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THE IMPACT ASSESSMENT OF DOWNSIZING ON THE DEVELOPMENT OF INTERNAL COMBUSTION ENGINES REFERRING TO THE COMPETITION "ENGINE OF THE YEAR"

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Abstract

Downsizing internal combustion engine is recognized as one of the development trends of the construction of thermal machines. Based on the design and operational factors of engines that winners are in different categories of the international competition "Engine of the Year" attempted to assess the real impact of the engine miniaturization. The paper discusses the idea of the competition and characterizes engines downsizing. Completing the goal of the research carried out various studies linking parameters such as torque and engine power, fuel consumption, carbon dioxide concentration and the downsizing factor. It has been demonstrated fulfilment of the downsizing idea in engineering practice and its impact on the development of the automotive industry. The study indicates that modern internal combustion engines should have a specific power with a value of more than 68 kW/dm^3, specific torque factor of 127 Nm/dm^3 and the volumetric emission of carbon dioxide form exhaust into the atmosphere should not exceed 83 (g/km)/dm^3.

Keywords: *Engine of the Year, downsizing*

1. Introduction

Due to the global population increases and the rapid development of industrialization, it brings the growth in carbon dioxide emissions, making the global warming caused by the greenhouse effect. One fourth of global emission belongs to the transport with combustion engines as still dominated sources of power [2-4, 6]. Human existence sounded the alarm and that makes automotive technology with the new requirements to improve engines efficiencies. At the same time, the latest legislative CO_2 requirements have been determined by many countries. Therefore, there are multi-pronged strategies in order to comply with the stringent emission norms that are being enforced around the world [7]. For the future, which direction of the engine developed? One of the options is combustion engine downsizing by reducing swept volume. Easily to understand that the engine downsizing is the use of a smaller engine in a vehicle that provides the power of a larger engine, through the use of recent technologies (boosting, direct fuel injection, variable valve timing, variable compression ratio, controlled auto-ignition or homogenous charge compression ignition etc.).

The most spectacular examples of the downsizing are the Ford's engines mounted among other vehicles to the Ford Focus model. In 2004, it was 1.6 dm3 16V-engine, which had the power of 73.8 kW at 5500 rpm and 150 Nm at a speed of 4000 rpm. In 2012, the engine called *EcoBoost* with swept volume lower by 38%, has replaced earlier, including 1.6 dm^3 mentioned. This engine has 0.999 dm^3 and gives a power of 90.5 kW at a speed of 6000 rpm and a torque of 170 Nm at 4500 rpm – so even higher than base.

If it deeper considers that the base engine for the 1.6 dm^3 was 3.5 dm^3 V6 engine and for it there was another engine with displacement of 6.2 dm^3 V8, it should be noted the presence of

a series of downsizing with a range of specific power figure of 46 kW/dm^3 for individuals 1,6 and 6.2 dm^3 to 90.5 kW/dm^3 for engine 0.999 dm^3. [5]

The fact that mentioned *EcoBoost* engine was a multiple winner of several categories of competition *Engine of the Year* made it was decided to verify the trend towards downsizing as the examples of the engines, which in many categories for several years were winning in that competition.

The International Engine of the Year is an annual competition for automotive industry of internal combustion engines. Judges from around the world apply their impressions from driving today's latest cars to help them find the power plants that offer the best drivability, performance, economy, refinement and reward manufacturers for the successful application of advanced engine technology. The Competition was started in 1999, and it has become a highly prestigious award [8]. There several competition categories regarding first of all engine capacity started sub 1-litre to above 4-litre. There are also the special categories to identify special properties like fuel economy for and technologies dedicated to environment protection – *Green Engine*, specifically design for sport performance – *Best Performance Engine*, brand new solution in engine application – *Best New Engine* and winners due to all things – *International Engine*.

2. Downsizing in automotive accomplishment

In reciprocating engine, displacement is the volume swept by piston inside cylinder in a single move from top dead centre to bottom dead centre. If an engine has more than one cylinder, the displacement is the sum of all the volume from each cylinder. Engine displacement is one of the most important structural parameters and is closely related with many design parameters and operating indicators as follows: number of cylinder, number of valves, block and cylinder head materials, torque, power, engine revolution, compression ratio, fuel consumption, carbon dioxide emission.

Directly to the user important is the relationship between swept volume and the power, torque and carbon dioxide. Values of power and torque are distributed evenly, with a slight upward trend in individual years, which means fulfilment of the expectations of users, but at the same time maintaining the proportions of these indicators in each category.

