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# High quality casting materials

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Materials

## ABSTRACT

**Purpose:** The paper briefly presents results of the new developed high quality cast materials.
**Design/methodology/approach:** The following materials are: hypereutectoid cast steel with various microstructure modular graphite obtained in as-cast condition (raw state), ductile cast iron of bainite-martensitic carbides structure obtained in a raw state, aluminum bronzes and silumins with additives of: chromium, molybdenum, wolfram, vanadium.
**Findings:** These alloys are characterized primarily by significant mechanical properties and high wear resistance. It was also discussed getting of layer products by combination of steel or cast iron using alphinated layer with silumin.
**Practical implications:** The paper discusses the high quality cast alloy, layer products and presents the high quality casting materials in the point of view principles of materials selection.
**Originality/value:** The above problem is shown in the background of "Rules of material selection" as well as a model of production system in company.
**Keywords:** Hypereutectoid cast steel with graphite; Ductile cast iron with carbides; Bronzes; Mechanical properties

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## 1. Introduction

In the Department of Materials Engineering and Production Systems worked out new materials with high usage properties primarily with high strength and significant wear resistance which can replace currently used conventional materials [1-4].

These materials have been implemented in industry and items made from them are rated highly in terms of durability and reliability. Further investigations are carrying out in this area. Due to the new quality of these materials they should be taken into account using pointed in the work rules of material selection-design taking into account model of enterprise production system which also was inserted in the work. A more detailed materials characteristics included in the work presented in the literature [1-8].

## 2. Principles of material selection

Principles of material selection for parts of machinery and equipment shown in Figure 1. They were elaborated based on personal experience and literature [9; 10]. The most important element in the rules for the selection of material is mainly correct determination of part load and results from this stresses. As a rule allowable stress can transfer several different materials. Then should be take into account additional factors affecting to a lesser extent on the functional properties of product and enforcement costs of: material, semi-finished product and finished item. Significant influence on it has applied production system which is mainly consists of preparatory process and manufacturing process. Generalized model of production system is shown in Figure 2.

