A Study on Problem, Causes and Aids of Cold Start Performance on Internal Combustion Engine

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Abstract —

Internal combustion engine is sensitive to atmospheric condition. In the stage of cold start of an internal combustion engine, the cold start performance of an internal combustion engine on normal working is significantly higher than the condition at lower surrounding temperature. In cold climate regions cold start problem is a big issue and the review tries to view about this critical issue.

Keywords—Internal combustion engine, cold start performance, lubricant, CI engine.

I. INTRODUCTION

The power to drive the wheels of a vehicle is achieved by the internal combustion engine. Easy starting from cold is very important requirement of a CI engine. To ensure easy cold starting, frequently compression ratios higher than necessary are used [1].The lubricant system and a coolant system needs to served in internal combustion engine. The lubricant system is used to reduce friction in moving elements of engine and the cooling system is used for maintaining the temperature of engine within safe limit.

Table.1 Nomenclature

I.C.	Internal combustion
NEDC	New European Drive Cycle
S.I.	Spark ignition
C.I.	Compression ignition

It is largely accepted that the combustion efficiency of a modern internal combustion (I.C.) engine is well optimized, with approximately 98% of the energy contained within the fuel being released on combustion in diesel engines and 95–98% in gasoline engines[2]. The properties of lubricants are highly temperature dependent and without exception, engine lubricants are designed to be at their most efficient at steady state operating temperatures which range between 100 ^{0}C and 110 ^{0}C[3,4].Will et al. [5,6] estimated that frictional losses in the engine during the early stages of warm-up (when the engine is in the region of 20 ^{0}C) can be up to 2.5 times higher than those observed when the lubricant is fully warm. If this temperature is reduced to a cold-start scenario of 0 ^{0}C, then Samhaber et al. [7] predicted increases in fuel consumption of up to 13.5%.

During the engine warm-up phase, there are effectively three thermal masses interacting with each other, namely the main engine block, the lubricant and coolant [3].Of the three the coolant is the fastest to respond owing to its temperature being closely coupled to that of the combustion gases [2,9,10].In contrast, the lubricant temperature and block temperature are generally much slower to respond owing to the block having a large thermal inertia and the lubricant being much less closely coupled to the combustion process [4,11,12].

The desired increase in temperature of the lubricant during the warm-up phase results from some direct transfer of heat from the cylinder walls, but primarily results from frictional dissipation in the engine systems such as the main bearings [4,13,14].A optimum temperature of the lubricant is desirable, the excess heat of lubricant is undesirable, so it must keep attention to avoid overheating of the lubricant .For ignition in the CI engine depends on high temperature and pressure of the compressed air. For the combustion to take place in the short time available, the temperature must be high enough to exceed the self ignition temperature of the fuel by a sufficient margin [1].The requirements of easy cold starting often conflict with the other requirements of the engine such as greater air utilization, smooth running, and less smoke and air pollution[1].

II. COLD START ENGINE PERFORMANCE

Now a days by the use of common rail fuel injection, catalytic converter, improved lubricants and modified engine design, the performance of internal combustion engine has been improved, but the problem of cold start is still present in case of internal combustion engine. Andrews et al. [15] demonstrated that engine fuel consumption has a linear dependence on ambient temperature and this is shown in Fig. 1 [15] for a Euro 1 compliant S.I. engine. Over an urban drive cycle, the fuel consumption was shown to increase by 18% when the ambient temperature decreased from 31 ^{0}C to 2 ^{0}C.The work of Tobergte et al. [5, 16] highlighted a similar trend for three different variants of engine (a 1200 cc 3 cylinder S.I. engine, A 1400 cc 4 cylinder S.I. engine and an 1800 cc S.I. engine) as did Goettler et al. [17] with a 3.3 l S.I. engine.

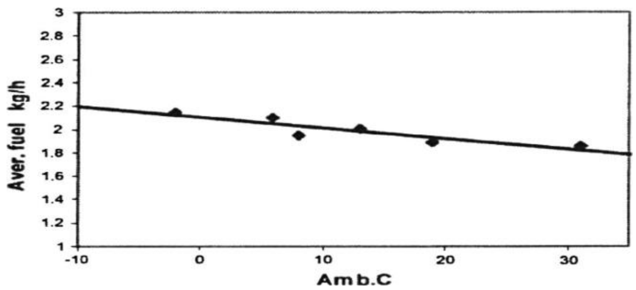

Fig.1. Effect of ambient operating temperature on fuel consumption over an urban drive cycle for a Euro 1 compliant S.I. engine [15]

Such observations are of critical importance to vehicle manufacturers as the NEDC test is required to beconducted from a soak temperature of between 20 ^{0}C and 30 ^{0}C [9] Similarly, Kunze et al. [12] presented data that showed that the fuel consumption of a gasoline engine reduced by an average of 10% over the duration of the NEDC when the start temperature was increased from 25 ^{0}C to 90 ^{0}C.

