PRZEGLĄD SPAWALNICTWA
Welding
TECHNOLOGY REVIEW

DOI: http://dx.doi.org/10.26628/wtr.v91i3.1044

Article

Energy intensity as an ecological factor in the selection of the manufacturing process

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Received: 12.02.2019; Accepted: 08.03.2019

Abstract: The article presents the analysis of the implementation of selected elements of car transport in the aspect of ecology. The basic issue that affects the protection of the environment (ecology) is the value of energy intensity in the manufacture of products. The elements made in the production process of plastic mouldings were compared. The amount of energy in kJ needed to produce 1 kg of a given product was estimated. Next, the dependencies between the value of computational energy intensity and the emission of gases affecting the environment of CO_2, SO_2, NO_x were presented. As a conversion factor according to GUS data, it was assumed that 1kWh production in Poland causes emission of 800 g CO_2, 7 g SO_2 and 3 g NO_x.

Keywords: manufacturing processes; energy intensity in production; ecology; precision castings;

Introduction

Energy intensity in the production of a specific product is the amount of energy consumed in the production process [1÷3]. In our case, we are talking about energy-intensive technology (ET). ET does not contain partial energy to obtain and process raw materials and materials contained in the finished product. Generally, $E_T = \Sigma E_i$, where E_i – energy intensity of the next phase of the technological process. It contains the sum of energy put into the process carriers, technological materials, machines and technological devices, as well as the work force used in the technological process. The total energy consumption of the production process is influenced, among others, by the tools that wear out during the manufacturing, processes related to the regeneration of used materials, or costs related to the planning of production processes [4÷8]. An important process in environmental protection (ecology) is the monitoring of air pollution, especially on the scale of gas pollution. The main pollutants in the gaseous state are mainly: carbon dioxide CO_2, sulfur dioxide SO_2, nitrogen oxide NO_x and hydrocarbons C_nH_m. [9,10]. In addition, it was found that SO_2 concentration of 0.5 mg/m^3 is very harmful to humans, animals and plants. In particular, the sulfur content of fuels should be minimized. Carbon dioxide is one of the main causes of the greenhouse effect. In addition, with a 0.4% CO_2 dose in confined spaces, we experience breathing problems. Nitrogen oxides affect living organisms just like chemical weapons and in higher doses can lead to death [11]. Considering the data presented in the summary, one should strive to reduce the energy intensity of manufactured products, by applying solutions which reduce the impact of production on the environment [12÷14] or using modern materials processed repeatedly with negligible environmental impact e.g. polylactide (PLA) [15÷17].

Assessment of energy intensity of selected elements of a car transport

To assess energy intensity the following components were selected:

1. Can, which is the seatbelt's casing (Fig. 1);
2. Car headrest – its skeleton (Fig. 2);
3. Frame, which is a casing used for the mounting of control systems (Fig. 3);

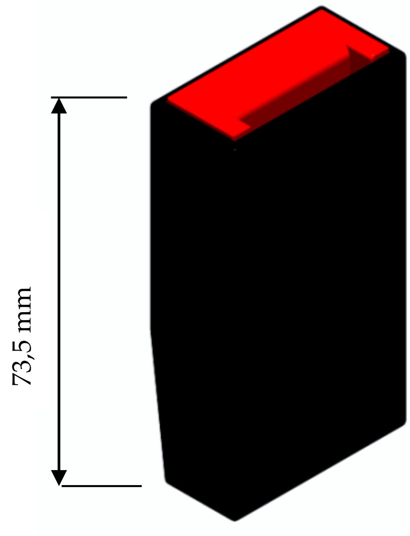

Fig. 1. Seat belt buckle element ''Can''

