APPLICATION OF ENVIRONMENTAL ASSESEMENT IN AUTOMOTIVE INDUSTRY

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Abstract

Over the years automotive industry has been one of the most rapidly developing branches of the world economy. However, the main reasons for development have changed. One of key point in its automotive development has become the effort to lower the industry's impact on the environment in particular, during the vehicle's use phase.
One of the challenges for the industry is the design of the vehicle, which in the use phase is able to fulfil the maximum permissible emission requirements specified in individual EURO series standards.
The present article contains a description of the applicable legal provisions (at the EU level) in relation to the phases of the vehicle life cycle. The main focus has based on the literature examples of LCA application to the selected elements of vehicles potentially be relevant when considering the full life cycle of a vehicle as well as preliminary results of LCA for aluminum pistons.

Keywords

Environmental assesement, LCA, automotive industry, automotive downsizing, aluminum pistons

JEL Classification

L20, L62, O10, O33, O44

Introduction

Many directions of development are created and directed by legal requirements. It's the amending rules, limit values, limits and injunctions in various countries and the EU, in some extent direct the development of individual technologies. It should be remembered, however, that the impact of many technologies in the automotive industry can take place directly but also indirectly. In the course of a changing reality, the way of their verification may also change.
One of the challenges for the industry is the design of the vehicle, which in the use phase is able to fulfill the maximum permissible emission requirements specified in individual EURO series standards. However, meeting the requirements of each subsequent directive increases the diversity of processes including production. In Europe, we have many legal requirements regulating the environmental impact of individual phases of a vehicle's life cycle. But only the LCA is contained in a comprehensive way. In order to address this issue from all angles as opposed to simply pick and choose particular legal regulations, the producers on the automotive market have agreed a common point of reference: the LCA –

Life Cycle Assessment tool, which includes an assessment of the environmental impact throughout all the stages of the product lifecycle.

The present article contains a description of the applicable legal provisions (at the EU level) in relation to the phases of the vehicle life cycle. Entails state-of-the art knowledge on the direction of changes implemented in the applied technologies within the automotive industry and present the most relevant findings of research carried out on the subject. They have been approximated methods of presenting environmental data by car manufacturers to increase and emphasize the environmental credibility of the chosen development directions of their products. Shows how the producers presents improve the environmental performance over the entire life cycle of a cars in successive model generations. Attention was also drawn to the key importance of the main suppliers of components for the automotive industry. Authoring projects that can be adopted by the final vehicle manufacturers are presented. Accordingly, the shape of the current eco-friendly initiative in the automotive supply and delivery chain has been called to question, especially taking into account the key role of the suppliers and the complexity of the environment data output at the production level.

1.1 Environmental legal conditions for all phases of the life cycle

The direction of development of the automotive industry for many years has been focused on lowering the environmental impact because 25% of global CO2 emissions come from transport and 13% from passenger cars (ACEA, 2018).

Due to the high ecological and social footprint of the automotive sector, car manufacturers are under pressure from policymakers and other stakeholders to improve the sustainability performance of vehicles at every stage of the life cycle. Starting from the extraction of raw materials where we have to deal with concessions in the mining of raw materials or mandatory waste recycling. Through the regulation of eco-design and production, including environmental taxes and fees. Coming up to a very important regulation for the use phase - emission standards. Ending on regulations related to the end of life of the vehicle when it becomes a waste and need to develop it – ELV Directive (Jasinski et al., 2015)

The efforts of both the EU legislators and national experts not have been limited to the use and recycling of vehicles but regulations regarding the use phase are developing most dynamically are defined in EC Directives named EURO 1-6 emission standards for vehicles (Directive 98/69/EC; Directive 2002/80/EC, Regulation (EC) No 715/2007).

Still, one of the primary challenges facing the automotive industry is the a creation of a vehicle that would meet the maximum allowed EU emission standards specified in the directives also taking into account changes in control standards. The requirements of each new “EURO” standard entail even greater variety of processes that every single car component needs to go through in order to meet them. In recent times, followed by significant change in the methodology of fuel consumption and emission tests.

1.2 The regulations on the measurement system for the use phase

New European Driving Cycle (NEDC) was designed in the 1980s to assess the emission levels of car engines energy efficiency in passenger cars and became outdated today due to several evolutions in technology and driving conditions. NEDC test determined values based on a theoretical driving profile. Moreover, the impact of the presence of optional features on the CO_2 and fuel performance of a car was not considered under NEDC (ACEA, 2018).

Having in mind imperfections European Union has therefore developed a new test, called the WLTP (Worldwide Harmonised Light Vehicle Test Procedure). WLTP cycle was developed using real-driving data, gathered from around the world. WLTP therefore better represents everyday driving profiles. The WLTP driving cycle is divided into four parts with different average speeds: low, medium, high and extra high. Each part contains a variety of driving phases, stops, acceleration and braking phases. For a certain car type, each powertrain configuration is tested with WLTP for the car's lightest (most economical) and heaviest (least economical) version. In WLTP was added new element as Inertia of rotating parts and Battery State Of Charge correction (Pavlovic et al, 2018).