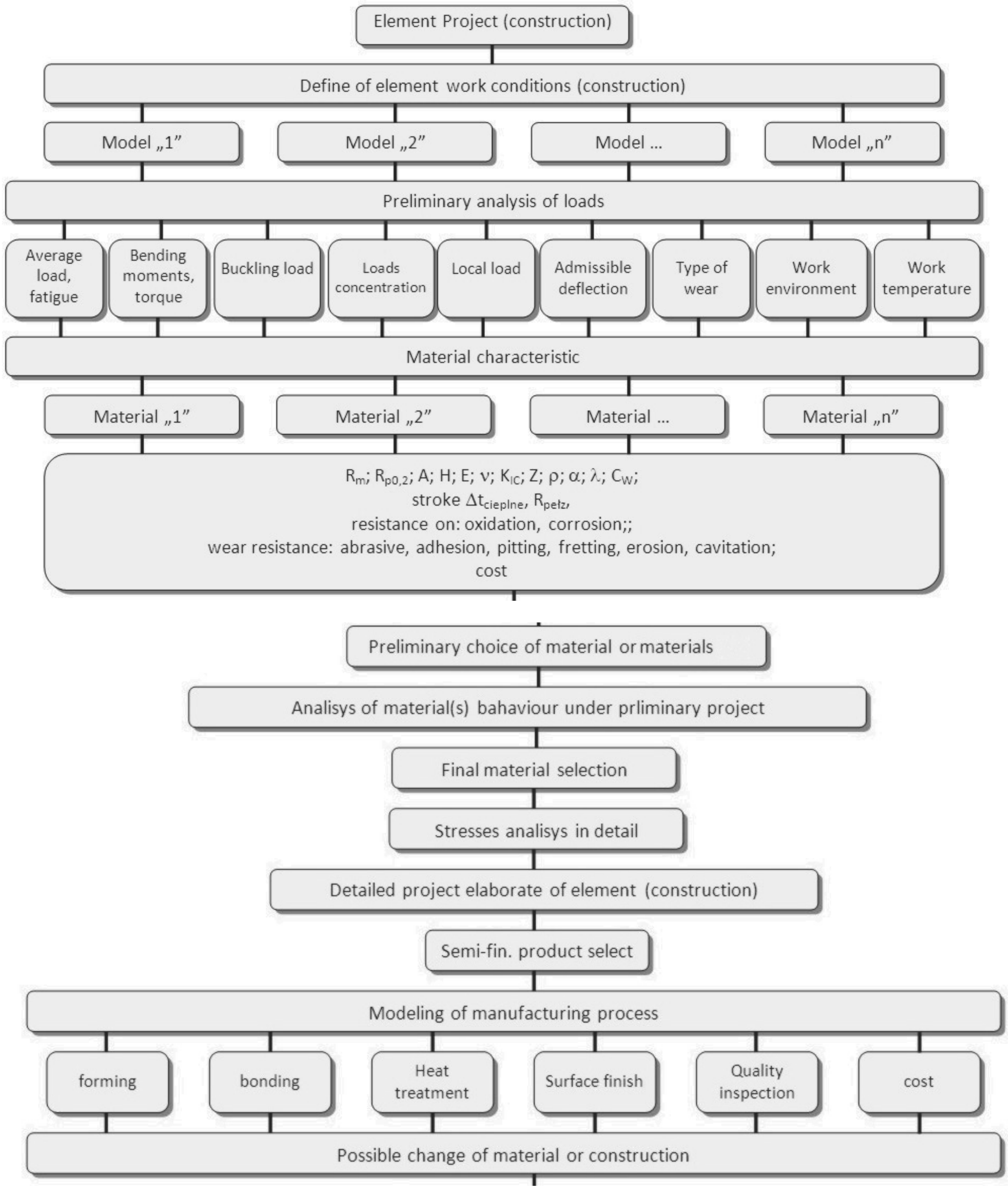



Fig. 1. Principles of material selection on machinery and construction devices

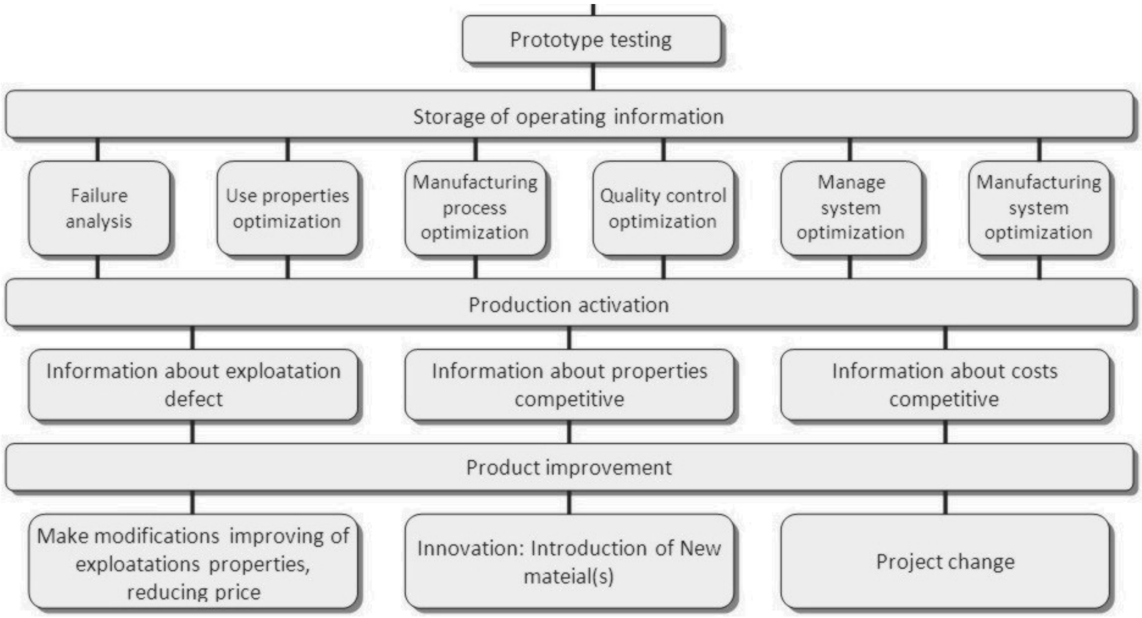



Fig. 1. cont. Principles of material selection on machinery and construction devices

