CASTING OF CARE WHEELS LOW PRESSURE OF AlSi7Mg MICRO-FOUNDRY – INTEGRAL PRESENTATION OF THE TECHNOLOGICAL CYCLE

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Abstract: *An integral representation of technological parameters of low pressure casting for the production of a car wheel is made. An algorithm and methodology for communication between micro-foundry and material science induced by the change Industry 4.0.*

KEYWORDS*: ALGORITHM OF INTEGRAL REPRESENTATION OF LOW PRESSURE CASTING TECHNOLOGY; GENERAL METHODOLOGY.*

1. Introduction – cast care wheels technology.

Full description in material science imposed by [1] and is on the base of principles [9]:

Processing→Structure→Properties→Performance. (PSPP)

Mechanical properties of the care wheel are shown in Table 1

Table 1: *Mechanical characteristics in three casting's zones*

Zone	$R_{p0,2}$ [MPa]	R_m [MPa]	A5 %	HBW -	DAS µm	LST s	Hµ -
Center	169.0	236.6	3.2	93.6	43.53	82.31	91.5
Ribs	156.0	246.0	5.8	91.2	44.10	85.77	81.3
Bed/ Board	175.5	266.0	8.0	91.4	24.38	14.53	83.5

where: $R_{p0,2}$ – yield limit; R_m – tensile strength; A5 – relative elongation; HBW – Brinell hardness; DAS – grain size; LST – local crystallization time; Hµ – micro-hardness.

The open thermodynamics system (OTS) is shown on Fig.1:

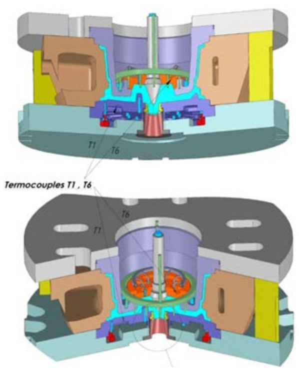
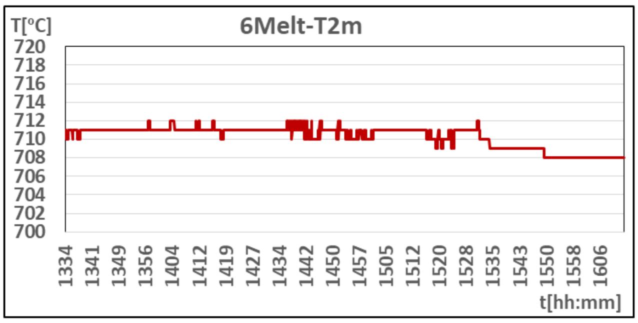


Fig. 1 *Mold for low pressure casting of care wheels with control sensors – thermocouples T1 and T6.*

Technological parameters measured at the casting of 20 automobile wheels are on Fig.2:



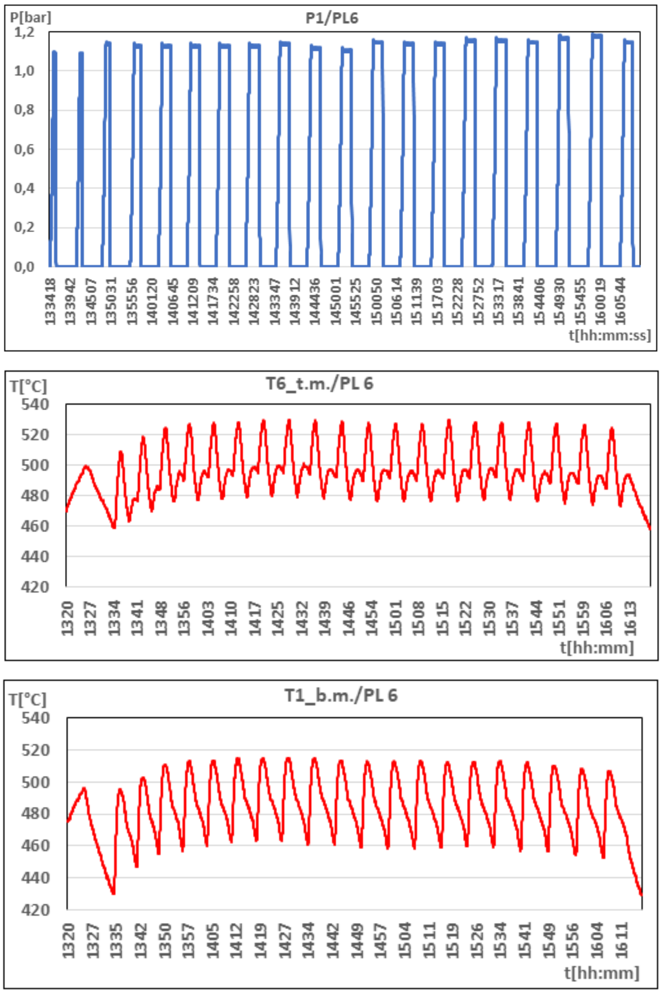


Fig. 2 *Technological measured parameters: melt temperature – $T2_m$; gas cycle P1; Thermocouples T6_t.m. and T1_b.m. (see Fig. 1).*

The quality cast according to (PSPP) the final structure of the care wheel is obtained after heat treatment:

- Homogenization – (535 $^{\pm 3}$ °C)/(6 hours), quenching in water (up to 45 ÷ 50 °C) not later of 10 sec after removing from the furnace;
- Aging at room temperature for 10 ÷ 12 hours;
- Artificial aging of (160 $^{\pm 3}$ °C)/(4 hours), cooling at room temperature;

but each of the two technologies of casting and heat-treating itself is subject to the principles (PSPP).

Aim of this paper is integral introduction of technological information to micro-foundry and scientific support in large and small scales.

2. Integral representation – basic information.

Integral representation of the baseline information through the parameters in the previous paragraph: Gas cycle times - P with temperature control of the mold by the temperatures T1 and T2, which provides maximum communication with a fast response capability. The integral representation of the low pressure casting of a car wheel from an AlSi7Mg alloy is shown in the following Fig. 3:

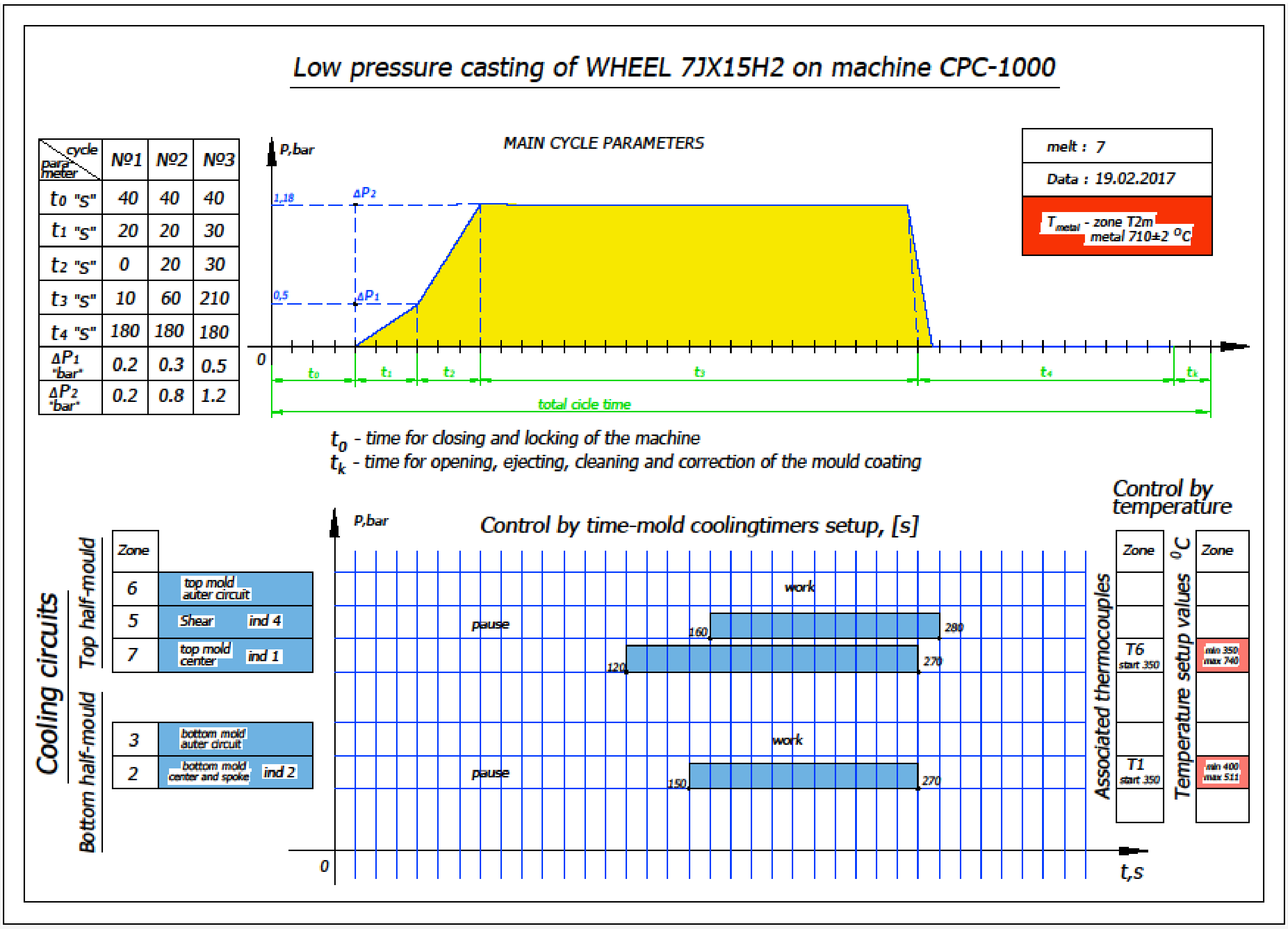


Fig. 3 *Integral representation of the basic information of low pressure casting of wheel AlSi7Mg on machine CPC-1000: The gas cycle – t_0, t_1, t_2, t_3, t_4 [s] and ΔP_1, ΔP_2 [bar]; the cooling circuits; the control by temperature with thermocouples $T6_{start}$ = 350 °C and [350÷740 °C], T1 $_{tart}$ = 350 °C and [400÷511 °C].*

To estimate tolerances of the above parameters (see Fig. 3), we select the following data for one cycle as follows: **1.** Temperature of the molten metal in the furnace of the machine; **2.** one machine gas cycle; **3.** Temperature upper mold; **4.** Temperature of lower mold.

Figure 4 shows two parameters 6Melt-T2m [°C] and P [bar]:

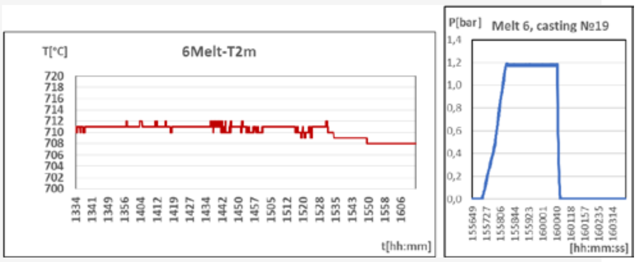


Fig. 4 Furnace of the Low pressure casting machine: Temperature 6Melt-T2m [°C]; the pressure P change of the gas for the production of one casting.

On Fig. 5 are shown the date thermocouples T6 and T1 [°C]:

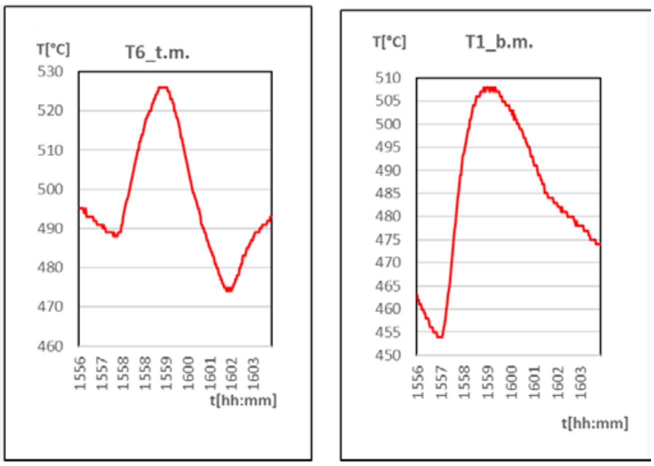


Fig. 5 Time-temperatures curves in mold: T6_t.m. and T2_b.m. [°C].