WLTP was developed with the aim of being used as a global test cycle across different world regions, so pollutant and CO2 emissions as well as fuel consumption values would be comparable worldwide. However, while the WLTP has a common global 'core', the European Union and other regions will apply the test in different ways depending on their road traffic laws and needs.

1.3 Direction of development - Car body and some equipment items

The weight of the car body plays a very important role in the total weight of the vehicle that affects the energy demand. One of the principal elements of a passenger vehicle that decides about its total mass is the car body, which may constitute as much as 40 to 60% of the overall mass (Zieliński, 2008) For example, it is estimated that a 10% reduction in a vehicle's weight translates into an increase in miles per gallon of 5% (Mayyas et al., 2011).

Despite the development of many material technologies, the main materials used for production remain metals: steel and aluminum. However, the development of metals is associated in particular with the introduction of extremely light alloys in places where it is possible (not forgetting about safety, which is also significantly affected by the body). The implementation of the latest technologies, such as laser beam welding, forging and hydroforming allows also help decrease the car body mass (Senkara, 2009).

It would have appeared that in times when most of the industry efforts have been aimed at lowering the fuel consumption and harmful emissions, the fate of steel is doomed and it will surely have been replaced with lighter alloys and composites by now. As it turns out, however, the steel industry has also been experiencing a dynamic growth. The innovative alloys, the forming and forging methods combined with the ease of recyclability maintain the position of steel among the prime materials used in vehicle construction. The key importance of proper construction of a car body becomes obvious when looking at the example of Mercedes. The metal components of the car body differ between different generations of the same car make. During the production of a Mercedes C-Class (from 2013) almost 40% more of aluminium alloys was used compared to the previous versions. The LCA assessment carried out proved that the choices of materials did allow to achieve a clearly positive result in terms of lowering the environmental impact during the exploitation phase, at the same time reducing the fuel consumption by 20% (Mercedes Benz, 2013).

Renewable raw materials help to reduce the consumption of fossil resources such as coal, natural gas and crude oil. In automotive production, the use of renewable raw materials concentrates on the interiors of vehicles. Established natural materials such as coconut, cellulose and wood fibres, wool and natural rubber are also employed, of course, in series production of the S-Class. The use of these natural materials gives rise to a whole range of advantages in automotive production. The materials used is for example leather for fabric covers for seats and backrests, wood for basic carriers of door panels, trim parts and steering wheel (Daimler AG, 2015).

In Mercedes S-Class, 51 components with an overall weight of 49.7 kilograms can be manufactured partly from high quality recycled plastics. These include wheel arch linings and underbody panelling. The mass of secondary raw material components has increased by 134 percent compared with the predecessor model. Secondary raw materials are obtained wherever possible from vehicle-related waste flows: Wheel arch linings are made from reprocessed starter batteries and bumper coverings.

Fuel consumption is strongly influenced by vehicle weight: about one third of total consumption directly depends on its mass (Koffler and Rodhe-Branderburger, 2010).

The weight reduction that Audi achieves by using lightweight materials permits welcome secondary effects in other areas of the vehicle. Lower body weight initiates a downward turn in the weight spiral, which permits chassis and drivetrain components to be downsized, for instance by reducing the size of the brakes. Weight-saving potential is possible in every technical area. In the life cycle assessment these savings help to compensate for the additional effort and expense incurred in the manufacture of lightweight materials (AUDI, 2011).

Following this rule during the production of a new Audi A6 model, the steel mass was reduced by 5% to the favour of aluminium (compared to the previous A6 model). The manufacturer stresses that the production of a new A6 model made use of more light metals characterized by increased energy consumption at the production level (which found its reflection in poor CO_2 results at the production level). However, already after 5000 km it reaches a breaking point after which every following kilometre looks better and better from the environment's point of view. The conclusions and comparisons between the faults and advantages such as the one above only confirm the validity of the closer look at the environmental impact, taking into consideration the full lifecycle of a vehicle.

1.4 Direction of development - Drive sources

The most common market share has been for years with vehicles with internal combustion engines. Diesel and petrol engines market share in the years 2012-2015 was over 97% (ACEA, 2017a). But recently it has started to change more intensively. In the first quarter of 2018, there is a clear drop in favour of alternative fuels. The most pronounced decline in the number of new diesel vehicles - 37.9% which gives a 17% decrease compared to last year, and the total result of the vehicles with combustion engine was 93,4% (ACEA, 2018) 6,5 % increase of Alternatively Powered Vehicles (APV) of which 1,5% are battery electric and 3,4% of plug in hybrid electric cars.