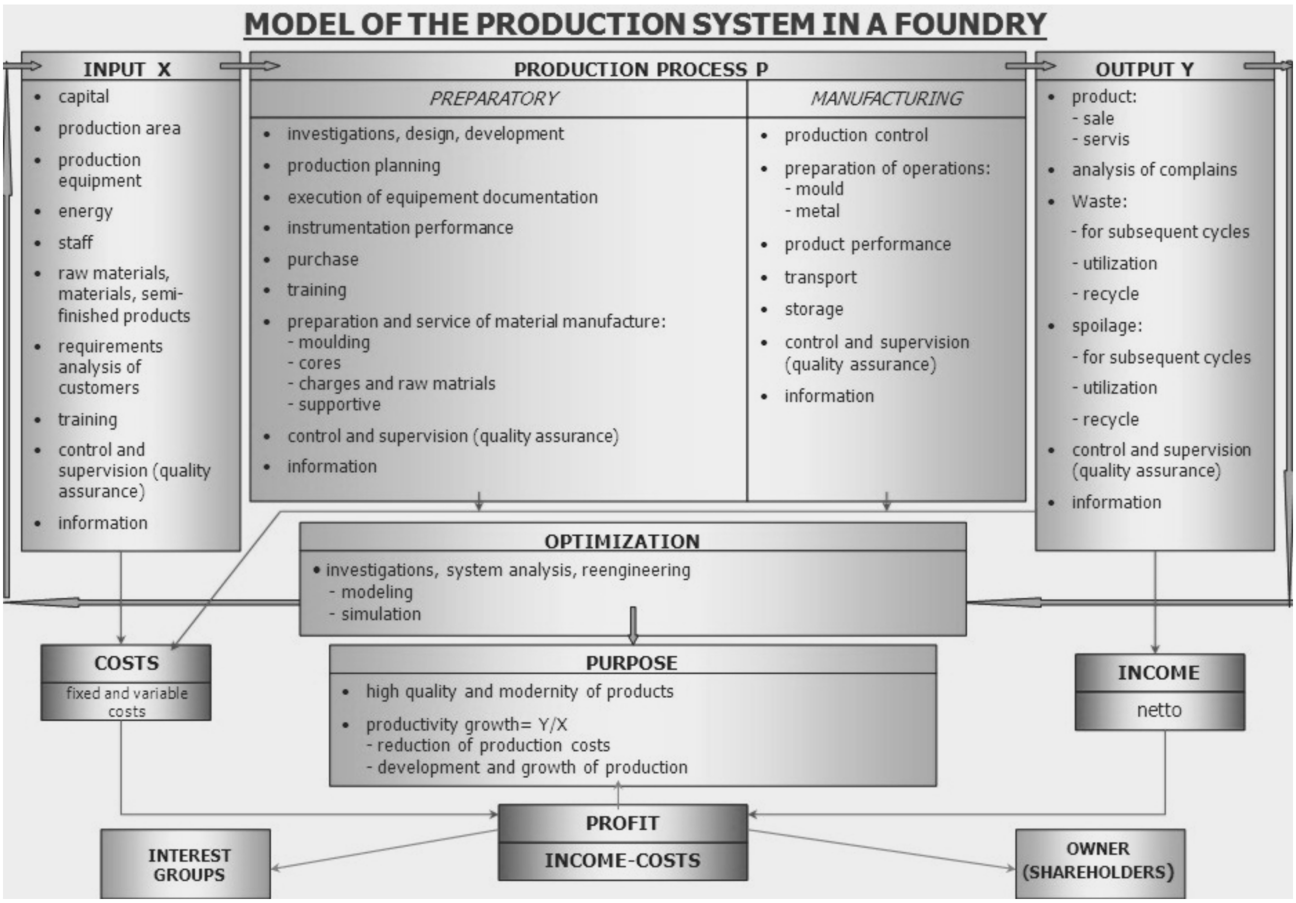
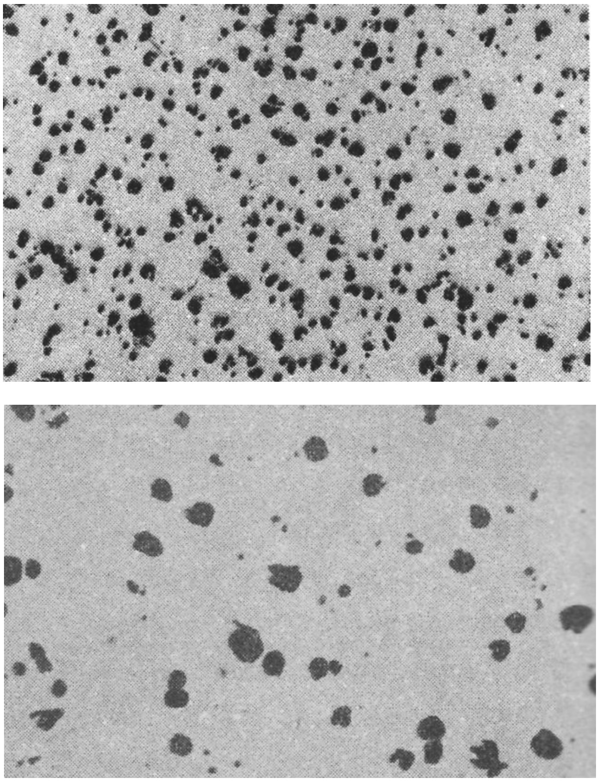


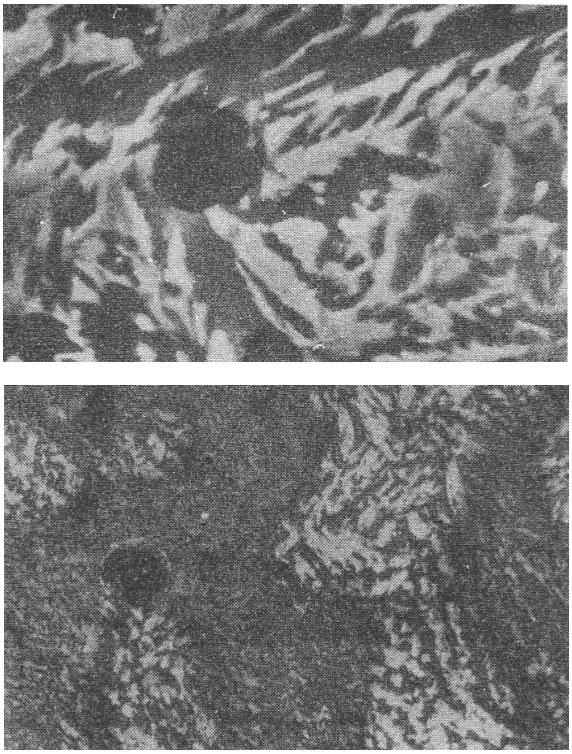

Fig. 2. Foundry generalized model of the production system



a)

b)

Fig. 3 (a, b). An example of graphite releases in modular cast steel



a)

