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ScienceDirect

Energy Procedia 82 (2015) 1 – 8

Energy Procedia

ATI 2015 - 70th Conference of the ATI Engineering Association

Effects of oil warm up acceleration on the fuel consumption of reciprocating internal combustion engines

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Abstract

The homologation cycle of vehicles for private passenger transportation or for light duty applications considers a cold start from ambient temperature. The most part of harmful substances (≈ 60-65 %) are produced during the thermal engine stabilization which occurs in the very of the driving cycle. This strongly influences also engine efficiency, i.e. fuel consumption. The more recent commitments on CO_2, therefore, reinforce the concept of reducing warm up time encountering it in the low carbon engine technologies. Due to this importance, engine thermal management has been the subject of a huge interest opening the way to new components, technologies and control strategies. This regards not only the coolant fluid, which undoubtedly influences engine warm up, but also the lubricant:an its heating acceleration produces much faster benefits.. The purpose of this paper is to assess the effect of a faster oil heating during the homologation cycle on the fuel consumption. An experimental campaign has been done on an 3L Iveco F1C engine mounted on a dynamometer test bench operated in order to reproduce the NEDC. The engine OEM has been characterized and the effect of the oil temperature has been studied according to: (a) an external heat source which brings the oil at its stabilized temperature value before engine start, (b) an internal heat source represented by the exhaust gases which almost immediately reach a temperature value able to heat-up the oil. The effects on CO_2 emissions during the cycle have been evaluated. The benefits are noteworthy and justify some oil circuit modifications.

Peer-review under responsibility of the Scientific Committee of ATI 2015

Keywords: internal combustion engine, oil thermal management, emissions, fuel consumption

1. Introduction

In response to actual global sensibleness on environmental issues, internal combustion engines lives a technological revolution in order to to achieve more efficient energy conversion and reduce pollutants emissions.In this regards, European Community and others international governments set important

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Peer-review under responsibility of the Scientific Committee of ATI 2015
doi:10.1016/j.egypro.2015.11.870

targets on pollutants (HC, CO, NOx and PM) and CO_2 emissions from passenger cars and light duty vehicles. European manufacturer are on-the-road to achieve the 95 g/km target (which is an average fleet value, based on the vehicle mass) on the carbon dioxide emissions: they reached a strong reduction in recent years, touching an average value of about 130 g/km in 2013 (Figure 1), but the yearly reduction can not keep this trend without a technological breakthrough. In fact, before EC first proposal of a regulation on the transportation emissions (2007) the yearly reduction was about 1%, and only after this milestone the average reduction reaches 3-4% per year (Figure 2).

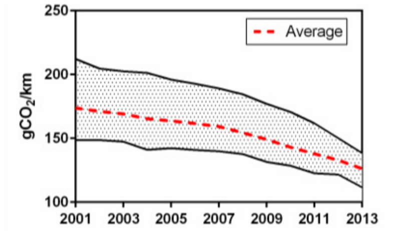

Figure 1: CO_2 emissions trend of European carmakers [1]

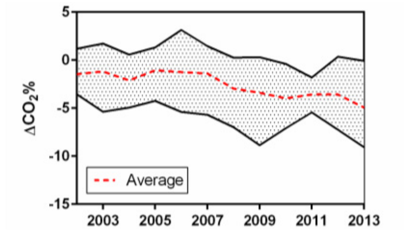

Figure 2: year reduction of CO_2 emissions of EU[1]

This CO_2 evaluation passes through homologation procedure according to specific driving cycles, which considers the cold start of the engine. Unfortunately, in a typical homologation cycle the engine reaches its thermal steady state very close to the end of the cycle and lubrication oil does not even reach a regime temperature. When these fluids and engine components are below their steady temperature, the thermal efficiency of an ICE is significantly reduced as it happens during the cold-start phase: combustion quality is poor and mechanical losses are high. A fast engine warm up decreases the cold phase in the homologation cycle and produces sensible benefits in terms of fuel saving and pollutant reduction [2, 3].

The technics to reduce warm up phase falls into the terms of “thermal management”: this subjectaims to lead as faster as possible metallic components to their stabilized temperatures, instead of waiting that the engine does it “naturally”, according to traditional technological solutions. Engine cooling strategies have recently evolved with the use of electronic components in the cooling system. Electric pumps, thermostats, and fans play major roles in decreasing the losses [4]. Use of switchable pumps reduces the parasitic losses from auxiliary components and allows better control of the engine temperature for the best engine efficiency [5, 6]. In the same way, new cooling layouts [7-9] and advanced thermostat [10] were considered. Light metal alloys were also extensively adopted with higher thermal conductivity [11].

Lubricating oil plays an important role in overall engine efficiency: a faster oil warm up would improve mechanical efficiency which is particularly low during homologation cycle when engine is cold. A decrease in lubricant warm up time, however, is more critical to be reached: oil warm up rate is about three times lower than the coolant one [12] and it does not reach its optimal temperature during a traditional homologation drive cycle [13]. During the warm up phase, oil viscosity is much higher than at regime condition and, so the engine FMEP can be till 25% higher during cold phase with respect to the hot stabilized phase [14, 15]. Only recently, the possibility to reduce the warm-up time of the transmission and engine oils have been introduced [16, 17]: using exhaust heat to increase their temperature, the fuel economy improvement is up to 4.4% on regulatory cycles.

In this paper, the Authors present an experimental campaign aimed to reduce oil warm up time. Tests were done on an Iveco F1C engine test bench, in steady working points and during a NEDC cycle. The engine OEM has been characterized and the effect of the oil temperature has been studied according to: (a) an external heat source which brings the oil at its stabilized temperature value before engine start, (b) an internal heat source represented by the exhaust gases which almost immediately reach a temperature able to speed up oil temperature. The effects on CO_2 emissions and fuel consumption during the cycle