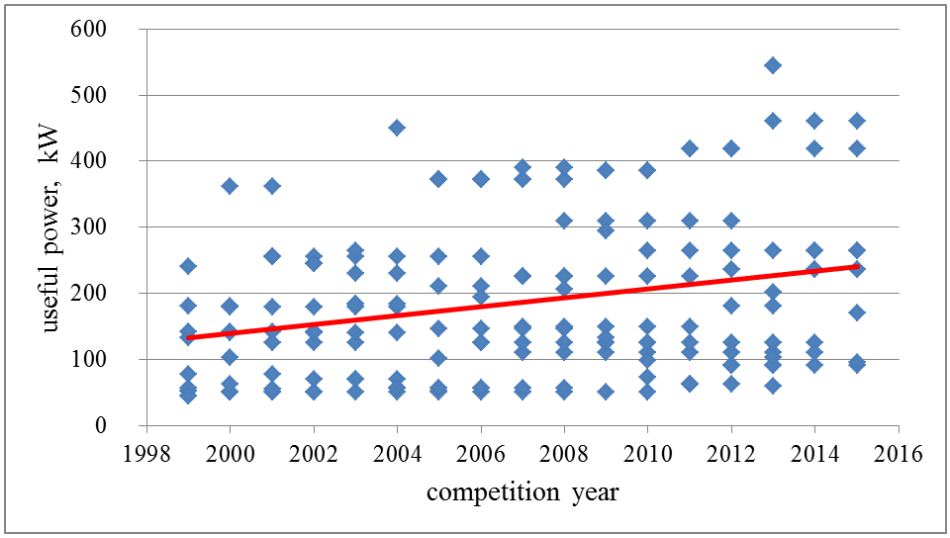

Fig. 1. Combustion engine useful powers of winners in the competition "Engine of the Year" for all categories

Emissions of carbon dioxide from exhaust into the atmosphere decreases as a function of the years of production (Fig. 3), which confirms the expected trend to reduce the causes of global warming.

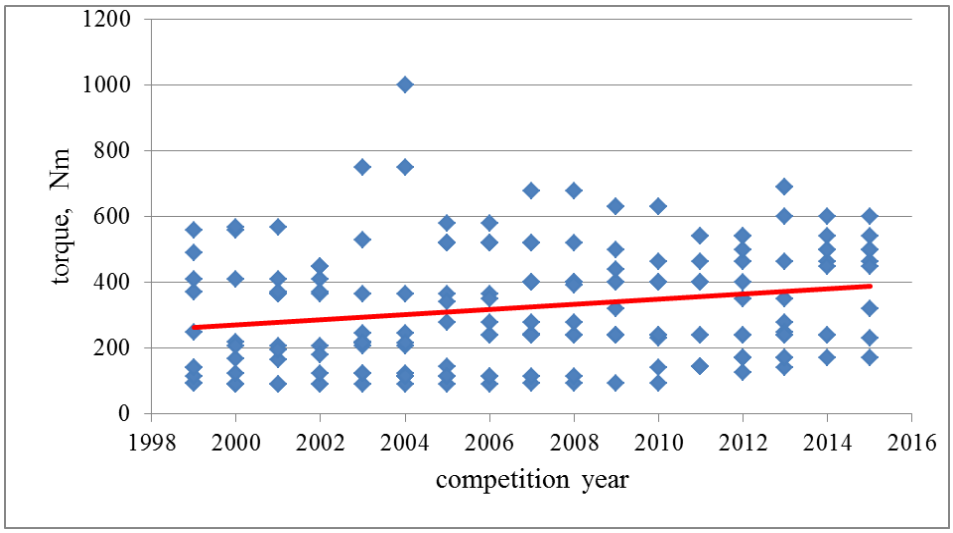

Fig. 2. Combustion engine torques of winners in the competition "Engine of the Year" for all categories