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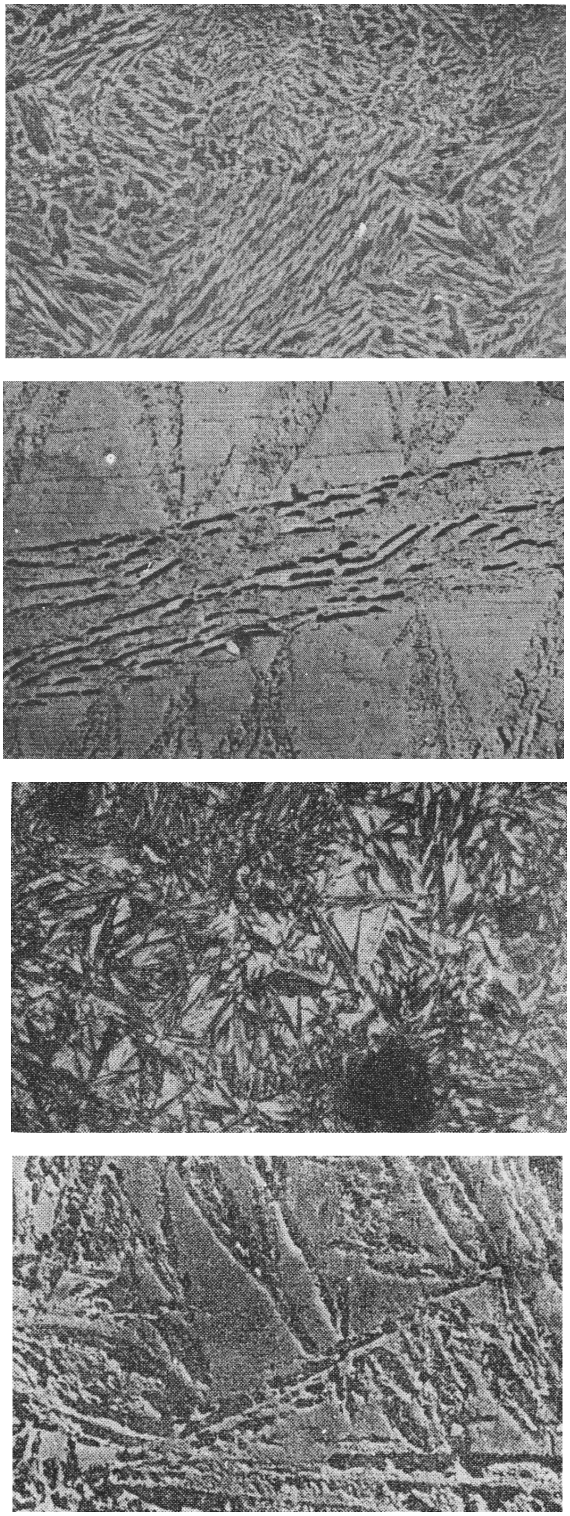

c)

d)

e)

f)

Fig. 4 (a-f). Examples of nodular cast steel microstructures obtained in a raw state: a – ausferrite (×6500); b – upper bainite (×800); c- upper with lower bainite (×2750); d – lower bainite with martensite (×4870); e – martensite (×500); f – martensite (×3400)

