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THE ANALYSIS OF AUDI A6 ENGINES MALFUNCTIONS

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Abstract

An awareness of a growing importance of quality and reliability of products against competitive international markets tends to improve the quality of all of the processes that make up their activities and to generate products of an increasing quality and reliability [1]. This analysis of quality and reliability is systematic and independent of the action in the field of quality assurance and reliability of products carried out in order to check whether these activities and their results are consistent with planned ones and if they are effectively used to achieve the objectives [2]. The aim is to carry out an analysis of Audi engines malfunctions, to be specific A6 model, types C6 and C7. The essence is based on verification that the new generation 2011 model has boosted the reliability of assembled engines. This topic is of particular importance, because it raises the aspect of actual quality and durability of new engines during their three years of operation. The available literature has no signs of related examination. The analysis of the reliability consists of four major stages: 1) structural and functional analysis of objects 2) qualitative analysis of the problem, the aim of which is to identify all possible factors affecting the reliability of the object 3) quantitative analysis of issues, leading to the estimate of measurement reliability, 4) draw conclusions [7]. The study 20 used Audi A6 cars was to compare randomly selected 10 vehicles C6 generation coming out in 2004, and another 10 vehicles C7 generation presented in 2011. In order to carry out a separate analysis of malfunctions of engines, in each type the cars were chosen in such a way, that the 5 of them were equipped with spark-ignition engine and another 5 with compression-ignition engine. The data of these faults was read from service programs such as Autostacja and ElsaPro on the basis of submissions in an authorized Audi service in Wroclaw.

Keywords: *quality and reliability of Audi A6 engines, fuel-injection technique, diagnostic variables*

1. Introduction

The quality and the reliability of choices are the essential elements in the international competition and, in the more excessive level, they decide about the market success of companies. In advertisement and promotion of the products, their quality and reliability are presented to potential purchaser, generally, as positives. Clients are more often ready to pay higher price for the product of high quality and reliability, which is supplied with the wide spectrum of service care by the producer [2].

The charting of new directions became the inspiration and philosophy of Audi brand-according to the motto: “Advantage through technology”. The launching of Audi 100 production at the end of '60s, started the history of higher-class Audi brand limousines. The vehicle, because of its classic style without ornaments, had the decisive impact on the appearance of the cars from the '70s. That car became the cornerstone of the types, which launched many legendary vehicles. Meanwhile, from the Audi 100 – according to the introduced names, the Audi A6 came into being. However, the thing that has not changed until nowadays is the typical for the brand the language of form, which is still common for, every its representative: timeless, innovative appearance together with elegance and sport character. The technical advantage covered by attractive and prospective project [11].

2. Construction and functional analysis of objects

2.1. Audi A6, type C6

The brand motto – “Advantage through technology” was continued in the sixth generation of business sport limousine Audi A6 '05, presented in Fig. 1. The applied technologies in the chassis of high dynamic are properly picked with optimal propulsive systems in the area of fuel consumption, directed on the pleasure of driving through FSI and TDI technology [5].

2.2. Audi A6, type C7

The seventh generation of Audi A6 limousine, presented on Fig. 2, is known as higher safety and comfort, matched sport character, lower fuel consumption, vibrancy and airiness through hybrid body construction and engines of high power – the project of tomorrow. The technology and the spectrum of comfort, which so far were typical for luxury class, in that project have the changes to enter the higher-class segment. The intelligent and light construction creates the new possibilities and ensures particularly good effectiveness. Audi A6'11 car joins the innovations resulting from every original Audi brand characteristics. The strength of Audi is also highly effective propulsive units FSI, TFSI and TDI with the Common Rail system of second generation. They distinguish in excellent parameters, confirming impressive acceleration and huge power potential [6].

