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QUANTITATIVE METHODS FOR MATERIAL SELECTION – MATERIAL PROPERTIES CHART

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Abstract: This paper presents the selection of optimal materials for the production of basic constituent elements of electric iron: housing, heater and warming plate using material properties chart (map) quantitative method and Cambridge Engineering Selection software (CES). This work is a continuation and expansion of research. The results were compared with results from the paper [1] in which selection of mentioned constituent elements of electric iron materials was done using two quantitative methods: the method of properties influence (digital-logic method) and the method of minimum deviation of actual properties compared to required (algebraic approach).
Keywords: quantitative methods, material selection, material properties chart (map), CES software

INTRODUCTION

In the modern world there is more and more attention focused on the procedures for selecting the material from which a certain part will be made. Therefore, there is the obligation of engineers to properly decide which material, from a range of possible, is optimal for use, Fig.1. [2].

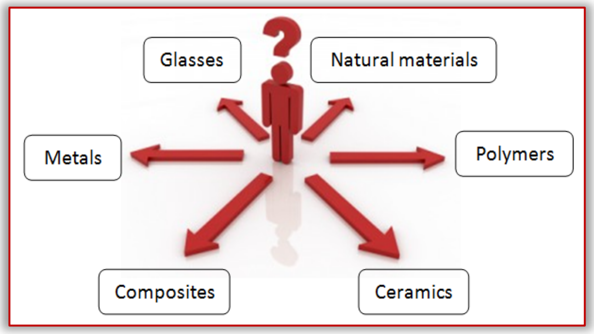

Figure 1. Selection of the appropriate material-downloaded and modified from [6]

In addition to materials for producing a particular product requires skills, knowledge and experience of the people, as well as methods of constructing and more or less complex methods of production [2]. The number, variety and quantities of materials are increasing-from massive amounts of a small number of species to the current very large amount of a combination of many types. Today it is estimated that there are more than 70 000 types of technical materials [3], among whom more than 40 000 alloys based on metals [4]. The basic purpose of the quantitative methods application is as much of objectivity in the selection of materials [5].

The paper [1] describes the procedure of selection of optimal materials for the production of electric iron constituent elements: housing, heater and warming plate using quantitative methods for the materials selection: the method of properties influence (digital-logic method) and the method of minimum deviation of actual properties compared to required (algebraic approach). This paper and the results obtained were used as a basis for comparison with the results of the selection of optimal materials of the same constituent elements of electric iron obtained in this study using material properties chart (map) quantitative method and software Cambridge Engineering Selection (CES).

METHODS FOR MATERIAL SELECTION

Material properties chart (map)

In comparing the materials it is not often enough to take one property as a criterion of evaluation, but it is necessary to consider a combination of properties. Thus, for example, for parts which have to be lightweight and be rigid at the same time the density and modulus of elasticity should be evaluated, or for structures to secure from sudden expansion of cracks and fracture it is important at the same time high yield strength, but also high ductility and toughness. On the basis of this approach so-called "Properties chart" has been developed [2] where the diagram represents the framework regions of a number of properties of different material groups (Fig. 2). Assume that there are limitations in the process of design in terms of elastic modulus (e.g. E>10 GPa) and the density of the material (e.g. ρ <3000 kg/m³), as shown in Fig. 2. Thereby, the materials should be selected in the window labeled "Search Region".

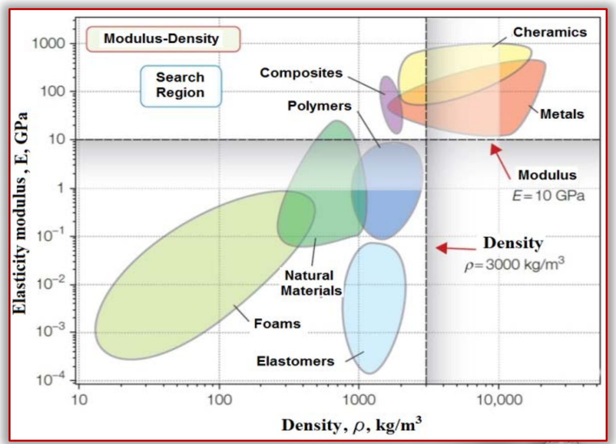

Figure 2. Material properties chart (modulus of elasticity-density) [2]

The closed line limits data for a group of materials, indicating a possible range of values regardless of the type of material. If the abscissa and ordinate are in logarithmic division, then the highest and lowest properties values can be displayed. In this way, it is easier to compare a group of materials, i.e. Framework material pre-selection. Diagrams feature gives the correlation between certain material properties.

