.

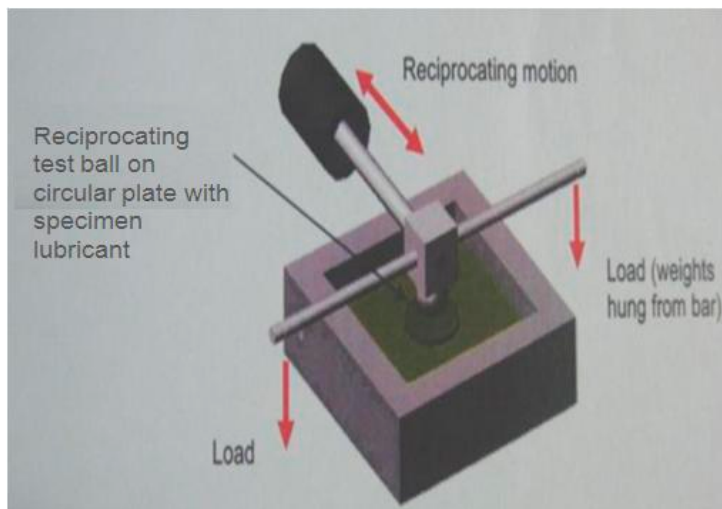


Fig 4 – High Frequency Reciprocating Rig

A ball is rotated on a circular plate with specimen oil in between. The load and stroke on the reciprocator arm and the oil temperature can be controlled as desired. The HFRR gives details of friction co-efficient and oil film thickness behavior at various engine oil temperatures.

Comparison of reference, X3 and X2 will show the effect of reduced kinematic viscosity and HTHS. All these oils do not have any friction modifiers.

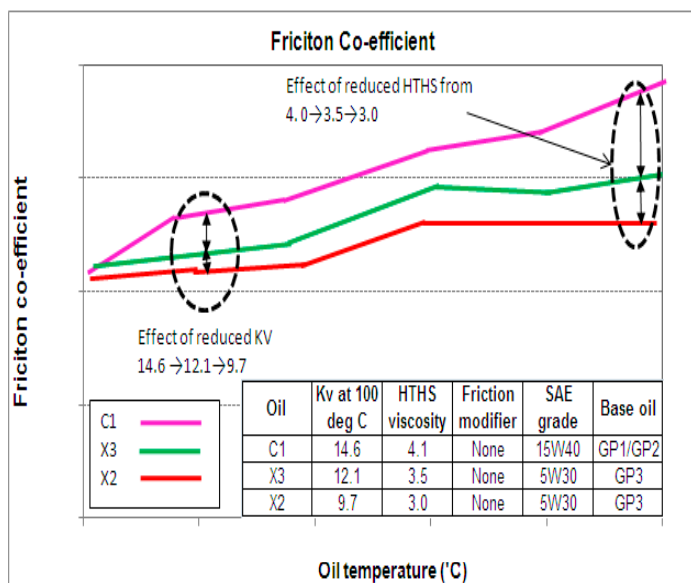


Fig 5 – Effect of Kinematic viscosity and HTHS

Figure 5 explains the influence of reduction in kinematic viscosity and HTHS. With oils X3 and X2, reduction in friction coefficient is seen. This reduction increases with increasing oil temperature. The reduction at low oil temperatures is primarily due to kinematic viscosity reduction. At higher temperatures, the friction reduction increases due to the effect of lower HTHS. This is evident from the fact that the friction reduction is larger with oil X2

than with oil X3. Oil X2 has lower HTHS than X3 even though viscometrics are similar.

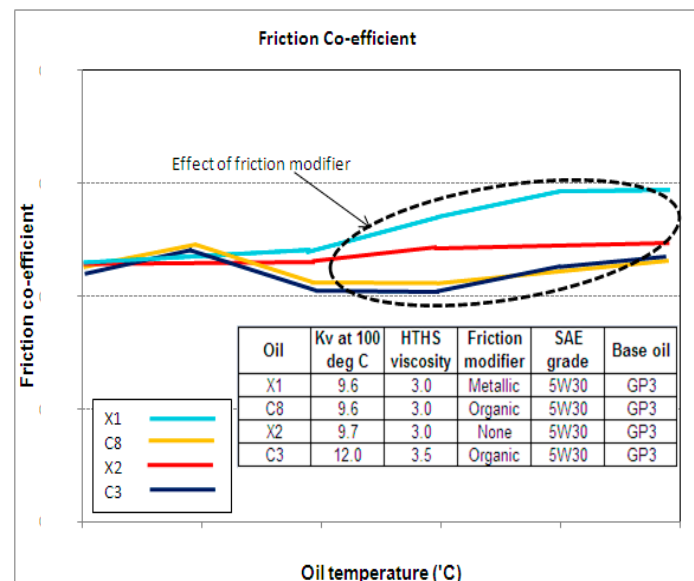


Fig 6 – Effect of Friction modifier

Shown in figure 6 is comparison of oils with similar kinematic viscosity and HTHS but different friction modifiers (FM). Oil X2 and X1 have similar kinematic viscosity and HTHS but X1 has a metallic friction modifier. Result is that up to a moderate temperature, the friction coefficient with X1 does not change but it increases substantially after that. This is contrary to the expectation that FM addition reduces friction. Oil C8 has kinematic viscosity and HTHS similar to X2 and X1 but has organic FM. C8 shows significant reduction in friction coefficient at higher temperatures. This is inline with the expectation of function of FM. This shows that effect of FM cannot be generalized and stated in isolation. Its affect is in combination with rest of the oil formulation and may also vary with the application.

Another interesting observation is with candidate oil C3, which is having higher kinematic viscosity and HTHS than X2. Still it is showing performance similar to C8. Both C3 and C8 are with organic friction modifiers. This proves kinematic viscosity and HTHS alone do not have influence in reducing friction. FM does have an effect in reducing friction co-efficient but only when it is selected carefully. Type of FM can sometimes have a detrimental effect in particular application like X1 in this case.

ENGINE BENCH RESULTS

On basis of rig tests, oils C3 and C8 were carried forward for further test. List of candidate oils tested on engine bench are mentioned in table 3.