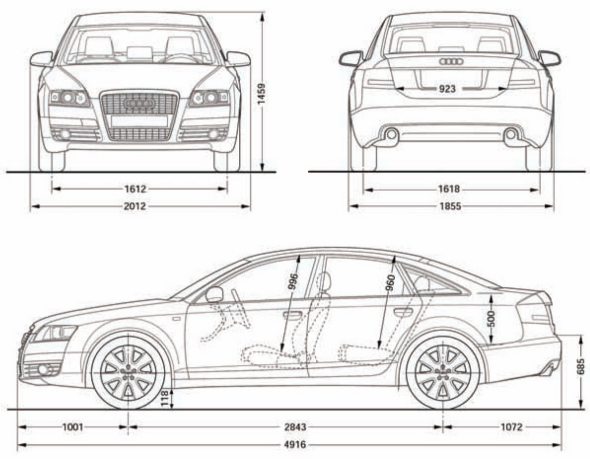

Fig. 1. Audi A6, type C6 [5]

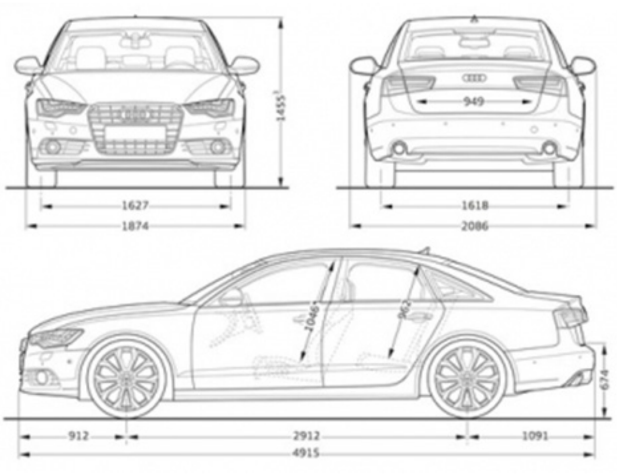

Fig. 2. Audi A6, type C7 [6]

2.3. Presentation of internal combustion engines

The modern engine differs significantly from its prototype from before 150 years. The major function of energy cumulated in fuel transformation, changing in the chemical reactions and heat processes in effective mechanical energy is still preserved, but the form of realization is very different. It happens because of the continuant engine construction development and new techniques of improving engine works application. For the most important among them, which complete the challenge of balanced development guarantying economic and ecological exploitation and ensure comfort of exploitation in the aspect of obtained indicators, there belong: direct fuel injection, boost, systems of variable valve timing and inlet system geometry, and variable compression ratio, as well as using the system of fumes recycling [10].

3. Quality analysis

3.1. The selection of diagnostic variables

In each multidimensional comparative analysis, at the beginning it is necessary to determine the comparison objects and the set of variables, which in comprehensive way characterize those, object properties, the so-called diagnostic variables. From the proper selection of the diagnostic variables, there are essentially dependent the research results, regardless of the methods and techniques applied in the further research stage. Moreover, the incorrect selection of variables may lead to false results of the comparative analysis. The multitude of variables describing the objects in multidimensional comparative analyses, which are the media of different information about the objects, cause that for the final analysis of variables, it is necessary to choose the most important ones from the research point of view. The selection of variables describing objects' properties depends mostly on the aims of analysis and its field. Regardless of the aim and field of analysis, there are certain rules and methods of their selection. The selection of diagnostic variables may be done by both extra statistic and statistic criteria. In the first case, as diagnostic variables, there are selected the variables which, according to the substantive knowledge about the tested phenomenon, are the most important for making the comparison analysis of the tested objects, and then, they are subjects for verification due to formal criteria[8]. The analysed in the work the variables of the first category are:

- the average service cost in reckoning per 1 km after three years of exploitation,
- the average amount of service orders after three years of exploitation,
- the part of cost oriented for defect elimination in the present component,

In the second case, the selection of variables is made through proper statistic procedures [8]. The analysed in the work the variables of the second category are:

- the factor of vehicle technical readiness,
- the average labour-intensiveness of technical service,

The most proper is the procedure of diagnostic variables selection, which makes use of the two-abovementioned issues. Acting in that way there is possible to obtain the final set of diagnostic variables that are the basis of comparative analysis [8].

3.2. Kinds and causes of mechanical objects malfunctions

The course of reliability state is a random occurrence. According to the way of appearing of that occurrence in time, the malfunction is divided on:

- progressive malfunctions – connected with the physical aging
- sudden malfunctions – connected with the sudden change of the determined parameter over the acceptable values.

