

THE PROFITABILITY OF DISPOSING OF VEHICLES FULFILLING THE OLDER EURO STANDARDS IN TERMS OF CO₂ EMISSION

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Abstract

The automotive market is developing very dynamically. In recent years, we can observe activities of automotive concerns in the production of new models of electric, hybrid and hydrogen vehicles, and conventional cars are supplied with increasingly economical and low-emission engines. There are also increasingly stringent standards related to exhaust emissions from the exhaust system. From September 1, 2018, passenger cars have to comply with the Euro 6d-Temp emission standard and be homologated according to the WLTP test procedure including the WLTC driving cycle and emission measurements in road traffic conditions. The exhaust components measured during the test, such as carbon oxides, nitrogen oxides or hydrocarbons, are toxic to living organisms. However, it seems that the most important issue in the long term may be the value of carbon dioxide emissions, the excess of which poses an ecological threat to the entire planet. The production of new vehicles equipped with modern complicated combustion engines, batteries, fuel cells and electronic devices is associated with a very high emission of this greenhouse gas. The authors of the following article, based on their own research, sought to estimate the ecological profitability of replacing a used passenger car meeting the Euro-4 emissions standard for a new vehicle bearing in mind the value of carbon dioxide emissions during vehicle production. The analysis was to indicate how intensive the annual operation of the vehicle should be to make it profitable to recycle and replace it with a modern car with lower emissions considering the global sum of carbon dioxide emissions.

Keywords: CO₂ emission, exhaust gasses, cars, engines

1. Introduction

The use of motor vehicles has certain consequences: economic, social, and ecological. In recent years, particular attention has been paid to the ecological aspects of car use. This is due to the fact that components such as carbon oxides, nitrogen oxides, or hydrocarbons released by internal combustion engines are toxic to living organisms. However, it seems that the most important long-term issue may be the value of carbon dioxide emissions, the excess of which poses an ecological threat to the entire planet.

The increase in the concentration of carbon dioxide in the atmosphere is the cause of a number of adverse phenomena, including global warming. Global CO₂ emissions, in the years 1990-2010, increased around 49% [1, 10]. In the same years, the average reduction of CO₂ emissions for European Union countries was 12%.

Officials of the European Union responsible for transport and environmental policy introduce increasingly restrictive standards related to exhaust emissions from the exhaust system. From 1

September 2018, passenger cars registered in the European Union must comply with the Euro 6d-Temp emission standard and be homologated according to the WLTP test procedure including the WLTC driving cycle and measurements of emissions in road traffic conditions. In recent years, we can observe activities of automotive concerns in the production of new models of electric, hybrid and hydrogen vehicles, and conventional cars are supplied with increasingly economical and low-emission engines. This is of course related to the new EU emission standards.

However, both officials and, above all, car buyers and the general public are missing the fact that the emissivity of the vehicle during its use by the buyer is just one of many, not the most important component, the total environmental impact of the vehicle throughout the product life cycle. It should be noted that the production of new vehicles equipped with modern, complicated combustion engines and electronic devices is associated with very high emission of carbon dioxide. The high emission of this greenhouse gas is particularly high in the case of the production of hybrid and electric cars equipped with high capacity batteries. The ecological impact of a new vehicle on the environment starts much earlier than the finished product leaves the company's production line. With serious carbon dioxide emission, we are already struggling at the stage of extracting raw materials necessary for the production of a car, through the whole production process, to transporting the finished car to the dealer's salon.

The above situation is profitable from the economic point of view for producers - they present mass production of new passenger cars and the replacement of a car park by buyers as a pro-ecological activity. In fact, it can only be an advertising gimmick or procedure in the field of public relations, because the carbon dioxide emission associated with the creation of a new passenger car is extremely high [1, 2].

It is also worth noting that the cumulative CO₂ emission in the production of a passenger car is directly proportional to its own weight. It should be emphasized at this point that despite the increasing use of lightweight materials for car construction, the own weight of subsequent models over the years 1990-2019 increased by a dozen or even more than 20 percent. In 1990, the average compact class car weighed 1000 kg – today it is usually around 1200 kg and more. In 1990, the average middle class car weighed about 1100-1200 kg; today it is usually about 1400 kg.