Due to increasingly strict requirements related to harmful emissions during the exploitation phase, some technological changes in the engines are also being made. Based on the manufacturers analyses, the environmental life cycle looks different for vehicles with different drive sources.

A comparison of the CO_2 emissions of the S 500 PLUG-IN HYBRID with the S 500, which offers similar performance, is presented on Fig. 1. Production of the S 500 PLUG-IN HYBRID entails a visibly higher level of CO_2 emissions, on account of the additional hybrid-specific components. However, over the entire life cycle, comprising manufacture, use over 300,000 kilometres and recycling, the plug-in hybrid clearly has the edge. External charging with the European electricity grid mix can cut CO_2 emissions by some 34 % (27.5 tonnes) in comparison to the S 500. Through the use of renewably generated electricity from hydro power a 56 % reduction (45.4 tonnes) is possible. In electrical vehicles, the key aspect here is the source of electrical energy. the emissions during the exploitation phase vary when the electricity is derived from carbon, gas or wind power.

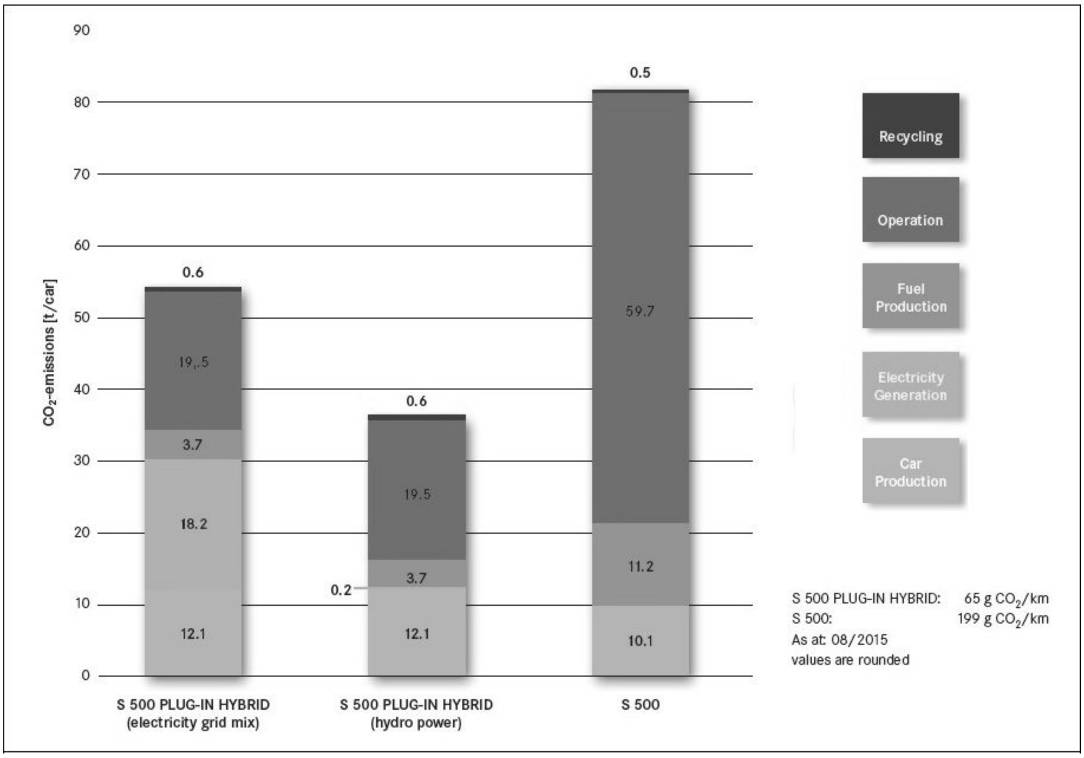

Fig. no. 1 Comparison of CO2 emissions of Mercedes S-Class with different power source
Source: Life Cycle Environ. Certificate Mercedes-Benz S-Class including S 500 Plug-in Hybrid

However, new trend is to change main material for production one of the most important engine components. In order to decrease the harmful emissions and limit petrol consumption, during the production of a combustion engine one of the manufacturers has used ultra-high strength steel, a seemingly heavier but much more durable material. The application of material that is far more durable than the commonly used aluminum has allowed for a change in dimensions and structure of the piston, which, in return, has lowered the emissions and petrol consumption by increasing the thermal expandability and lowering friction, among others. The steel construction has also permitted to reduce the piston height by 30%, which made room for the use of a longer traction rod that reduces the lateral forces by 10% (Mercedes-Benz, 2014). This kind of seemingly insignificant changes generate lower CO$_2$ emissions (between 2% to 5%). That said, clearly some substantial modifications in the production technology are required to achieve that effect. It is not just the materials for the piston, but also the number of production processes that is altered. As a result of the above, a full-scale comparison has been carried out of the environmental impact during the production of aluminium and steel pistons, respectively. In our previous paper (Grygiel et al., 2017) we signalled the beginning of the LCA analysis for pistons. Now preliminary results of such analysis based on the data from producer will be presented for aluminium pistons**.**