Material selection of electric iron constitutive elements

The main criteria to be met by materials for electric iron constituent elements are shown in the Table 1[1]:

Table 1. Criteria for material of housing, heater and warming plate

Housing	Heater	Warming plate
Low density	High specific thermal resistance	Good thermal conductivity
Low thermal conductivity	Low electrical resistance (excellent electrical conductivity)	Density
Low electrical conductivity	High temperature Providing	Corrosion resistance
Shaping	Oxidation resistance	Abrasion resistance
Fracture toughness	Spontaneous combustion resistance	Solubility
Hardness	Machinability	Machinability
Price	Price	Recyclability
		Price

Electric iron housing

Seven material properties were considered [1]: density, thermal conductivity, electrical conductivity, solubility, fracture toughness, hardness and price. Using CES Selector software, limitations for electric iron housing materials that can be considered are set. Lighter material with a density of 1100-1300 kg/m³ with the maximum price of 3 €/kg is selected. Based on these properties, it is important that the fracture toughness is at least 4 MPa·m$^{1/2}$, the value of thermal conductivity is a maximum of 0.3 W/m⁰C and that potential material is a good electrical insulator. Of course, the material must be machinability, so, it can be easily shaped by methods of injection molding, extrusion and the like, so that the required machinability is a minimum of 4. Based on the above, the CES software offers as a result of 5 different materials: acrylonitrile butadiene styrene (ABS), polyamide, polycarbonate, polyethylene terephthalate (PET) and polyvinyl chloride (PVC). If we take into account the hardness of the material, which is very important in this case, and limit the search to a minimum of 25 HV, we obtain the optimal material for the production of electric iron housing: polyamide, Fig. 3.

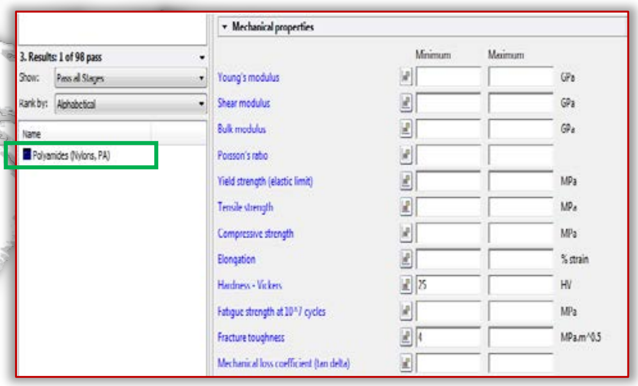

Figure 3. Optimal material for production of electric iron housing

Based on the given limits, the same result using the material property chart (map) is gotten (Fig. 4), where we can see that the optimal material, polyamide, is in the area shown in yellow.

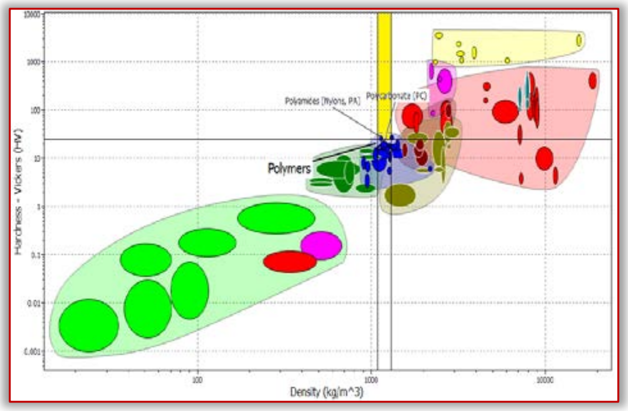

Figure 4. Material properties map (chart) for electric iron housing material

Electric iron heater

Six material properties were considered [1]: electrical resistance, thermal conductivity, electrical conductivity, the maximum heating temperature, machinability and price. The material that may be submitted by high-temperature heating during operation (800-900^{0}C) is selected while at the same time there are no its physical and chemical properties changes. Electrical resistance is also important, which should not exceed the value of 130 μohm·cm. Of course, the material must be a good electrical conductor and extremely machinable (drawing, bending) in order to achieve the desired shape of the heater. Based on the previously, CES software offers as a result a large number of different materials, even the 192. One of the main properties that the material for iron electric heater must meet is thermal conductivity. Its value is limited by interval of 9-10 W/m^{0}C. The price of material is indispensable. In this case, the maximum price should not be higher than 22 €/kg. If the last criteria is considered, the optimal material for the electric iron heaters is, in this case, Ni-Cr-Fe alloy (Nichrome), Fig. 5.