The cumulative CO₂ emissions occurring in the construction phase of the VW Golf class car in 1990 are 4.1 tons, while its equivalent in 2000 is 4.3 tons of CO₂ / vehicle [2]. It is assumed that the CO₂ emission associated with the production of a modern B / C class car is 5.6 tons of CO₂ / vehicle [4].

What is also worth noting, despite the fact that the cumulative energy inputs occurring in the construction phase of passenger cars from 1990 and 2000 decreased, the summary of cumulative CO₂ emissions occurring in the construction phase of these cars indicates their upward trend (with the same mass of the compared passenger car). The cumulative emissions of noxious SO₂ and NO_x gases occurring in the construction phase of a passenger car, comparing the 1990-2000 models, also increased (by 10% in the case of SO₂ and over 25% in the case of NO_x) [4].

The situation of CO₂ emissions related to vehicle production is primarily due to major material changes that have been noted in the last decades in the field of car construction. First of all, it is about the increase in the use of aluminum and its alloys, as well as a very large increase in the share of plastics and rubber in the mass of subsequent models introduced for the production of passenger cars. This increase took place at the expense of reducing the share of steel, cast steel, and cast iron. Such changes concerned and concern cars of all makes and classes [3].

The tendencies demonstrated above on the example of cars from 1990 and 2000 in the following years not only did not stop, but even experienced high acceleration. More and more new car designs are made completely or almost entirely of aluminum and its alloys. This applies not only, as before, to individual elements, but also to the whole structure of cars, their skeletons, and all elements of the cover. An example is the BMW 5 F10 Series introduced in 2010. The technique of building entire cars made of aluminum and its alloys, reserved in the nineties for super sport

cars and the most expensive limousines (e.g. Audi A8d2 introduced in production in 1994), is increasingly used in popular cars of lower classes at the present time [5].

Life cycle analysis (LCA) is a commonly used methodology to estimate the environmental impact of any product, from the extraction phase of necessary raw materials, through the production phase, through the use phase, to the utilization phase.

The correctness of the results of such analyses is obviously dependent both on the adoption of analogous ranges of estimates carried out, as well as on similar technical and operational parameters of the tested vehicles and analogous methods of determining the data entered into the calculations. In the case of motor vehicles, it is necessary to introduce operational data for compared vehicles obtained by the same methods, that is, either from laboratory tests or from tests in real traffic. Therefore, it is necessary to use the results of tests carried out in accordance with the uniform methodology in the comparative analysis of the tested vehicles [8, 9].

In the case of cars with internal combustion engines, for CO₂ emissions generated in the production process of the car, it is necessary to add the CO₂ emission generated during their operation. Its level depends on fuel consumption, which depends on many factors alongside engine volume and its power, on the vehicle's power and aerodynamics, speed and traffic conditions, driving style (technique), tire pressure, number and degree of use of accompanying equipment, type of road surface, road conditions, etc. Currently, WLTP test procedures containing the WLTC driving cycle and emission measurements in road traffic conditions are considered to be the most reliable method for testing vehicle emissivity.

The presented comparative analysis of CO₂ emissions of Ford Fiesta 1.0 EcoBoost and Toyota Corolla E12 1.6 cars was based on the WLTC driving cycle, which is an integral part of the Euro 6d-Temp homologation standard, effective from 1 September 2018.

2. Test object

The subject of the research was a Toyota Corolla vehicle (Fig. 1) and Ford Fiesta Ecoboost (Fig. 2). The basic vehicle data is provided in Tab. 1 and Tab. 2. Prior to the emission tests, the technical condition of both vehicles was checked. Both the Toyota Corolla, produced in 2006 and the Ford Fiesta, produced recently, passed the technical review and there were no errors recorded in the engine controllers, which proved that the exhaust gas system was working properly.



Fig. 1. Toyota Corolla car mounted on a chassis dynamometer

3. Measuring devices used in tests

The following set of measuring devices was used during the tests:



Fig. 2. Ford Fiesta test car

Tab. 1. Basic data of Toyota Corolla vehicle

| | |
|----------------------|----------------------|
| Make | Toyota |
| Type | Corolla |
| Engine displacement | 1598 cm ³ |
| Power / engine speed | 81 kW / 6000 RPM |
| Vehicle category | M1 |
| Emission standard | EURO 4 |
| Maximum speed | 190 km/h |
| Odometer | 103 000 km |