Generally, there are distinguished the causes of malfunction as resulting from:
- construction faults and technological errors of the object,
- incorrect exploitation,
- external factors (surrounding conditions variables) [9].

4. Quantity analysis

4.1. Preparing of exploitative research

The quality research is carried out, generally, on a certain group of pieces creating the so-called piecemeal sample, which is selected form of portion or series of products in a possibly random way. Then, there are created the optimal conditions of sample representativeness in relation to entire portion of researched products. The exploitative research is maximally efficient when the set of original information is maximally effective, so the information is:
- complete,
- credible,
- in the sufficient, amount responsive to the needs of statistic inference [9].

In the research, 20 Audi A6 cars were used. For comparison, there were randomly selected 10 vehicles A6 generation, and another 10 vehicles A7 generation. Taking for studying too big sample, increases time of preparing the results and delays the period of realization practical conclusions of carrying out research. In order to carry out a separate analysis of malfunctions of propulsive systems, in each type the cars were chosen in such a way, that 5 of them were equipped with spark-ignition engine and another 5 with compression-ignition engine. The comparison of researched vehicles is presented in the Tab. 1. The history of vehicles usage submitted to further analysis has been read from service program Autostacja 2 and ElsaPro. Those systems set the electronic information source guarantying constant access to all data in an automatically actualized form. To make the split of researched cars, their type, part of body number (according to protection of personal details), year of production, type of engine, power, and type of gearbox were noted. Obtaining of malfunction characteristics and data compression takes the first and the most important place in every technique used in monitoring systems of technical construction condition [7].

4.2. Diagnostic statistic variables

Each element, unit or car should be renewed when the terminal state is achieved. It is assumed the discreteness for car elements – the vehicle is either exploited or renewed in the exploitative time t, for which the total time of exploitation Tu(t) and total time of renovation To(t) were assigned. Functions Tu(t) and To(t) take the value of range [0, t] and their sum Tu(t) + To(t) =t for each $t \geq 0$. The exploitation process may be described as function, which arguments are the moments belonging to time of car exploitation and the values – its exploitative conditions [4].

The diagram for the discrete process is presented in Fig. 3. e_1 and e_2 are the tops of the diagram, responsive to exploitations conditions, and the arches are responsive to possibilities of staying in the conditions (e_1 and e_2) as well as the transitions in between conditions ($e_1 \rightarrow e_2$ and $e_2 \rightarrow e_1$). There are also determined the possibilities of staying in time t in the particular exploitative condition [3].

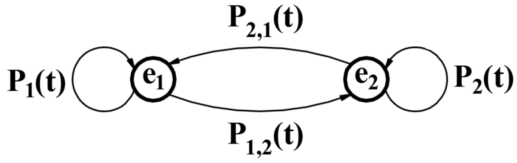

Fig. 3. The diagram of transitions in-between conditions in the discrete process [3]

Tab. 1. Set of researched vehicles

	Brand	Model, Type	Year of Production	Body Number	Type Of Engine	Power [Kw]	Gearbox Type
1	Audi	A6, C6	2006	Wauzzz4f…758	Zi 3.2fsi	130	6g
2			2006	Wauzzz4f…016	Zi 3.2fsi	130	Multitronic
3			2006	Wauzzz4f…080	Zi 3.2fsi	188	Tiptronic
4			2006	Wauzzz4f…133	Zi 3.2fsi	188	Tiptronic
5			2006	Wauzzz4f…508	Zi 4.2	246	Tiptronic
6			2006	Wauzzz4f…610	Zs 2.0tdi	103	6g
7			2007	Wauzzz4f…678	Zs 2.7tdi	132	6g
8			2007	Wauzzz4f…652	Zs 2.7tdi	132	6g
9			2007	Wauzzz4f…229	Zs 2.7tdi	132	Tiptronic
10			2006	Wauzzz4f…521	Zs 3.0tdi	165	Tiptronic
11		A6, C7	2011	Wauzzz4g…023	Zi 2.0tfsi	132	6g
12			2011	Wauzzz4g…661	Zi 3.0tfsi	220	S-Tronic
13			2012	Wauzzz4g…292	Zi 3.0tfsi	220	S-Tronic
14			2011	Wauzzz4g…957	Zi 3.0tfsi	220	S-Tronic
15			2011	Wauzzz4g…405	Zi 3.0tfsi	220	S-Tronic
16			2011	Wauzzz4g…895	Zs 2.0tdi	130	6g
17			2012	Wauzzz4g…961	Zs 2.0tdi	130	6g
18			2011	Wauzzz4g…919	Zs 3.0tdi	180	S-Tronic
19			2011	Wauzzz4g…574	Zs 3.0tdi	180	S-Tronic
20			2011	Wauzzz4g…990	Zs 3.0tdi	180	S-Tronic

