# INFLUENCE OF COMPOSITION AND PROCESSING MODE ON THE PHYSICAL AND MECHANICAL PROPERTIES OF POWDER MATERIALS

ẢNH HƯỞNG CỦA CÁC THÀNH PHẦN VÀ CHẾ ĐỘ CÔNG NGHỆ ĐẾN THUỘC TÍNH VẬT LÝ VÀ CƠ HỌC CỦA VẬT LIỆU BỘT

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## ABSTRACT

*The results of experimental studies on the powder materials show that in order to identify the influence of some factors (composition, heat treatment regimes, etc.) on the mechanical properties needed to conduct a thorough analysis of the statistics and presentation in graphical form in order to prevent a false interpretation. In this article we will review the achievements in research the effects of the carbon, nickel, chromium, copper, temperature of hardening, speed of cooling and temperature of furlough to present the physical and mechanical of the products made from steel powder.*

## TÓM TẮT

*Kết quả của nghiên cứu thử nghiệm trên các vật liệu bột cho thấy để xác định ảnh hưởng của một số yếu tố như thành phần, nhiệt chế, v.v.. đến thuộc tính cơ học cần tiến hành phân tích sâu về các số liệu thống kê và những kết qủa đạt được bằng các biểu đồ minh họa nhằm loại trừ những kết luận không chính xác. Trong bài này chung tôi xem xét những kết qủa đạt được trong qúa trình nghiên cứu những ảnh hưởng của thành phần carbon, nickel, chronium, đồng, nhiệt độ hoá bền, tốc độ làm nguội và nhiệt độ đến các thuộc tính vật lý và cơ học của những sản phẩm kim loại bột.*

## I. INTRODUCTION

Modern technology makes increasingly stringent requirements for materials working in conditions of high pressures, velocities, deformations, aggressive environments. Powder metallurgy is the technology covering the processes of obtaining powders of metal, compounds of metal similarity and processes of manufacturing products from them without melting is one of the most effective and prospective directions for the ensuring the given material properties by increasing the density, adding alloying elements, heat and chemical-thermal processing. The methods of powder's metallurgy (PM) have increasingly been putting into practice of the production with various appointments and cover a wide range of industries. It is caused by series of advantages, such as the possibility of creating materials with special mechanical and physical-chemical properties which are very difficult to obtain by traditional technologies, of obtaining the finished products that do not require further machining, of using the waste of industries.

In addition to the advantages, there are a number of shortcomings that limit the use this prospective direction of production the parts in mechanical engineering. These include economic efficiency which is only in mass production the parts because the high cost of equipment, difficulty of technology for production some components, a high investment in research and development ensuring the production. In addition, some products of powder metallurgy after heat treatment is often inferior to the properties of steel obtained by traditional methods. The reason is that the complex physical and chemical processes as a result of the energy impacts make specific or non-specific changes in the structure and properties of sintered materials. The most characteristic features of powdered steel that make the use of known technological modes and methods of thermo-chemical treatment is their low thermal conductivity, chemical heterogeneity, high number of crystalline structure defects, hereditary fineness, porosity [3].

The main technological operations of powder metallurgy include processes of obtaining the powders of pure metals, alloys, preparation the powder mixtures with a given chemical composition and grain size, pressing the powder mixture in order to obtain the billet of given form and sizes, sintering (heat processing) the pressed billets to give them the necessary mechanical and physical, chemical properties.

Heat treatment of sintered products leads to increasing the endurance characteristics, due to the presence of porosity, and in some cases of non-equilibrium structural state [1, 2, 3].

Feature austenitic transformation in powdered steel also has a significant influence on the properties of materials. Cooling of evtektoid powdered steel with porosity 14-16% at the speed 2-3 0C/s leads to increasing the tensile strength from 470 up to 690 MPa. Increasing the speed of cooling to 10 0C/s helps to grind the structure and improve the bending strength up to 750 MPa. Increasing the porosity of powder steels changes the micro-hardness of hardened structure, strength of original Fe-C-Cu materials varied from 200 up to 350 MPa. To increase the porosity also decreases the stability time of super-cooled austenite and the hardness of samples of powder steel hardened with optimal temperatures is always lower than shedded steels of similar composition. The level of strength properties increased with alloying nickel and molybdenum [3].