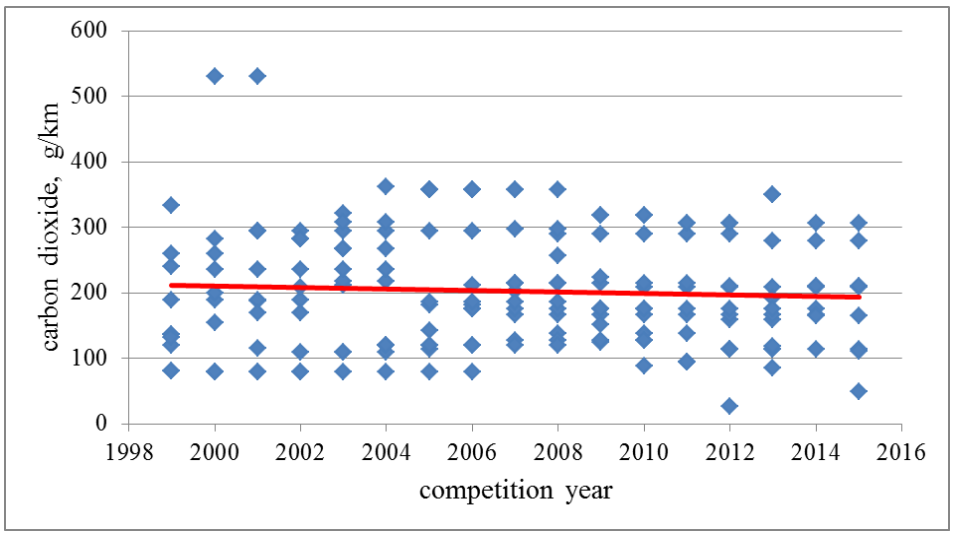

Fig. 3. Carbon dioxide emission regarding to the NDES test for combustion engines as winners in the competition "Engine of the Year" for all categories

The essence of market recognition of the implementation of the internal combustion engine downsizing techniques is to assess the volumetric indicators, called specific power, specific torque and specific carbon dioxide emission. Comparing two separate specific indicators: power and CO_2 emissions in one graph (Fig. 4.) and engine torque and carbon dioxide emission (Fig. 5.) as indicators directly related to the process of downsizing, obtained an engaging zone of combustion engines covered by the competition *Engine of the Year* as a reference area for other engines.

They were also studied the geometric mean of two-dimensional surfaces, which are indicators of development engines. They are 83 (g/km)/dm^3 for carbon dioxide emissions, 68 kW/dm^3 for useful power and 127 Nm/dm^3 for the torque. On this basis, it could make a comparative analysis of other engines, recognizing the values determined by the statistical parameters of the internal combustion engine base indicators.

The presence of downsizing techniques in a group of engines covered by the competition *Engine of the Year* over the years can also be demonstrated by the global geometric mean in terms of specific power and carbon dioxide emissions (Fig. 6). The figure shows the different rate of change (coefficients of linear function), which are the strongest for volume strength indicator (a = 2.7645) towards decreasing function of changes in carbon dioxide emissions with constant a = = –0.2375. Characteristic is also the convergence of the geometric mean of volumetric indicators

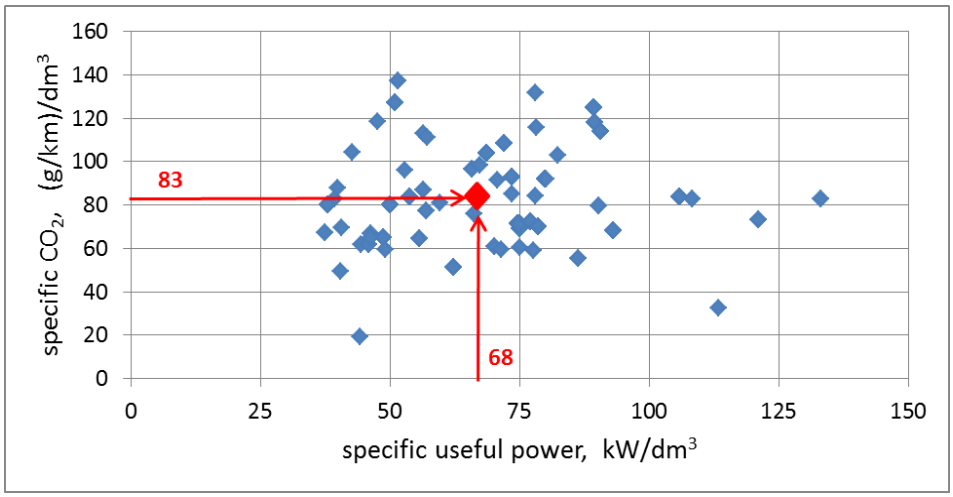

Fig. 4. The volumetric power and carbon dioxide emissions indicators of engines as winners in the competition "Engine of the Year" for all categories