The reliability of the fixable devices, such as car, is characterized by the system variable, expressed by the relations of at least pair of random variable, among which one describes the condition of capacity whereas the second one describes the incapacity condition. By the use of total exploitation time and total renewal time, there is possible to count two factors taking the values from the range [0, 1]:

– $k_g(t) = \frac{Tu(t)}{Tu(t)+To(t)}$ – the factor of car technical readiness to exploitation,

– $k_o(t) = \frac{To(t)}{Tu(t)+To(t)}$ – the factor of car renewal.

The vehicle readiness is most often defined as the probability that the device will be able to work at the moment t [4].

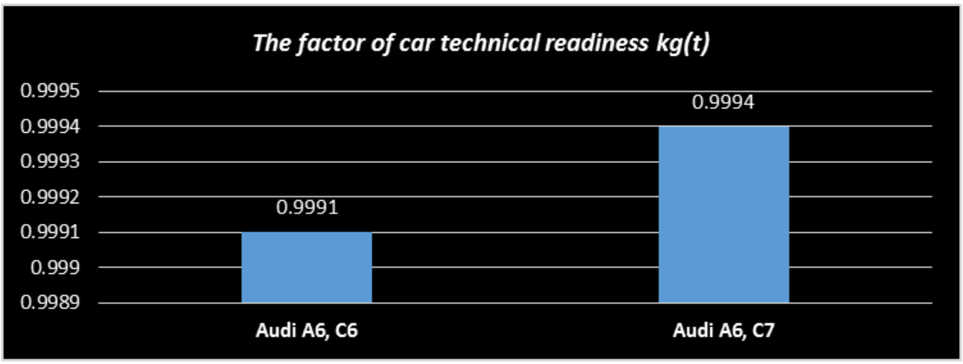

Fig. 4. The value of car technical readiness factor in dependence on the model generation

The abovementioned diagram shows the diversity of described factor. For the previous generation of model it is lower − its value equals 0.9997. With the new generation entrance − its value increased and equals 0.9994. The second sum is closer to the expected unity and testifies about longer time of vehicle availability for exploitation in the three years' time of exploitation.

The increase of the product readiness for the proper functioning may be realized through increasing the average time of exploitation – Tu, as well as shortening the average time of renovation – To, and also by increasing Tu and shortening To simultaneously [2].

The factor of car technical readiness is related with the average work consumption of technical service, which is counted for the course of 1000 km, which is the significant factor of vehicle reliability characterizing its fixing susceptibility (Fig. 5):

$$P_{ot}=\frac{1000}{\sum_{j=1}^{N_o} L_j}\sum_{j=1}^{N(0)}\sum_{j=1}^{n_j} p_{ij}, \tag{1}$$

where:

pij – work consumption of i-number of service on a j-number of car [rbh],

nj – the number of services on the j-number of car,

N(0) – the number of objects in the sample,

Lj – the course of j-number car [km].

Due to shorter visits of the newer generation model in an authorized Audi service of about 26%, the factor of car technical readiness reached more beneficial, expected value. For the fixable objects the issue of fixing is understood as regeneration or regulation, or the change for a new one [4].