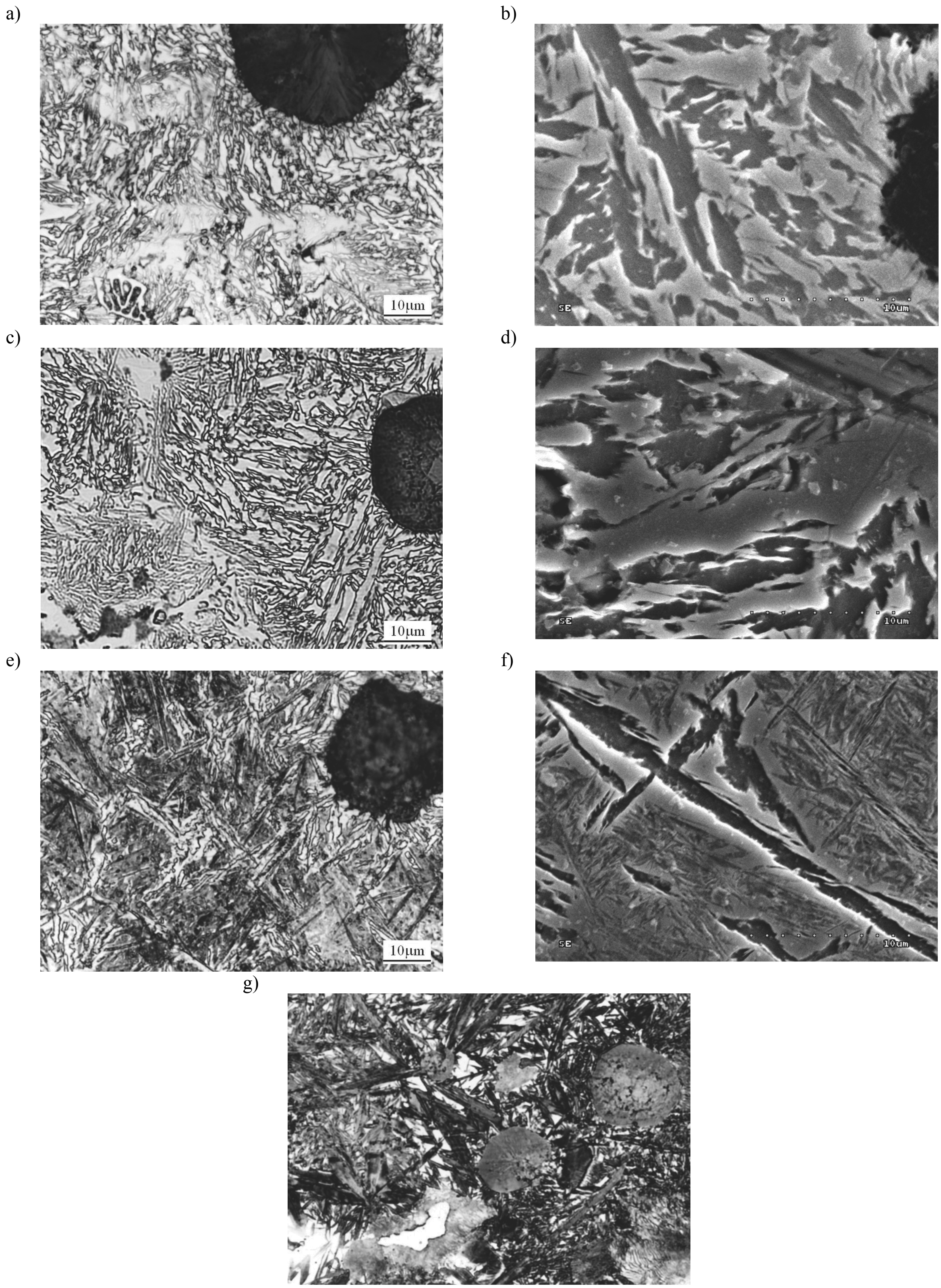


Fig. 5 (a-g). Microstructure examples of nodular cast iron with carbides: a – ausferrite (×500); b – ausferrite; c – upper bainite (×500); d – upper bainite; e – upper with lower bainite; f –upper with lower bainite; g – martensite

It shows that the high quality of the product and its cost is affected by many factors, which should also be taken into account in choosing the appropriate material. The proper choice of materials does not mean that during operation of machinery and equipment it should not be changed. The competitiveness of products requires an increase in its life and reliability of equipment which is determined by material most. Hence is the need for the development and application of new materials. Below are examples of new high-quality cast materials fulfil different requirements.

## 3. High-quality cast alloys

Material with high wear resistance, having in mind significant strength resistance, is cast steel with modular graphite obtained in a raw state. Modular graphite in cast steel can be obtained by slag treatment causes its deoxidize and desulfurization. An example of modular graphite in cast steel is shown in Figure 3 (a, b).

Modular graphite crystallize directly from liquid at the end of crystallize process of cast and from austenite after crystallize process ended in result of variable solubility of carbon. Chemical composition of cast steel is in the range: 0.90-1.50% C, 1.90-3.60% Si, 0.10-0.50% Mn, 0.005-0.05% P, 0.01-0.005% S, 20-70 ppm $O_2$. By the addition, into cast steel, of Ni, Cu and Mo elements in dependence on cast cooling rate various kinds of microstructures: ausferritic, bainitic, martensitic or its mixture and modular graphite in a raw state can be obtained. Examples of obtained microstructures are demonstrated in Figure 4 (a-f). Mechanical properties of modular cast steel: $R_m$ = 950-1900 MPa, $R_{p0,2}$ = 800-1750MPa, $A_5$ = 0.0-10.0%, 30-60 *HRC*.

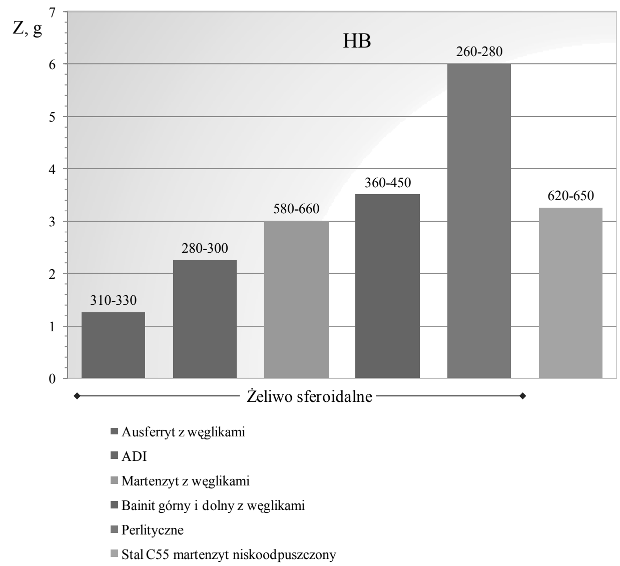


Fig. 6. Abrasive wear resistance of nodular cast iron with various microstructure and C55 steel

Another alloy with significant wear resistance, having in mind significant strength resistance is nodular cast iron with carbides with bainitc-martensite microstructure obtained in a raw state. Chemical composition of cast iron: 3.20-3.80% C, 2.20-3.00% Si, 0.35-0.75% Mn, 0.00-1.50% Cu, 0.50-2.00% Mo and 0.00-2.00% Cr. In dependence on cast iron chemical composition and cast cooling rate they can possess carbides in ausferritic matrix, upper and lower bainite, martensite or its mixture in a raw state. Its microstructure examples are presented in Figure 5 (a-g).

Abrasive wear resistance of mentioned cast iron in compare with other materials is presented in Figure 6.

Mechanical properties of this cast iron: $R_m$ = 800-1300 MPa, $R_{p0,2}$ = 650-1100MPa, $A_5$ = 0.0-5.0%, 280-660 *HB*.

Bronze CuAl10Ni4Fe4 with Cr, Mo, W and V (one by one or together) is an alloy resistant on wear and corrosion with significant mechanical properties. Amount of additive contain in a range of 0.05-0.80%. Representative microstructure example of bronze is presented in 7.