The base information is: (6Melt-T2m [°C], P [bar] + T6_t.m. and T2_b.m. see above). The data shown (Figures 4 and 5) is a swirl of an optimized Low pressure casting of care wheel 7JX15H2 in machine CPC–1000.

Optimal casting process we understand casting without defects and with a structure giving the best working properties of each casting. In principle (PSPP), it follows that the ultimate performance requirement is the market and the maximum life of the vehicle here. The aggregate information in Figure 3 suggests that it integrates into a well-understood scheme as an idea of the basic standard of micro-foundry communication for assessing the fundamental results of material science. Such a scheme is proposed in Fig. 6:

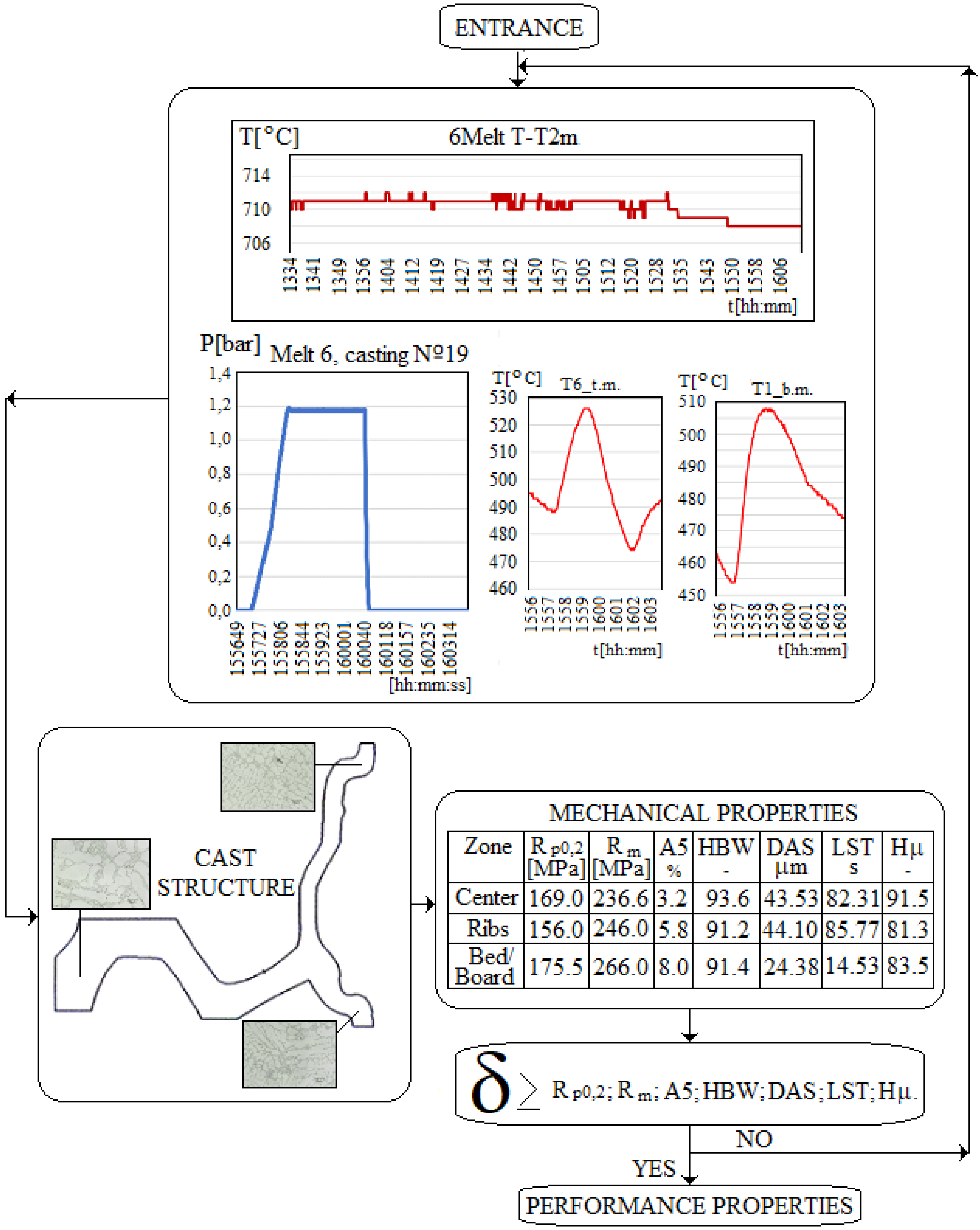


Fig. 6 *Standard scheme for communication between micro-foundry and fundamental scientific results and fundamental results of material science. This scheme is a computational algorithm for assessing necessary (new and old) knowledge such as mathematics, mathematical physics; the need to assess future market requirements for castings. Estimates of future requirements are a probabilistic answer to the questions: What structures and working properties are needed for casting materials? Are secondary alloys used without / (or minimal) losses?*

3. Materials science in Industry 4.0.

The properties of materials are determined by their structures. A. Balevski's definitions of alloys in article [2] are:

Such a combination of mechanical and technological (and in some cases, physical and chemical) properties, which no pure metal possesses, whatever mechanical and thermal treatment it is subjected to; (A, 1)