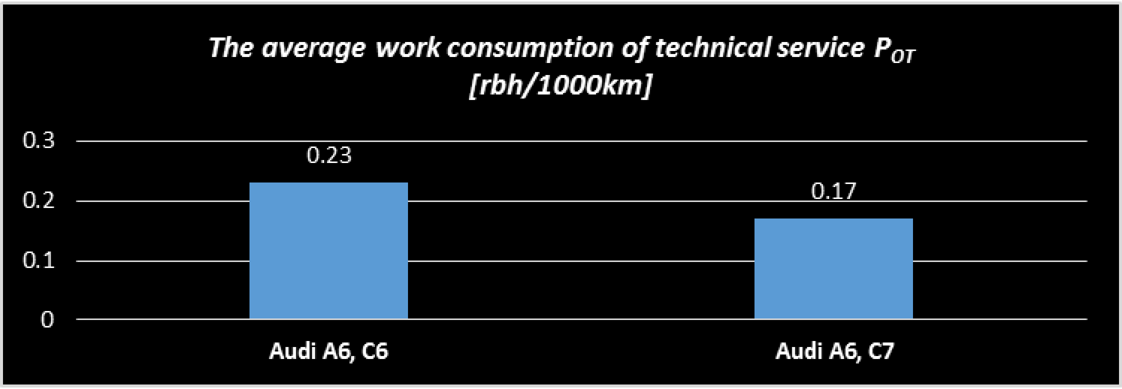

Fig. 5. The value of average work consumption of technical servicing in the dependence of a model generation

4.3. Extra statistic diagnostic variables

There was controlled the rightness of actions towards improving the engine constructions made by the producer. The essential and massive technological leap concerns Audi compression ignition engines, which makes the work concentration mainly on those units. The described costs were divided according to the type and kind of the engine (Fig. 6).

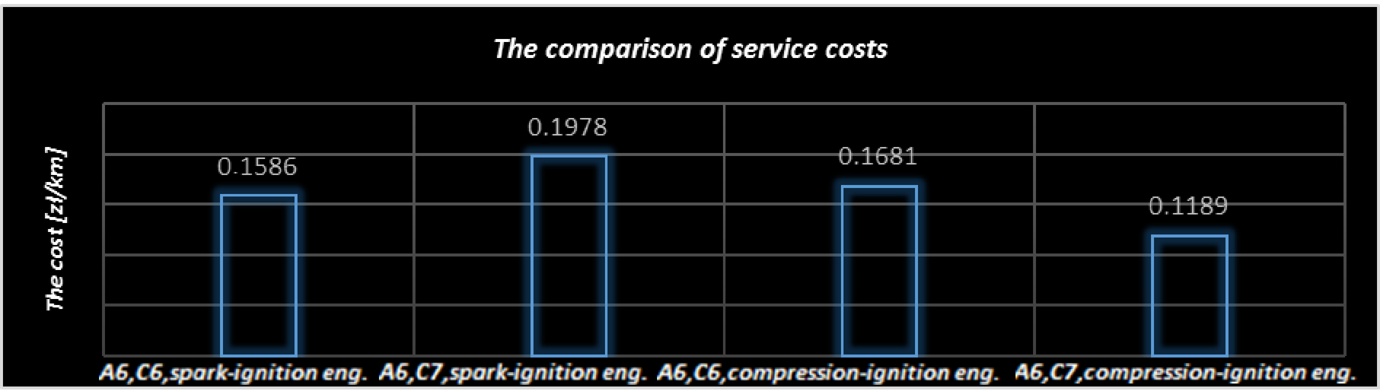

Fig. 6. The comparison of service costs of particular generation with the type of engine division

The abovementioned results synthesis indicates the victory of vehicles powered by the compression-ignition engines assembled in the newest A6 model generation. The cost of their services is lower of about 30% in comparison with the previous generation, which relates to significant savings of the users. In the case of the spark-ignition engines, there is visible the opposing dependence. The necessary service costs in case of the C7 generation increased nearly of 20%.