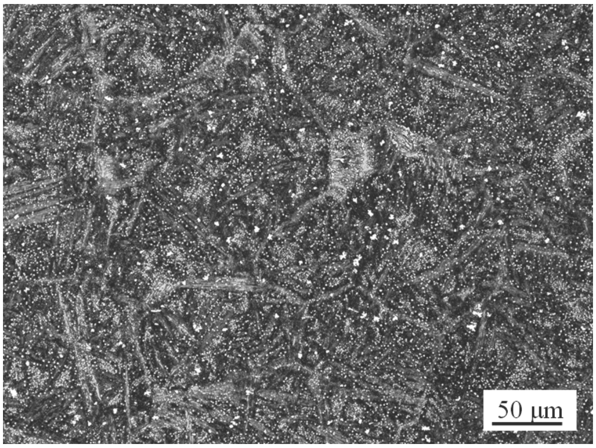


Fig. 7. Microstructure of CuAl10Ni4Fe4 bronze with additives of 1.30% Si, 0.60% Cr and 0.017% W. Phases: $\beta+\alpha+\gamma_2+\chi_{FeCrMoWSi}$

Such significant abrasive wear resistant of this bronzes is obtained in result of $\chi_{FeCrMoWSi}$ phase release. Examples of bronze hardness without and with: Si, Cr, Mo, W are presented in Figure 8. In Figure 9 is presented CuAl10Ni4Fe4 bronze abrasive wear resistance without and with: Si, Cr, Mo, W.

From the data displayed in Figure 8 and 9 results that alloy additives Si, Cr, Mo and W increase hardness of bronze up to 30% and wear resistance up to 50%.

Also silumins hypo-, hyper- and near-eutectic with additives of: Cr, Mo, W and V in amount of about 1.00% in its group are characterized by the highest wear resistance, hardness and high mechanical properties. It is caused by multicompound phases releases of AlSiCuFeNiMgCrMoWV, $Al_3CuNi$, $AlNiCu_3$, $Mg_2Si$ types crystallizing pre-eutectic or eutectic. Microstructure example of this silumins is presented in figure 10 (a-c). These silumins have the following mechanical properties: $R_m$ = 350-550 MPa, $R_{p0,2}$ = 200-400 MPa, $A_5$ = 0.5-5.0%, *HB* = 120-220.

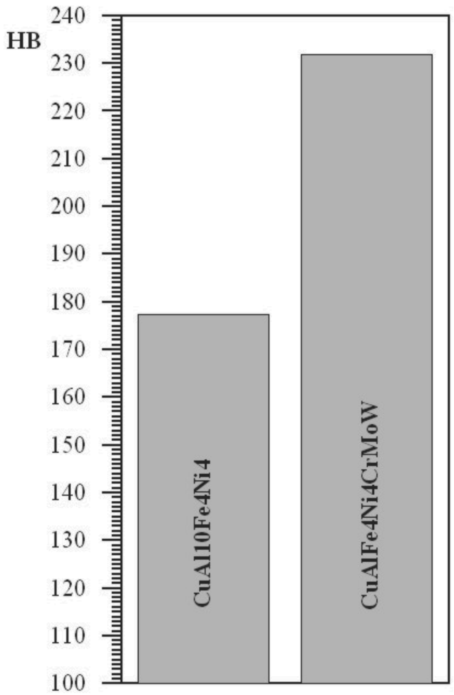


Fig. 8. Hardness of CuAl10Ni4Fe4 bronze and with additives of: Si, Cr, Mo and W

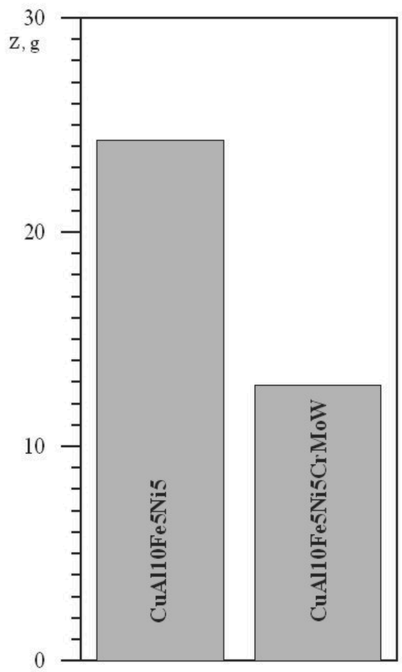


Fig. 9. Abrasive wear resistance of CuAl10Ni4Fe4 bronze and with additives of: Si, Cr, Mo and W