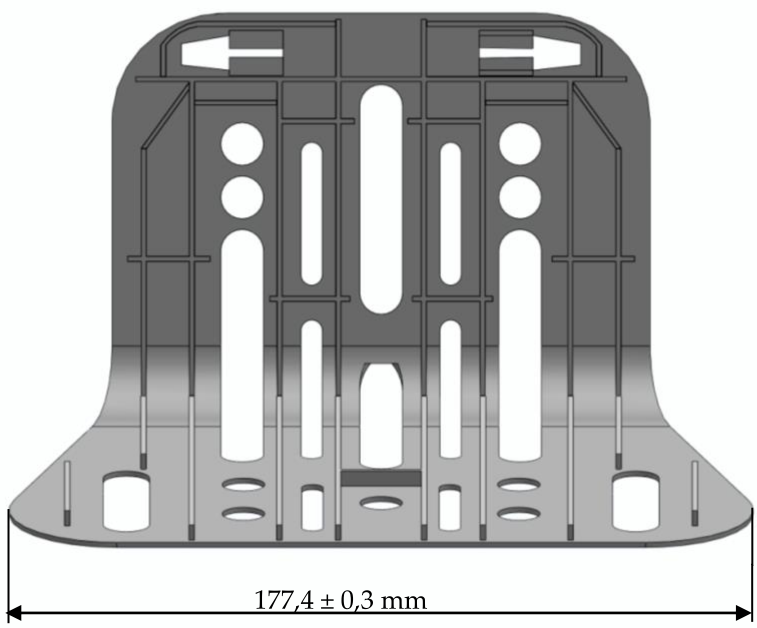

Fig. 2. Element of the headrest

The main material for the above-mentioned products are plastics. The can and headrest are made of polypropylene, whereas the frame is made of the highest strength plastic, which is the PC polycarbonate.

In an embodiment of the can element, calculations of the energy intensity of making a can element will be made, taking into account all energy intensity used in the production of the plastic element.

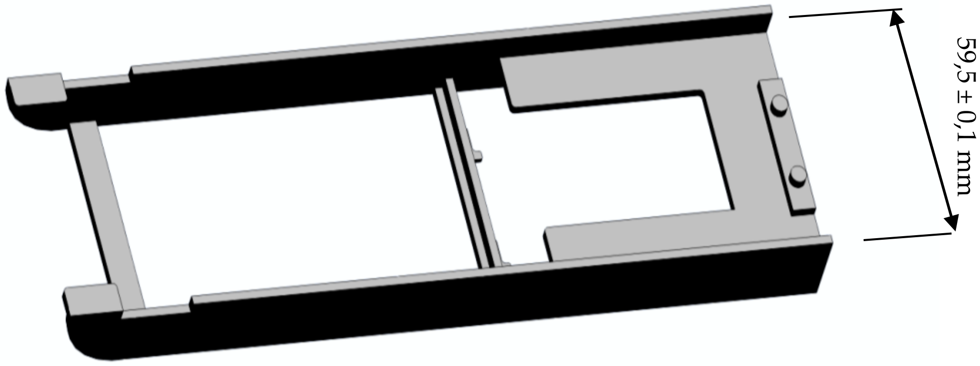

Fig. 3. Element used for the assembly of control systems "Frame"

The total technological energy intensity $E_{Tcał}$ is:

$$E_{Tcał}=E_{tw}+E_{mf}+E_{f}+E_{tukł}=5500+14{,}8+100{,}8+3560 = 9175{,}6 \text{ kJ/1 kg of product},$$

where:

E_{tw}= 5500[kJ/kg] of plastic material based on CSO data;
E_{mf} – energy consumption needed to produce material for the injection mold;
E_{f} – energy consumption of the injection mold, 100,04 kJ/kg for 100000 injections;
$E_{tukł}$ – energy consumption in the production process per 1kg of product kJ/kg.

For the headrest and frame, the calculations have been made as above, and the summary results are shown in Figure 4.