The vehicle gives acceptable performance when it fully warm up, a poor cold start performance being assigned a high fuel consumption. Therefore it is necessary to make attempts to improve the cold start and warm up phase of IC engine, particularly for a consumer whose driving habits are for a short distance that the engine doesn't reaches the optimum operating temperature of the engine. Goettler et al. [17] estimated that up to 80% of trips made in the United States of America are less than 15 km in length whilst Jarrier et al. [18] claimed the mean European car journey is approximately 10 km. Andrews et al. [19] reported the findings of André who found that from a survey of 35 vehicles, 52% of the vehicle journeys made were less than3 km in duration. Later work by André [20] concluded that one third of car journeys are completed before the engine is fully warm.

III. COLD START CAUSE AND PROBLEM

To ensure easy cold starting, frequently compression ratio higher than necessary are used. Even so, cold starting may difficult in:

1. Extreme cold climate like Himalayan region
2. When the cylinder liner is heavily worn, and
3. When the valves are leaky. It is, therefore, sometimes necessary to provide some electrical aid for cold starting [1].

Considering the work of Trapy and Damiral [4] , Zammit et al. [21], Andrews et al. [13] and Shayler et al. [14,22], it can be concluded that the primary mechanism of lubricant heating during the warm-up phase of an I.C. engine is from increased frictional work in the bearings. Critically, both Zammit et al. [21] and Shayler et al. [22] show that much of this heat is not effectively retained in the lubricant but is instead transferred via the bearings to the rest of the engine.

A engine cold start performance is lower due to increased frictional losses in bearings. The viscosity of lubricants is to high at lower temperature.

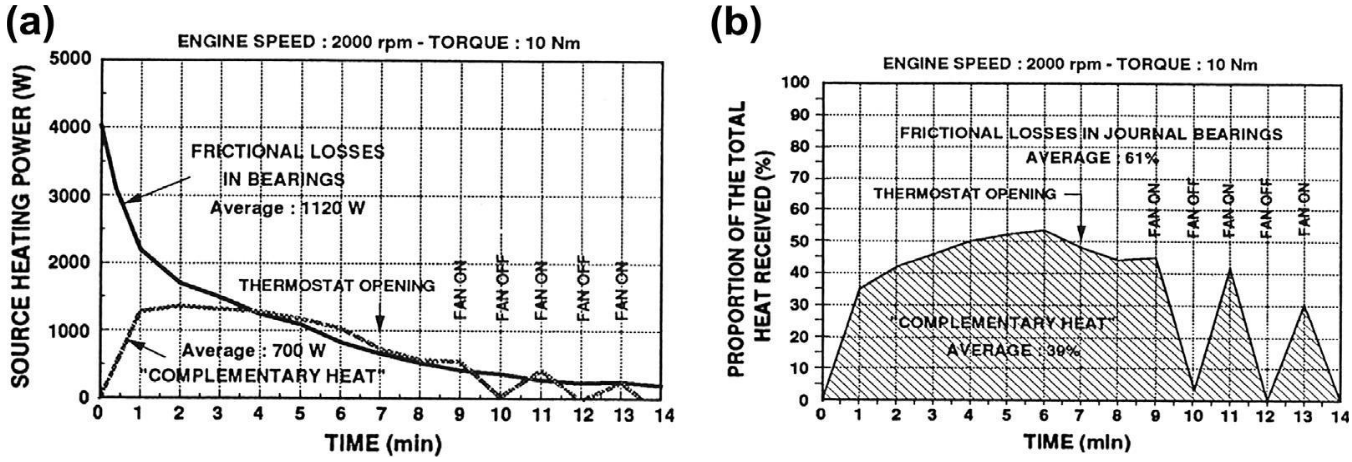

Fig.2. Frictional losses within an I.C. engine providing heat input to the lubricant system for a 1.7 l S.I. engine. Complementary heat to the lubricant is also shown and is a term for all other heat sources to the lubricant including combustion heat and heat from the coolant [4].

The sensitivity of lubricant viscosity to temperature means that the viscosity has resulted in the lubricant viscosity reducing by 65% in the first 20 ^{0}C of heating and therefore small temperature increases could reduce friction considerably [15]. Kunze et al. [12] estimated that to heat the 10 l of lubricant in an S.I. engine would require 2.0 MJ of energy. Andrews et al. [15], accounting for lower ambient running conditions and a higher peak temperature requirement believed that 2.5 MJ would be a more accurate estimate and that the CO_2 emission penalty for such a process was 12.5–22 g CO_2 km 1 which represents 18% of the 130 g km 1 target. Will [6] estimated that if engine friction can be reduced, then the running cost of the vehicle over a 150,000 km lifetime could reduce by €1500–2100.

The problem of cold start is take place on vehicles which are used for short journeys, in that case the engine doesn't reach its operating temperature before being the vehicles stoppage. There is both a minimum and maximum speed for cold starting of CI engine. At very low speeds the engine will not start because of high heat losses to the cold walls of the cylinder during compression and greater time available for leakage past the piston rings. Though it may look somewhat uncon – vincing, the engine may also not cold start at too high speed because of too short a time available for vaporization and preparation of mixture chemically for ignition. The optimum speed for cold starting depends on surface-volume ratio (which controls the heat loss to cylinder walls), intensity of air swirl (higher swirl makes the cold starting difficult due to removal of stagnant 'insulator' gas film), and the physical condition of engine (leakage past piston and valves reduces temperature and pressure of compressed air) [1].