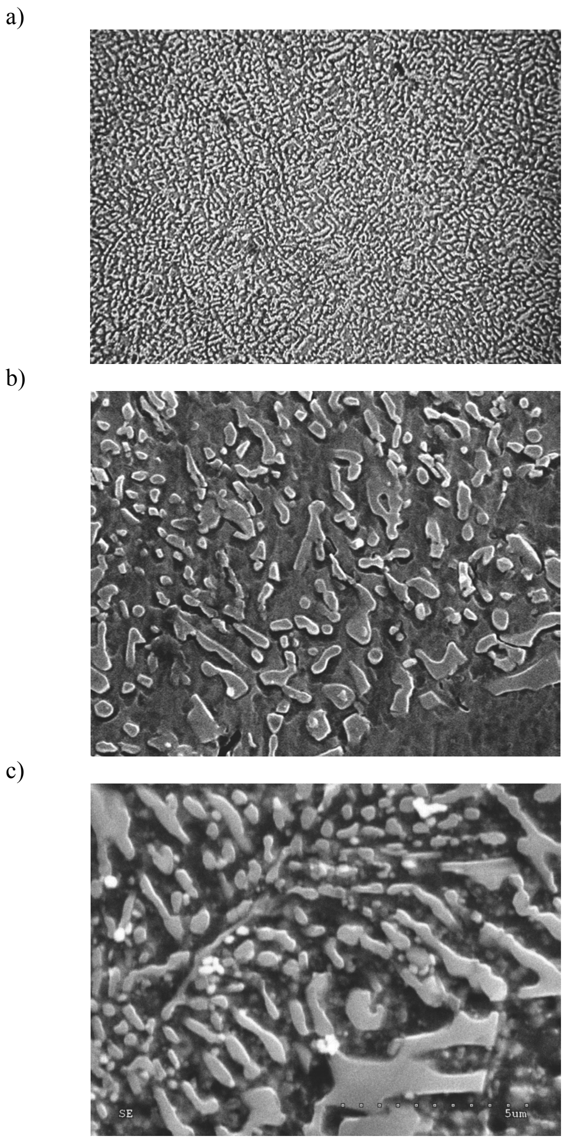


Fig. 10 (a-c). Microstructure of AlSi7Ni4Cu2Mg0,5Cr0,3Mo0,3 silumin. Phases: α, AlSiCrMoNiFeTi, $Al_3NiCu$, $Mg_2Si$, $Al_2Cu$, eutectic mixture α+β; a – raw state (×100); b and c – after release consolidation

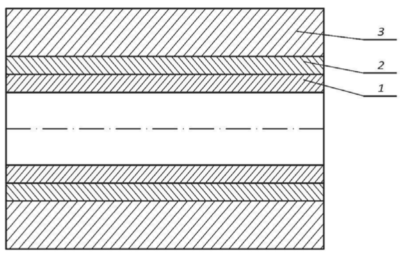


Fig. 11. Construction scheme of laminar products: 1 – basic material meet the functional requirements , ex. steel or cast steel wear and corrosion resistant (sample); 2 – interlayer (ex. alphinated); 3 – external part made of for ex. Silumin

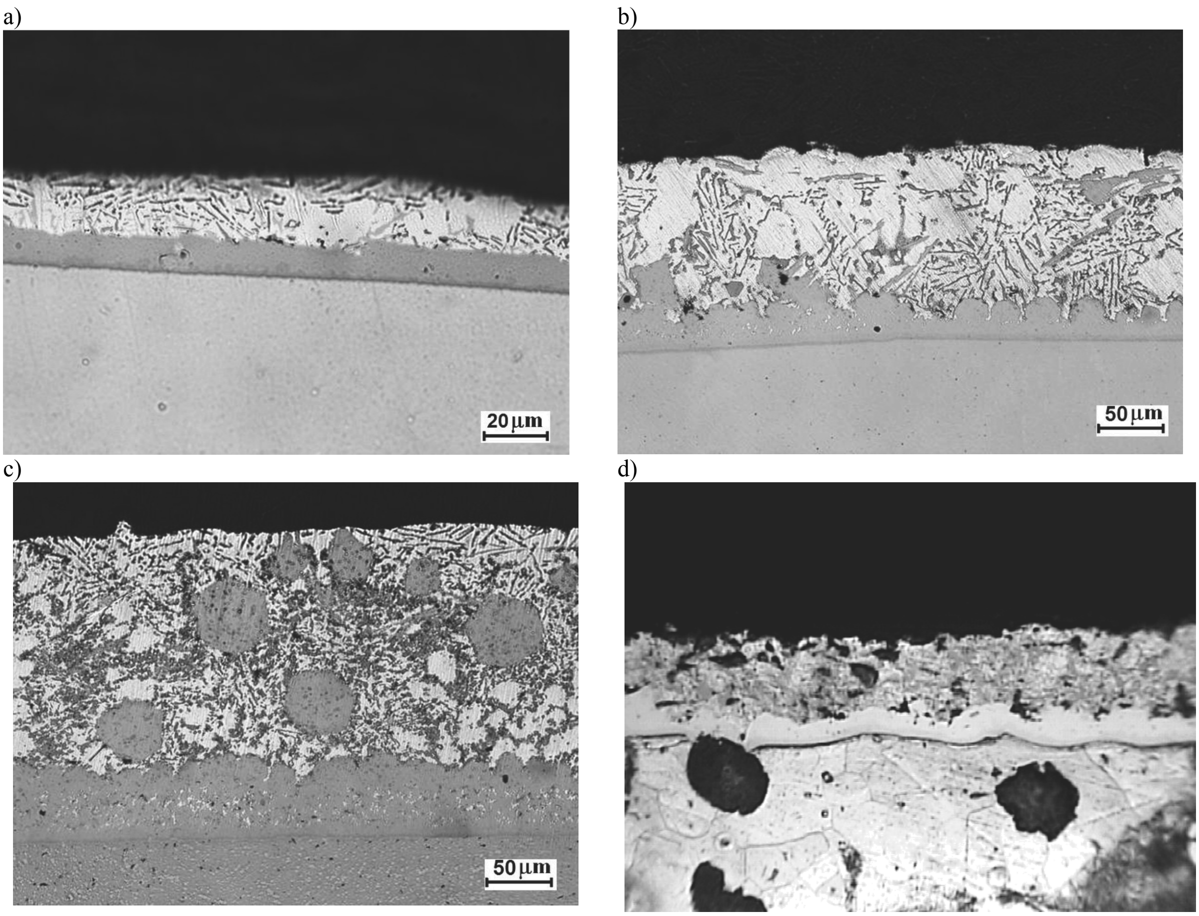


Fig. 12 (a-d). Alfinated coating on steel: a – 1H18N9T; b – 4H13; c – SW7M; d – modular cast iron