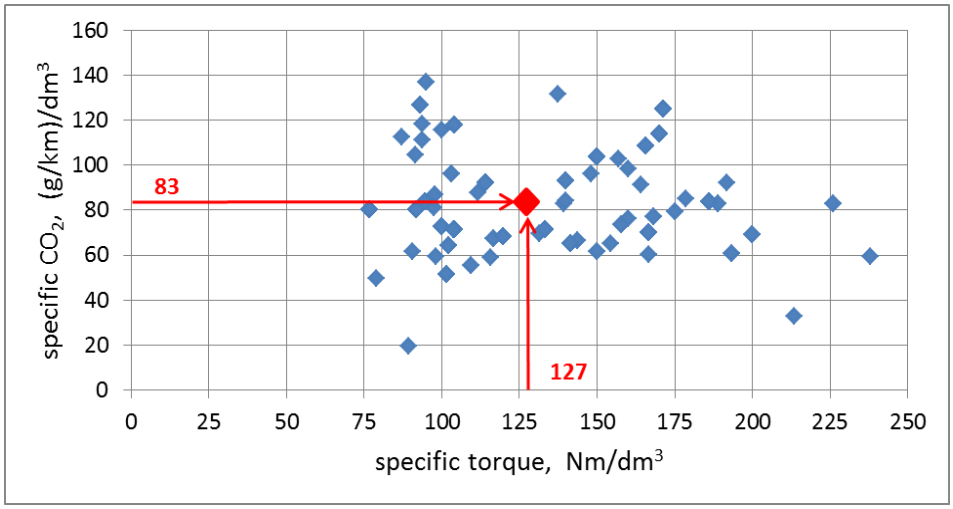

Fig. 5. The volumetric torque and carbon dioxide emissions indicators of engines as winners in the competition "Engine of the Year" for all categories

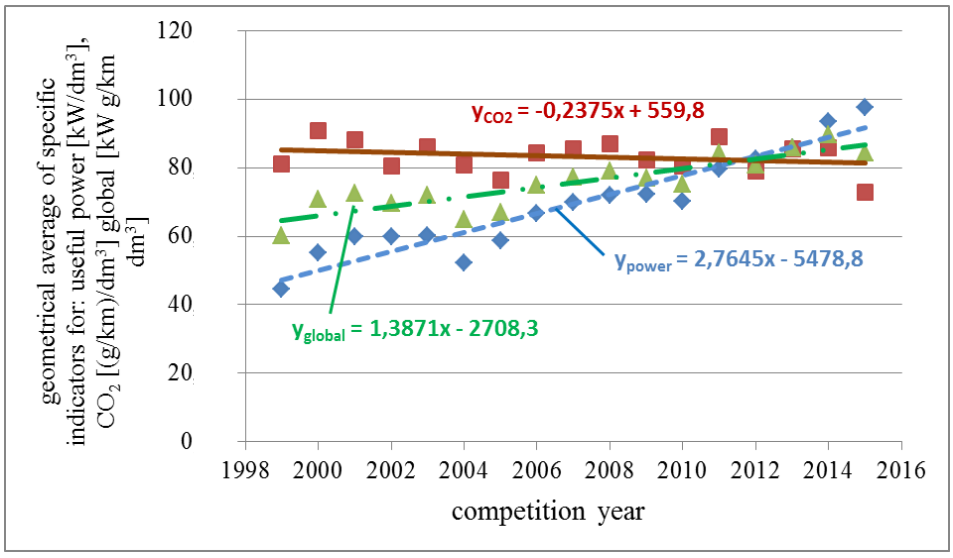

Fig. 6. Changes in geometric mean of specific power and CO_2 emission and global trend vs. manufacturing year within the competition "Engine of the Year"

over the years, which in 1999 formed the interval from 44 to 80 and in 2015; this range has shifted in the direction of larger values and narrowed down from 72 to 97 values of indicators.

Similarly, the global geometric mean in terms of volumetric values for torque and CO_2 emissions could be defined (Fig. 7).