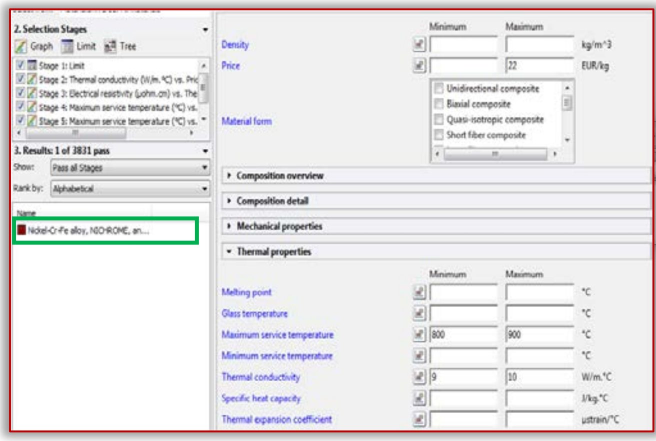

Figure 5. Optimal material for production of electric iron heater

Based on the given limits, the same result using the material property chart (map) is gotten (Fig. 6), where we can see that the optimal material, Ni-Cr-Fe alloy, is in the area shown in yellow.

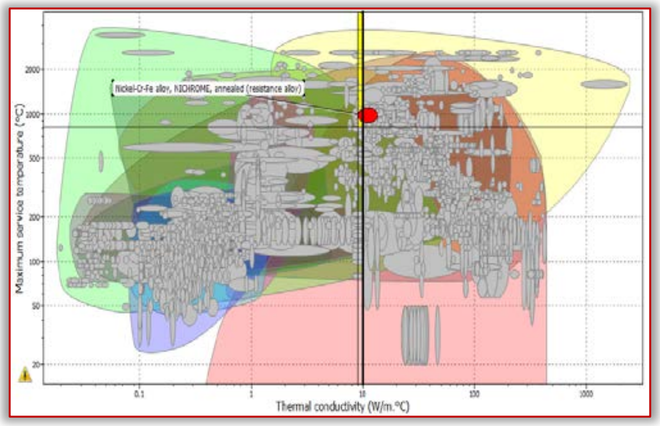

Figure 6. Material properties map (chart) for electric iron heater material

Electric iron warming plate

Five material properties were considered [1]: thermal conductivity, the maximum heating temperature, density, hardness and price. The material that needs to meet a minimum hardness of 50 HV is selected. One of the most important properties is the thermal conductivity, which the lower limit is set to 15 W/m^{0}C and the maximum temperature that the warming plate material can achieve during working life which value must be at least 150^{0}C. Based on the previously, CES software offers as a result of 3 different materials: Al alloy, Mg alloy and Silicon. An important property for the warming plate material is the mass of the material, i.e. its density, which is, in this case, limited by the value of up to 3000 kg/m^3. The price of material is indispensable. In this case, the maximum price should not be higher than 2 €/kg. If the last criteria is considered, the optimal material for the electric iron warming plate is, in this case, Al alloy, Fig. 7.

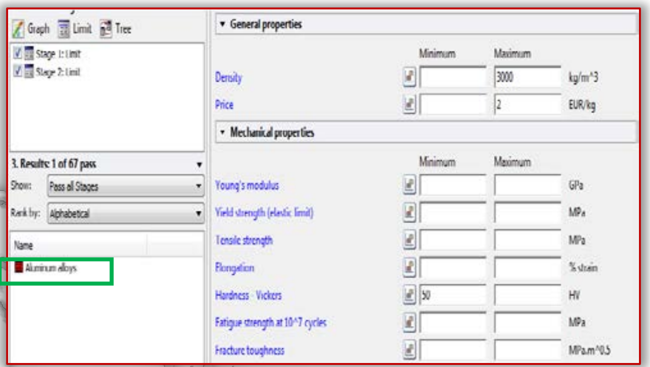

Figure 7. Optimal material for production of electric iron warming plate

Based on the given limits, the same result using the material property chart (map) is gotten (Fig. 8), where we can see that the optimal material, Al alloy, is in the area shown in yellow.