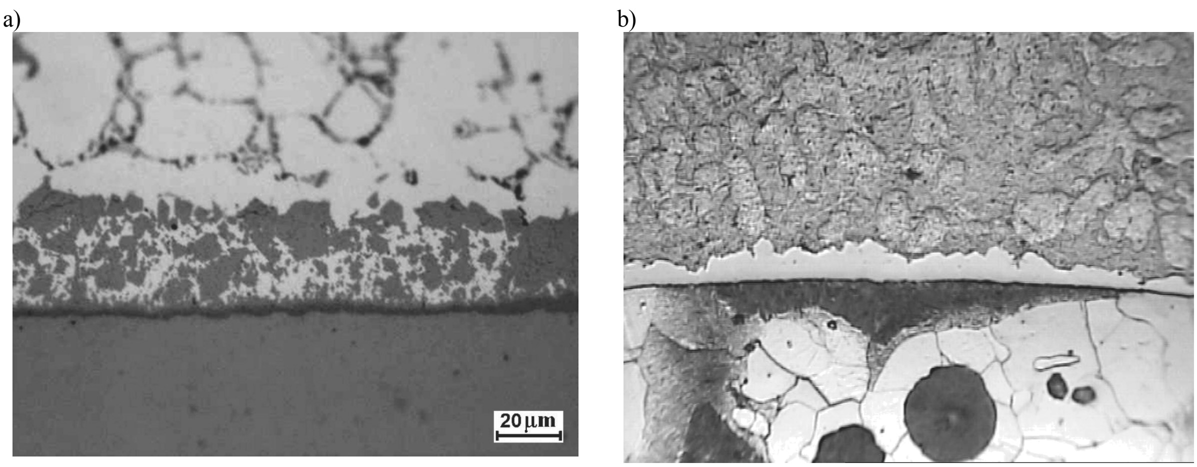


Fig. 13 (a, b). Junction of AlSi8 silumin by alfinated coating with: a – 4H13 steel; b – modular cast iron

## 4. Layer products

Their purpose is products weight reduction, increase the durability of element, increase corrosion resistance or aesthetics improvement. Schematically the layered structure of the product is shown in Figure 11.

Most often, in this way, laminar products, in steel (cast iron) – alfinated layer – silumin system are made. In this case steel or cast iron fulfil functional conditions of machine or device part, while deposited by alfinated layer silumin has to perform other requirements ex. esthetic. Examples of alfinated coatings, immersion deposited in AlSi11 silumin, is illustrated in Figure 12 (a-d). Alphinated layer thickness depends on sample material, alphinating bath composition, its temperature and sample immersion time.

Characteristic is that in this coating are carbides occurred in those steels. An example of junction between AlSi8 and 4H13 steel by such coating is demonstrated in Figure 13 (a, b). It results that connection between steel and alfinated layer as well as silumin and mentioned layer is high enough. Presented example illustrates possibility of mass part decrease and in many cases costs too.

## 5. Conclusions

From the data presented in the paper the following conclusions results:

- must be strictly obeyed the rules of material selection during choosing the most optimal one, with particular emphasis on production system occurring in producing company,
- described a new high quality casting alloys are characterized by high mechanical properties including significant wear resistance,
- at the present time particular attention should be paid to layer products obtained by alphinating coating.

## References


[1] S. Pietrowski, Krystalizacja, Crystallization, microstructure and mechanical properties of low siliceous aluminum alloys with Ni, Cu and Mg additions, Polish Metallurgy in 2002-2006, Committee of Metallurgy PAN, 2006, 403-416 (in Polish).

[2] S. Pietrowski, T. Szymczak, Model of the alphinising coating crystallisation on iron alloys, Archives of Foundry Engineering 7/3 (2007) 123-128.

[3] S. Pietrowski, G. Gumienny, Carbides in nodular cast iron with Cr and Mo. Archives of Foundry Engineering 7/3 (2007) 223-230.

[4] B. Siemińska, A. Jankowski, S. Pietrowski, The pistons from novel composite allozs for future combustion engines of low emission exhautsts gases and low noise levels, Congress Proceedings Vol. III Future Powertrain Solutions, Springer Automotive Media, 2008, 484-494.

[5] S. Pietrowski, T. Szymczak, Silumins alloy crystallization. Archives of Foundry Engineering 9/3 (2009) 143-158.

[6] S. Pietrowski, G. Gumienny, Bainite obtaining in cast iron with carbides castings. Archives of Foundry Engineering 10/1 (2010) 109-114.

[7] S. Pietrowski, New high qualitalive casting alloys. Tendency of optimization of productivity system in foundry, Foundry Commission, Katowice-Gliwice, 2010, 157-170 (in Polish).

[8] S. Pietrowski, T. Szymczak, B. Siemińska-Jankowska, A. Jankowski, Selected characteristic of silumins with additives of Ni, Cu, Cr, Mo, W and V. Archives of Foundry Engineering 10/2 (2010) 107-126.

[9] M.F. Ashby, H.D. Jones, Engineering materials, WNT, Warsaw, 1996 (in Polish).

[10] R. Wrona, A. Stawowy, A. Maciol, Bases of foundry engineering designing. Krakow, 2006 (in Polish)