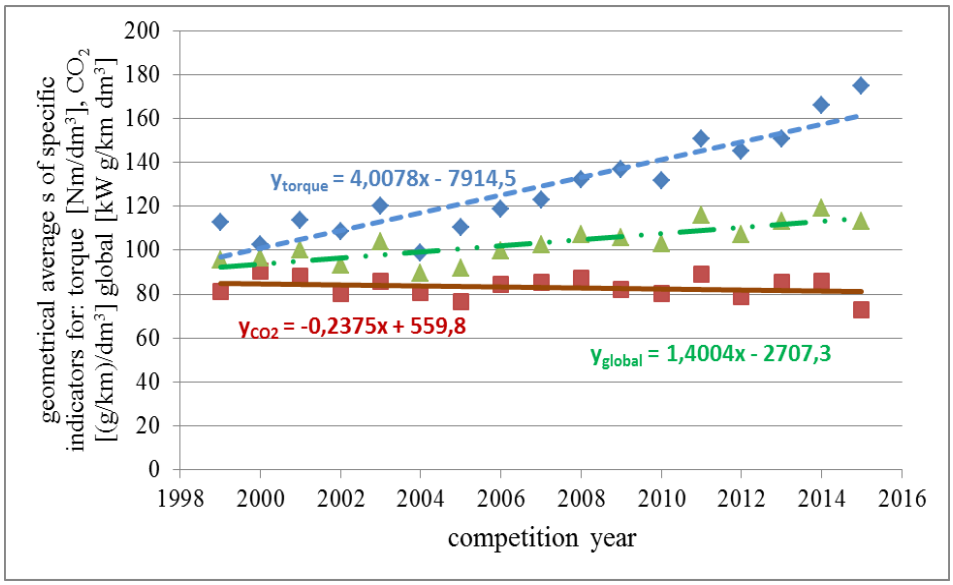

Fig. 7. Changes in geometric mean of specific torque and CO_2 emission and global trend vs. manufacturing year within the competition Engine of the Year

From the mentioned figure can be read rate of change in each indicators over several years. For the specific torque (which corresponds to the change of mean effective pressure in the combustion chamber) function factor is a = 4.0078, which means a much larger increase in changes in relation to power and in opposition to the declining function of changes in carbon dioxide emissions with constant a = –0.2375. In the case of torque, it could be observed divergence in the geometric mean of volumetric indicators over the years. It confirms the trend of development of internal combustion engines, for which specific torque increases versus decreasing the emission of carbon dioxide.

The collected data refer to engines have gained top ratings, but there were much wider set of models. It is estimated that average per year in each competition typed are 5 to 10 units for each category, which makes the research group over the 16 years from 1000 to 2000 units. If, therefore, in this wider group will be identifying the actual share of downsizing, it can point to a few master examples, as follow: 2.0 FSI vs. 1.4 TSI Volkswagen manufactured, 1.4 FIRE vs. 0.9 TwinAir by Fiat and 1.6 16V vs. 0.999 EcoBoost by Ford.

The 2.0 FSI engine was a drive unit in 2005 for VW Passat. Its power reached the value of 110.4 kW at 6000 rpm and the torque equalled to 200 Nm at 3000 rpm. This engine has been replaced by 1.4 TSI with the same power but a slight greater torque of 220 Nm at 5500 rpm. The change in displacement is 30%, which is a measure of downsizing.

Another example is the Fiat 1.4 FIRE engine mounted in a vehicle; inter alia, the Fiat 500. It had, in 2010, the power of 70.1 kW at an engine speed of 6000 rpm and torque of 127 Nm at 5500 rpm. In 2011, it produced its "successor" with swept volume of 0.9 dm^3, codenamed TwinAir, which parameters were as follows: power = 77.2 kW at 5500 rpm and 145 Nm of torque to 2000 rpm. Change the swept volume in this case is 35% and is accompanied by an increase in power and torque.

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engine with lower swept volume by 38% called EcoBoost with 0.999 dm^3 replaced earlier ones, including 1.6 dm^3. This engine has a power of 90.5 kW at a speed of 6000 rpm and a torque of 170 Nm at 4500 rpm.

If it considers that the base engine for the 1.6 dm^3 was 3.5 dm^3 V6 engine and for it there was another engine with displacement of 6.2 dm^3 V8, it should be noted the presence of a series of downsizing with a range of volumetric indicators of 46 kW/dm^3 for individuals 1.6 and 6.2 dm^3 to 90.5 kW/dm^3 for engine 0.999 dm^3.

3. Summary

After systematizing data on the engines of the competition, *Engine of the Year* demonstrated environmental efforts in the development of internal combustion engines. It highlights the significant changes volume indicators: power, torque and emissions of carbon dioxide. The study indicates that modern internal combustion engines should have a specific power with a value of more than 68 kW/dm^3 and the volumetric emission of carbon dioxide form exhaust into the atmosphere should not exceed 83 $(g/km)/dm^3$.

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