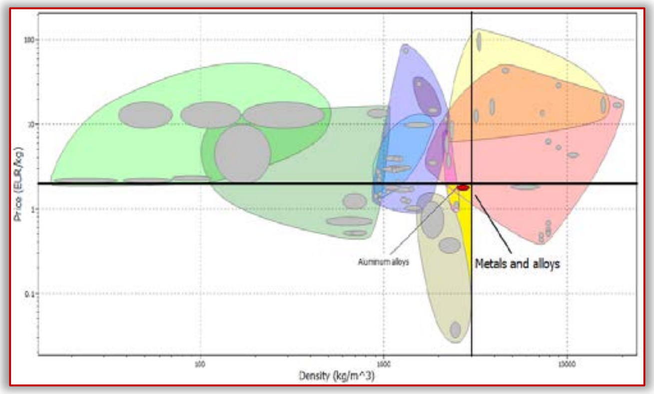

Figure 8. Material properties map (chart) for electric iron warming plate material

RESULTS AND DISCUSSION

Table 2 presents comparative results of the electric iron constitutive elements optimal materials obtained on the basis of two quantitative methods in paper [1] and results based on material properties chart (map) quantitative method processed in the previous section of this paper.

Table 2. Comparative results of the electric iron constitutive elements materials

Electric iron constitutive elements	Method of properties influence (digital-logic method) [1]	Method of minimum deviation of actual properties compared to required (algebraic approach) [1]	Material properties chart (map)
	Material		
Housing	Polyamide	Polyamide	Polyamide
Heater	Ni-Cr-Fe (Nichrome)	Ni-Cr (Nimonic 81)	Ni-Cr-Fe (Nichrome)
Warming plate	Al alloy	Polytetra-fluor-ethylene (Teflon)	Al alloy

CONCLUSION

The material selection process is present in every part of the design process and directly affects the lifetime of the product [7]. Based on personal experience, developed methods for the appropriate materials selection and based on software support, it is possible to make a proper decision on the material to be used. This paper presents the optimal materials selection of the constituent elements of electric iron: housing, heater and warming plate using material properties chart (map) quantitative method. Based on the mentioned method, optimum materials for the housing, the heater and the warming plate of electric iron are, respectively, polyamide, Ni-Cr-Fe alloy (Nichrome 81) and Al alloy. The results were compared with the results of the optimum material from the paper [1] obtained using two quantitative methods: the method of properties influence (digital-logic method) and the method of minimum deviation of actual properties compared to required (algebraic approach). Based on these results, using the method of properties influence (digital-logic method) and material properties chart (map) quantitative method, we can ascertain that the obtained materials for the electric iron constituent elements are exactly the same, while in method of minimum deviation of actual properties compared to required (algebraic approach) Polytetrafluorethylene is approved as well as the optimal warming plate material. Of course, each of these quantitative methods has its own characteristics and, hence, the recommendation in the choice of materials is to use at least two of the methods. Further research can be extended by using some of the remaining quantitative methods for the materials selection.

Note

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References

[1] Vučetić, N., Adamović, D., Jovičić, G., Material selection of electrical devices using quantitative methods, XV International Scientific-Professional Symposium “INFOTEH”-Jahorina, Vol.15, pp.430-435, 2016.
[2] Filetin, T., Izbor materijala pri razvoju proizvoda, Fakultet strojarstva i brodogradnje, Zagreb, 2006.
[3] Ashby, M. F., Materials Selection in Mechanical Design, Butterworth-Heinemann, Oxford, 2001.
[4] Farag, M. M., Materials and Mechanical Design, The American University in Cairo, Egypt, 2006.
[5] Filetin, T. Metode izbora materijala, Fakultet strojarstva i brodogradnje, Sveučilište u Zagrebu, Zavod za materijale
[6] *** <http://www.psiholoskikutak.com/racionalno-i-iracionalno-razmisljanje/>, 31.05.2016.
[7] Đurić, A., Marković, B., Vučetić, N., Pelkić, S., Calculation of factors LBKz and its significance for the development of light weight construction, The 3rd International Conference “Mechanical Engineering in XXI Century”, Niš, 2015.
[8] Vučetić, N., Quantitative methods for material selection – material properties chart, The VIth International Conference Industrial Engineering and Environmental Protection 2016 – IIZS 2016

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