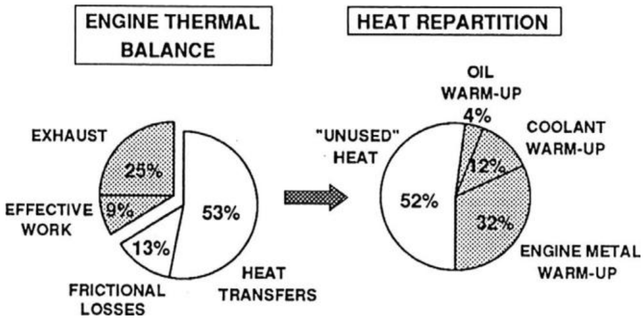

Fig.3. Energy thermal balance diagram during warm-up of a 4 cylinder 1.7 l S.I. engine [4]

Fig.3.presents data which describe the energy balance of an engine during the warm-up phase. The left-hand chart provides an energy thermal balance at the combustion chamber and the right-hand chart provides a breakdown of the

53% of energy that is transferred as heat to the cylinder walls. The energy transferred to the cylinder walls causes the coolant, the metallic structure (including the block and crankshaft) and the lubricant to warm up. However, what is indicated is that 52% of this heat energy is not found to warm-up any of the ancillary circuits (such as the lubricant or coolant), but is instead lost directly to the environment (termed 'unused heat'). It should also be noted that only 4% of the heat from combustion will be found to actually warm up the lubricant [8].Similarly, the theoretical modelling work of Samhaber et al. [7] detailed the energy balance of the heat sink of a diesel engine (offering comparative data to that presented in the right hand part of Fig.3). In this work, it was found that 60% of the energy was used to heat the structural parts, with approximately 20% being absorbed by the coolant and 10% by the lubricant. Thus, the lubricant once again receives a small proportion of the energy available [8].The proportion retained in the metal structure is higher in the work re-ported by Samhaber et al. [7] and a possible reason may be that the work of Samhaber et al. was based on the NEDC with varying load.

IV. COLD STARTING AIDS

Many methods have been used in the past to achieve easy cold starting. Few of them are described below:

1. *Injection of a small quantity of lubricating oil or fuel oil:* This method helps by temporarily raising the compression ratio and sealing the piston rings and valves.

2. *Provision of cartridges:* This may be self-igniting or requiring lighting before insertion into the combustion chamber.

3. *Starting as petrol engines:* The engine is provided with a sparking plug and carburetor. At starting, compression ratio is reduced by providing an auxiliary chamber and the engine is started as a petrol engine.

4. Preheating the engine cylinder by warm water.

5. Modified valve timings for starting [1].

Basically three types of starting aids are used on modern high speed diesel engines:

(i).Electric glow plugs in the combustion chamber.

(ii).Manifold heaters which ignite a small feed of fuels.

(iii).The injection into the intake, of controlled amounts of low ignition temperature liquids, usually ethyl-ether with addition of other author fuels [1].

Electrical glow plugs are used as localized igniter to start the combustion with optimum reliability. However the presence of the plug and its recess reduces the engine performance slightly [1].Manifold heaters used small electrical heaters which heats the ingoing air passing through the heaters. The combustion is start due to this heat of the air as well as chemical reaction of the products of combustion [1].

Ether has a very low self ignition temperature and has wide range of mixture strength. Therefore injection of a small amount of externally carbureted mixture (with limited air to avoid too high pressure rise) would fire a diesel engine even at very low ambient temperature or at low cranking speeds [1].

V CONCLUSION

Through the study, it is seen that, the cold start performance of the IC engine is poor at cold climate like Himalayan region. However the fuel consumption and emission are controlled to a optimum level. When the vehicle driven to a short distance, the temperature of the engine doesn't reach the actual operating temperature of the engine (i.e. it is not fully warm up).Then the cold start performance is poor and slightly higher compression ratio is required.

It is necessary to improve the cold start performance of the engine with other requirements like smooth running, better air utilization and less smoke & air pollution.

During cold start it has been seen that there are following considerable facts:

(i).For well combustion condition and greater emission quality it is necessary to improve cylinder liner temperature warm-up.

(ii).For minimize the friction between moving elements of engine, it is necessary to improve the rate of lubricant warm-up.

(iii).For treatment of exhaust gases, catalytic converter is used.

Given that it has been shown that there is a consumer trend to complete multiple short trips in a day, with an average stationary period of 3 h 45 min [20], the ability to maintain lubricant temperatures 10 C higher than normal after 2.25 h [9] is of clear benefit, particularly given the sensitivity of lubricant viscosity to temperature.

For easy cold starting many aids are used, in past are injection of a small quantity of lubricant oil or fuel oil, provision of cartridges, preheating the engine cylinder by warm water, modifying valve timings for starting. And modern cold starring aids are use of electric glow plugs, manifold heaters and injection of ether [1].

In conclusion, it tries to give a review about cold start performance of internal combustion engine. It must tries to view the internal combustion engine cold start problem, causes and cold start aids.

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