Such a combination of mechanical and technological (and in some cases physical and chemical) properties, which does not have any cast of pure metal, regardless of the mechanical and thermal treatments it undergoes. (A, 2)

The structure of metals and alloys is: an ideal crystal lattice, but defects are polycrystalline (grains - diameter, orientation) and carry the working properties (A, 1, 2). (A, 3)

In addition to the phase transitions of first and second order, the processes of hot and turbid elastic and plastic deformation also affect the structure. [2]. S. Vodenicharov makes an important development of the toughness assessment [5]:

Toughness – the ability of the metal structure to resist under impact conditions in the presence of one or several acute overcuts causing stress concentration; **Measure** - the amount of energy needed to destroy a sample body at a given temperature; **Two types**: toughness with cut and toughness against destruction of the monolithic body. A physical model and calculation algorithm for the process of destroying metal structures for very short time intervals is develop in [5].

The material properties will be obtained through design with new knowledge and technology. For this reason, we offer a general methodological approach to phase transitions technology in Material Science of Industry 4.0 on Fig. 7:

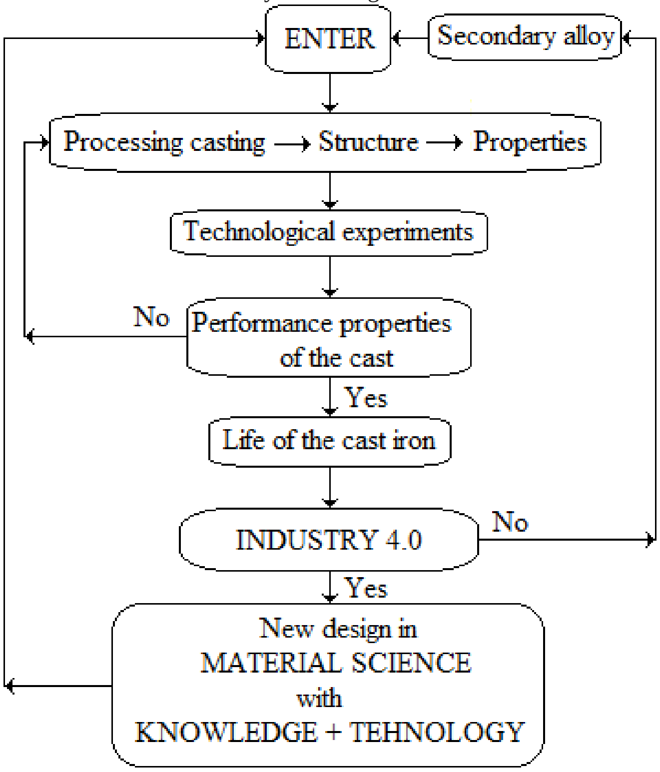


Fig. 7 *General methodology to approach the phase transition of first and second order in Material science of Industry 4.0 [1].*

Industry 4.0 is great change [1], which is connected with the need for very intensive scientific development of material science and new technologies [12]. The principles of material handling [8] may change (robots), but general principles remain [9]. Electron microscopy is intensively developing [6 and 7].