Tab. 2. Basic data of Ford Fiesta vehicle

| | |
|----------------------|---------------------|
| Make | Ford |
| Type | Fiesta |
| Engine displacement | 999 cm ³ |
| Power / engine speed | 74 kW / 6000 RPM |
| Vehicle category | M1 |
| Emission standard | EURO 6.2 |
| Maximum speed | 180 km/h |
| Odometer | 12 000 km |

- emission measurement system manufactured by AVL:
 - CFV-CVS type CVS i60 LD S2 by AVL exhaust gas collection system,
 - a set of AVL AMA i60 D1-CD LE analysers equipped with two-band analysers to measure the concentrations of the following gases:
 - carbon dioxide CO₂,
 - nitrogen oxides NO_x,
 - carbon monoxide CO,
 - hydrocarbons THC,
 - methane CH₄,
 - Vaisala weather station type PTU303 for measuring temperature, humidity, and air pressure during test cycles,
- single-roll chassis dynamometer with adjustable resistance curve by AVL-Zoellner to simulate the resistance of vehicle movement on the road,
- hytherograph with LAB-EL type LB-701, version M with reading panel LB-702B, for controlling and recording of environmental conditions during vehicle conditioning before tests.

4. Measurement results

Measurements in the WLTC cycle were performed at the chassis dynamometer where the temperature and humidity of the air were maintained in the ranges of $23\pm 5^{\circ}\text{C}$ and $50\pm 5\%$, respectively. The table presents the coefficients of the motion resistance curve simulated by the dynamometer.

Tab. 3. Coefficients of the second degree polynomial of the motion resistance curve simulated by the dynamometers (absorbed force) used in the tests of both vehicles

| | Toyota Corolla | Ford Fiesta |
|---|----------------|-------------|
| R _w [kg] | 1360 | 1394 |
| F ₀ [N] | 64.640 | 12.440 |
| F ₁ [Ns/m] | 4.0477 | -1.4608 |
| F ₂ [Ns ² /m ²] | 0.51176 | 0.47349 |

Before the measurement, the car was conditioned for at least 12 hours.

Tab. 4. CO₂ emissions from the Toyota Corolla exhaust system in the WLTC test

| No. | 1 | 2 | 3 | 4 | 5 | average |
|------------------------|--------|--------|--------|--------|--------|---------|
| CO ₂ [g/km] | 161.13 | 161.06 | 161.11 | 161.15 | 161.05 | 161.1 |

Tab. 5. The results of CO₂ emissions from the Ford Fiesta exhaust system in the WLTC test

| No. | 1 | 2 | 3 | 4 | 5 | average |
|------------------------|--------|--------|--------|--------|--------|---------|
| CO ₂ [g/km] | 130.65 | 130.75 | 130.76 | 130.79 | 131.15 | 130.82 |

5. Conclusions

It is undeniable that newly manufactured passenger cars are characterized by lower CO₂ emissions than cars manufactured 10 or 15 years ago. However, contrary to what they are trying to convey to the potential buyers the advertising and PR departments of large automotive concerns, these are not big differences. The article describes the case of two cars with similar engine power and similar mass. It turns out that the most modern automotive product meeting the Euro 6.2 standard has the emissions tested at the WLTC test of 130.82 g CO₂ / km and Toyota Corolla from the production year 2006 meeting the Euro 4 standard has an emissivity of 160.1 g CO₂ / km. It is worth noting that the Toyota Corolla model with this engine model has been in production since 2002 and maintained in good condition should exhibit emissivity as it was found during the tests.

From the above tests and calculations made it is clear that the ecological profit of purchasing and using a modern vehicle that meets the Euro 6.2 emissions standard and replacing it with an older car complying with the Euro 4 emission standard appears only after driving a new vehicle 187000 km. It results directly from the fact that the production process of a modern car is a seriously damaging effect on the natural environment as a result of high CO₂ emissions, and the difference between the emission level of currently produced cars and the emission level of cars manufactured a dozen or so years ago is not very high.

Automotive companies that advertise the purchase of new cars as pro-ecological activity is escaping the fact or are rather not aware of this issue as a big burden for the environment is the production of a new passenger car. The presented research shows that for a wide group of users of passenger cars who use them several thousand kilometres annually, the more ecological behaviour will be the use of a previously owned passenger car while maintaining its good technical condition. Its replacement with a brand new vehicle will involve several tons of carbon dioxide emitted into the atmosphere.

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