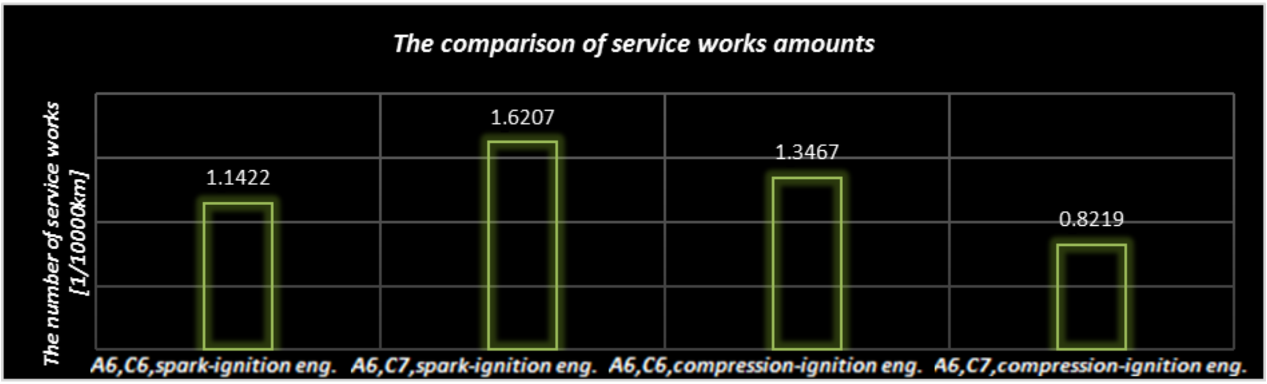

Fig. 7. The comparison of service works amounts of particular generations with the type of engine division

The above-mentioned, obtained values of indicators are convergent with the indicators presented in the Fig. 6. In case of cars in the configuration with the spark-ignition engines, with the entrance of A6 model new generation, there is visible the increase of the number of service works of nearly 30%. Taking into consideration the cars equipped with the compression-ignition, there is visible the convergent dependence. There occurred significant decrease of the indicator resulting almost 40%. With this result, there is connected less number of necessary visits in the Audi authorized service, the timesavings, and also the increase of users' contentment. There may be stated that the actions connected with the improving of diesel units are moving in the right direction.

Then, the analysis of object structure reliability has been worked out, which took into consideration the dependences between object reliability and reliability of its components [9].