Metal Science [2] developed with the research of the theory of solidification and crystallization of metals and alloys [4]. The description of phase transitions requires the use of quantum mechanics, for example, the methodological connection between works [2] and work [3]. To day the application of quantum mechanics in material science is essential for understanding and describing the structure and properties of materials [9]. To create a casting technology, it is necessary to assess the controllability of solidification and crystallization processes [11].

The use of secondary alloys [10] is essential. The use of secondary alloys is likely to become a "metal and alloy circle" based on known and new technologies.

4. Conclusions

The results of technological experiments and the optimal technology for obtaining a cast wheel type are presented. For communication micro-foundry and material science are proposed: a general algorithm for creating a casting technology for low-pressure casting; and a methodology for a common approach to industrial change caused by Industry 4.0.

5. Reference

1. K. Schwab, The fourth industrial revolution, Hermes, Plovdiv, 2016. ISBN 978-954-26-1630-6

2. A. Balevski, Metal Science, „Technics“, Sofia, 1962. (In Bulgarian)

3. M. Borisov, Introduction to solid state physics, part I, Science and art, Sofia, 1977.

4. M. S. Flemings, Solidification processing, Peace, Moscow, 1977. (In Russian)

5. S. Vodenicharov, Dynamic destruction of metal structures, *Bulget Ltd.*, Sofia, 2011. ISBN978-954-92552-3-2

6. G. Z. Gerginova, Z. P. Martinova, Structura na metalite elektronnomicroslopski atlas, „Tehnika“, Sofia, 1995, ISBN954-03-0389-3. (In Bulgarian)

7. C. Kisielowski, B. Freitag, M. Bischoff, H. van Lin, S. Lazar, G. Knippels, P. Tiemeijer, M. van der Stam, S. von Harrach, M. Stekelenburg, M. Haider, S. Uhlemann, H. Müller, P. Hartel, B. Kabius, D. Miller, I. Petrov, E. A. Olson, T. Donchev, E.A. Kenik, A.R. Lupini, J. Bentley, S.J. Pennycook, I.M. Anderson, A.M. Minor, A.K. Schmid, T. Duden, V. Radmilovic, Q.M. Ramasse, M. Watanabe, R. Erni, E.A. Stach, P. Denes, U. Dahmen, Detection of Single Atoms and Buried Defects in Three Dimensions by Aberration-Corrected Electron Microscope with 0.5-Å Information Limit, Microscopy and Microanalysis 14, 454–462, 2008. doi: 10.1017/S1431927608080902 5.

8. Material Handling Institute, *Education•Research•Training Serving•Industry Since 1945*, 8720 Red Oak Blvd., Suite 201, | Charlotte, NC 28217-3992 USA. *https://www.mapquest.com/us/north-carolina/m-h-i-352274470 or* www.mhia.org

9. D. William, Jr. Callister, Fundamentals of Materials Science and Engineering, Fifth Edition, an Interactive e • Text, John Wiley & Sons, Inc. New York Chichester Weinheim Brisbane Singapore Toronto, ISBN 0-471-39551-X, Printed in the United States of America 10 9 8 7 6 5 4 3 2 1

10. A. S. Maneva, Thesis of PhD Investigating the structure and properties of castings from sub-eutectic aluminum alloys depending on the ratio of primary and secondary, Bulgarian academy sciences, Institute of metal science equipment and technologies with center of hydro- and aerodynamics, Sofia, 2013. (In Bulgarian)

11. S. Bushev, Thesis of PhD Controllability problems of crystallization process in casting, Technical University – Sofia, 1993.

12. S. Bushev, Knowledge Transfer Industry 4, International Scientific Journal, Industry 4.0, No 4, p. 51-54, Year 1, ISSUE 1/2016. ISSN (PRINT) 2543-8582