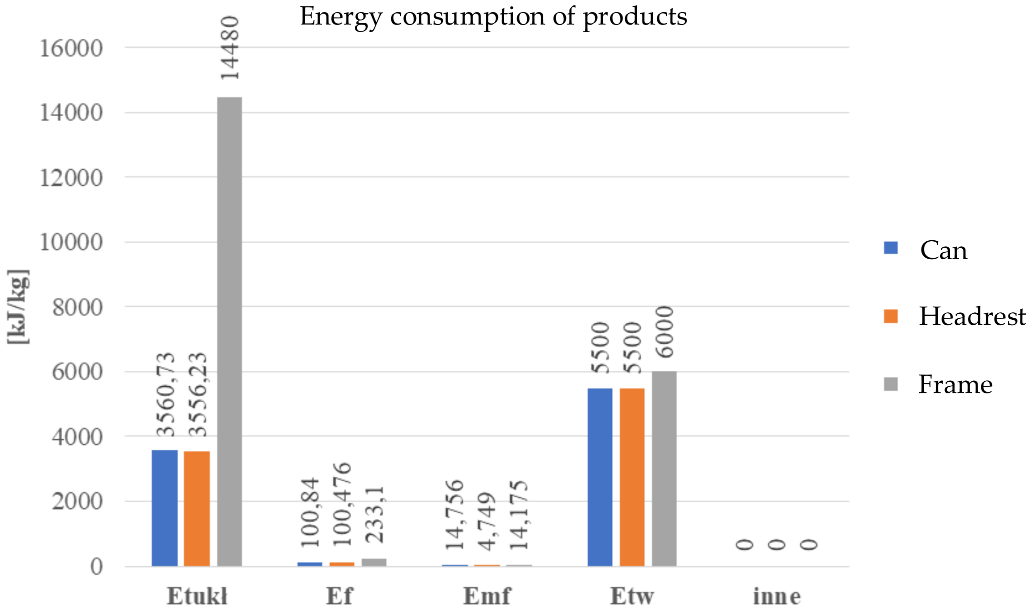

Fig. 4. Energy intensity of the manufacturing of a can, headrest and frame

Energy intensity in the production of material for the aforementioned products was included in the CSO materials [18], this also applies to materials for injection molds (material for the tool).

Based on the calculation of energy intensity of the elements presented in the article, the following total energy-intensive technologies were obtained:

1. Can – 9175 kJ/kg;
2. Headrest – 9161 kJ/kg;
3. Frame – 20727,27 kJ/kg.

If we replace elements made of plastic with elements made of metal, then the result would be the following:

1. For the Can, the best technology will be a precision casting from AlSi with an energy consumption of 40 MJ/kg;
2. For the Headrest element, it is proposed to make an AlSi cast in an accurate sand form made on the basis of PERMASET furan binders with energy consumption of about 40 MJ/kg;
3. For the Frame, machining of the pre-material with a thickness of approx. 8 mm can be used. Due to the large amount of chips, energy consumption may exceed 100 MJ/kg. Another method of production can be the execution of an accurate AlSi alloy casting. Then the energy consumption of the product will be about 40 MJ/kg. The limitation is the need to use hard waxes for melted models.
4. Using the reference to the ecology of the plastic elements obtained with a batch of 10,000 items, assuming according to the CSO data, that the production of 1 kWh in Poland results in the emission of 800 g CO_2, 7 g SO_2 i 3 g NO_x. For plastic elements, we get the results shown in the table I. If we use AlSi elements for production, we will get the ecological parameters presented in the table II.

Table I. Ecological parameters of obtaining plastic elements for 10000 items

		Can	Headrest	Frame
	Weight [kg/pcs.]	0,023	0,1245	0,02
	Lot weight [kg]	230	1245	200
	$E_{Tcał}$ [MJ]	2110,5	11404	4144
	$E_{Tcał}$ [kWh]	586	3167	1151
Emission of harmful gases	CO_2 [kg]	469	2534	921
	SO_2 [kg]	4,1	22	8
	NO_x [kg]	1,76	9,5	3,5

Table II. Ecological parameters of obtaining metal elements for 10000 items

		Can	Headrest	Frame
	Weight [kg/pcs.]	0,062	0,335	0,054
	Lot weight [kg]	620	3350	540
	$E_{Tcał}$ [MJ]	24800	167500	21600
	$E_{Tcał}$ [kWh]	6890	46528	6000
Emission of harmful gases	CO_2 [kg]	5512	37222,4	4800
	SO_2 [kg]	48,2	325,7	42
	NO_x [kg]	20,7	130,6	18

Conclusions

1. The use of AlSi material instead of plastics to manufacture the elements used in car transport causes a significant increase in energy consumption of the production process.
2. Emission of harmful gases CO2, SiO2 and NOx in the case of the above-described elements is much greater when they are made of AlSi than from plastics. For individual parts we obtain:
   - Can – the number of emissions is more than 11 times greater;
   - Headrest – the number of emissions is more than 14 times greater;
   - Frame – the number of emissions is more than 5 times greater.
3. The use of plastics for the aforementioned elements causes a much smaller environmental contamination resulting in a lower impact on the health of people.

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