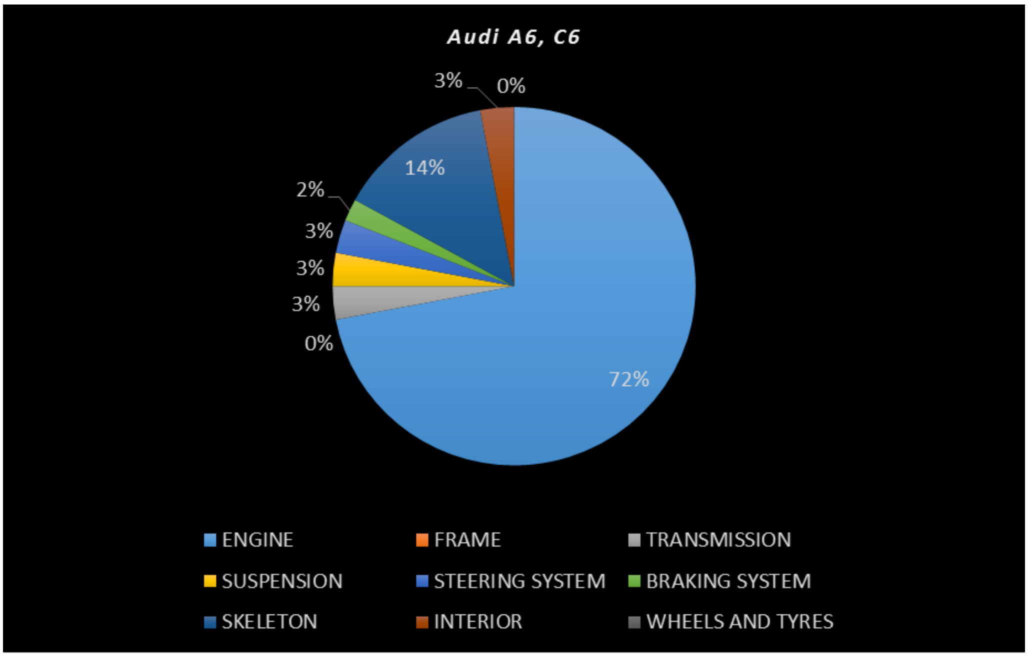

Fig. 8. The comparison of costs input-type C6

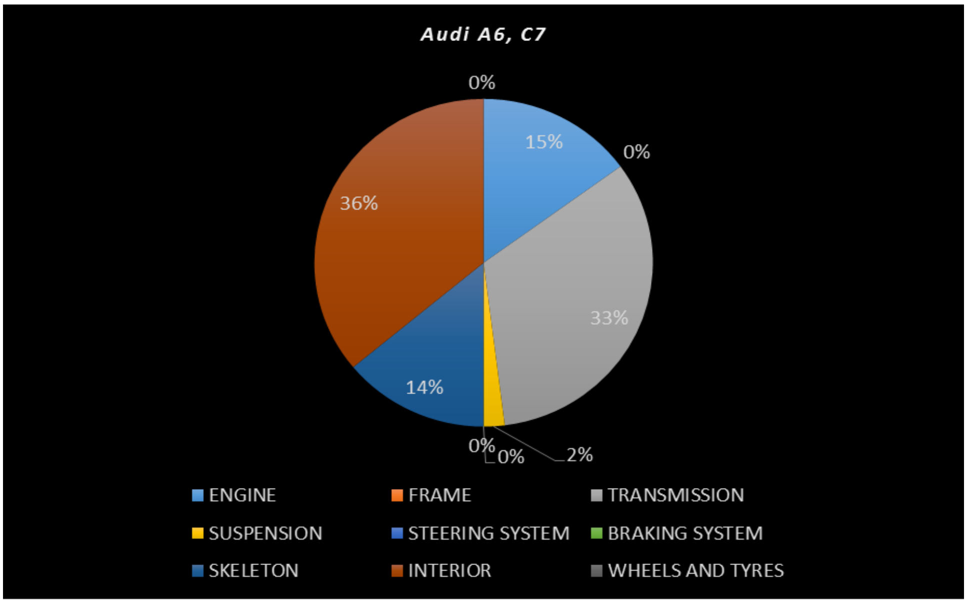

Fig. 9. The comparison of costs input-type C7

Among the percentage values, presented in Fig. 8, the maximum value, several times higher than the rest is assigned for the segment of engine (72%). In the older type, there occurred serious and expensive engine malfunctions influencing the obtained results. The particular malfunctions concerned the exchange of head, under head seal, valve unit, and 6 injectors. In the C7 generation case (Fig. 7), there is visible the significant decrease of costs, which proclaims the right direction of this unit improvement. This result is impressive and has reflection in the made-up technological progress, having impact on the increase of engines persistency. In the diesel engines there was made the transition from the united injector technology to Common Rail system of the first and then the second generation.

5. Summary and conclusions

The carried out analysis of malfunctions in the parameter set allowed answering the question concerning the quality and reliability of engines of the newest Audi A6 generation. The obtained results made the basis to carry out the system analysis of the tested vehicles, through which the following conclusions were formulated:

- as a result of shorter work consumption of technical servicing counted for 1000 km of about 26% A6 model C7 generation, the car technical readiness factor obtained more beneficial, expected value. The obtained result proclaims about longer time of vehicle availability for exploitation in the three years of exploitation,
- 30% lower cost spent on the servicing of A6 model C7 generation with the compression-ignition engine, significant decrease of service works of nearly 40%, impressive decrease of cost spent on unit malfunction elimination – engine with equipment, and less total number of engine malfunctions confirm the right direction of Audi diesel engines improvement. There made the transition from the united injector technology to Common Rail system of the first and then the second generation, influencing the increase of compression-ignition engines persistency,
- in the case of spark-ignition engines, assembled in the newest Audi A6 generation, there was noticed the bigger number of malfunction connected with their accessories, which related to the increase of the service work of nearly 30%. The cost input spent on the mentioned malfunctions is much lower, which proclaims the smaller importance of the discovered failures.

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