Methods

The aim of the study was to assess the environmental aspects of aluminum pistons production with the use of Impact 2002+ LCIA method. Functional unit (FU): production of 1 million of aluminum pistons per year. The system boundary included the processes realized in the plant and upstream processes (from cradle to gate) for which data has been collected from Ecoinvent database. Processes realized in the plant were divided into two groups: basic processes (processes leading to the manufacturing of a finished product) and auxiliary processes (supporting processes). The first group included melting of aluminium, casting and cutting of cast iron forms, casting of pistons, heating, machining and surface treatment . The second group consisted of salt cores production, refining, furnace cooling, quality control, internal transport and neutralization of gases and waste water.

Preliminary results of LCA for aluminum pistons

Presented results are attributable to the annual production of aluminum pistons (nearly 17 million pieces) in analyzed manufacturer from Wielkopolska/Poland. Production of aluminum pistons affects the environment at the level of 99.05 kPt. The most significant is the impact on the human health category (more than 40% of the total Single Score). Environmental impact includes also interventions that contribute to climate changes and then natural resources depletion (29% and 23% of the total Single Score). Environmental aspects of analysed system production and their contribution to the indicator's total value are presented in Table 1. In terms of environmental harmfulness, the group of basic processes definitely dominates. Environmental impacts generated during these processes is almost 93 kPt. If we compare particular unit processes it can be notice that the most environmentally significant is melting of aluminium. It generates environmental impact at the level of 75.77 kPt, representing about 77% of the total Single Score (Figure 2). The most important source of negative impact caused by the melting process is consumption of production materials. The calculated ecoidnicator for this aspect is 72.63 kPt (about 73% of the total Single Score). The next important issue is energy consumption in heating, machining and surface treatment and generates environmental impact at the level of 12.80 kPt, representing almost 13% of the total Single Score.

Table no. 1 Total Enviromental impact of aluminum pistons production

Environmental Aspects	SINGLE SCORE			
Materials production and consumption	76,54	kPt	77,27	%
Energy consumption	22,13	kPt	22,34	%
Air emissions	0,44	kPt	0,44	%
Emissions to water	0,17	kPt	0,17	%
Solid waste	-0,244	kPt	-0,25	%
TOTAL	99,05	kPt	100	%

Source: results of own analyzes.

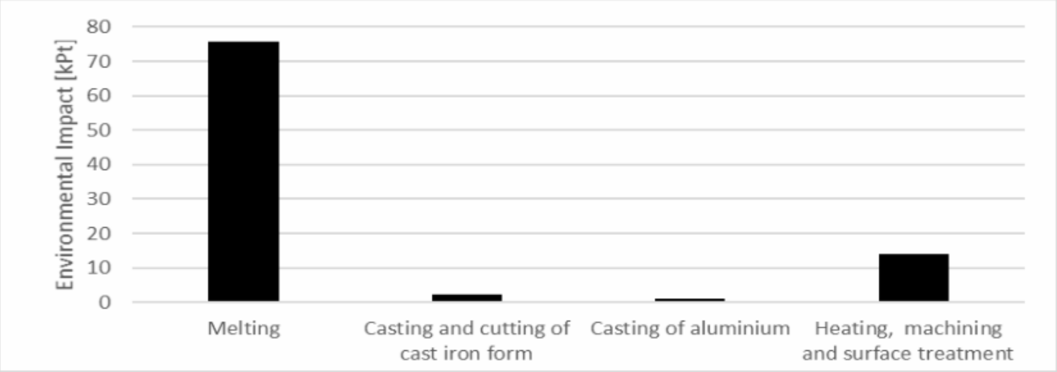

Figure no. 2. Environmental impacts of unit processes classified as basic processes expressed as the Single Score

Source: results of own analyzes.

Conclusions

LCA has been gaining prominence in the production process and is becoming more and more important for the manufacturers when designing and improving their products. The automotive's LCA research to date has been focused on the selection of raw materials which thanks to their characteristics ensured that substantially favourable results could be achieved in terms of fuel consumption, easy dismantling and pro-environmental waste disposal.

Detailed LCA studies of the production phase of aluminum pistons conducted on the data obtained from the subcontractor of the engine components indicate that the most ecologically troublesome unit processes in the production of pistons are aluminum melting, followed by machining and surface treatment of cast pistons.

The most important is the impact on the category of human health, followed by climate change and then depletion of natural resources.

The results of the LCA survey should gain importance for the design stage of these products because they provide knowledge and awareness of environmentally-specific unit processes.

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