## II. EXPERIMENTAL AND ANALYSIS

Thus, the main regulating and managing factors which determine the mechanical properties of powder metallurgy products (PMP) in the selected mode with taking into account the speciality of the structural condition, deformation, heating and cooling of the porous bodies are optimization the composition of the used powders, technological modes of forming, thermal and thermo-mechanical processing of powder steels.

Experimental studies provide the empirical dependence of physical and mechanical properties of these factors, which in act as carbon, copper, nickel, chromium in the structure of powder material, hardening temperature, cooling rate, the temperature of the furlough. As dependent variables are porosity, hardness, elongation.

According to the results of factor analysis which allows to determine the contribution of technological parameters on the quality characteristics the influence of the carbon content, temperature, heating of hardening on the porosity, hardness and plasticity of the material can be reveal (Table 1).

*Table 1. Summary table estimates the degree of influence factors on the dependent variables*

| Factors | Dependent variable | | |
|---|---|---|---|
| | Porosity | Hardness | Elongation |
| Content of carbon | **-0,43** | **0,291** | **-0,22** |
| Content of copper | -0,005 | -0,031 | -0,035 |
| Content of chromium | -0,013 | -0,012 | 0,002 |
| Content of nickel | 0,004 | 0,005 | 0,018 |
| Temperature of hardening | **0,463** | **-0,625** | **-0,662** |
| Speed of cooling | 0,009 | 0,026 | 0,005 |
| Temperature of furlough | -0,014 | -0,008 | -0,054 |

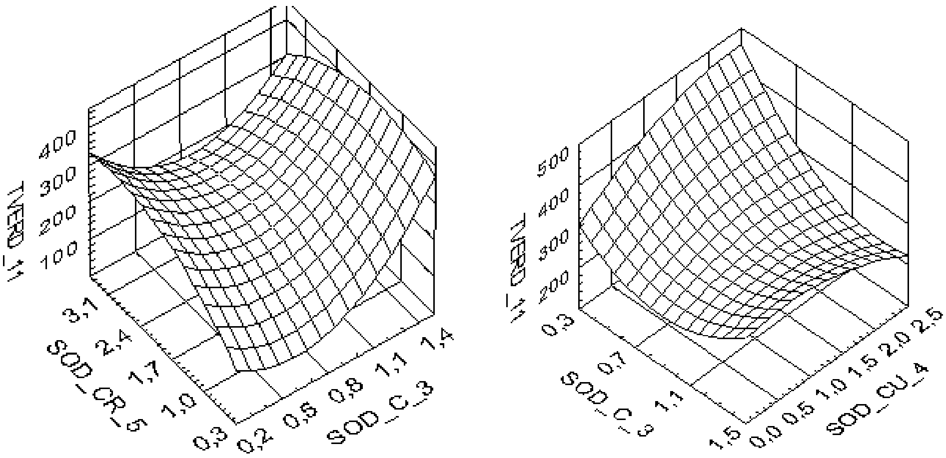
Construction the models and dependence based on linear relationships is not desirable, because the errors can be significant, therefore, necessary to evaluate the pair of impacts and the combined effects to determine and allocate particular complex interaction of variables.

Interdependence pair of variables is revealed by results of correlation analysis (Table 2), which show that the most powerful twin dependence observed between the percentage of chromium and copper (0.77), chromium and carbon (0.61). At a lower level is the interaction between the percentage of copper and carbon (0.47), porosity, and chromium (0.39), porosity and copper content (0.38), porosity and nickel (0.35). The sign of correlation coefficient indicates the direction of interaction, they are amplified or attenuated. The most significant influence (correlation) of the mechanical characteristics observed between the carbon and elongation (plasticity index), the contents of copper seriously affect the porosity, chromium and nickel - to the porosity, hardness and elongation. Identified the significant impact of technological regimes as the temperature of normalization (0.27), cooling rate (0.16), the plastic properties.

Introduction of these dependencies pair of influence in the form of three-dimensional graphs simplifies the process of analysis and identifies the optimal region of values (Figures 1, 2). When the content of carbon 0.3% and copper 2.5% the maximum hardness is observed, when the content of carbon 1.5% increasing in the number of copper reduces the hardness of the sample. When copper content of 2.5% is increasing in the number of carbon (from 0.3% to 1.5%), it reduces the hardness of almost 2-fold from 480 to 220 HB. The minimum value of the hardness of the samples (200 HB) is observed in the carbon content over 0.7%, slightly increased with increasing copper content (0÷2,5%) and reaches 230 HB.

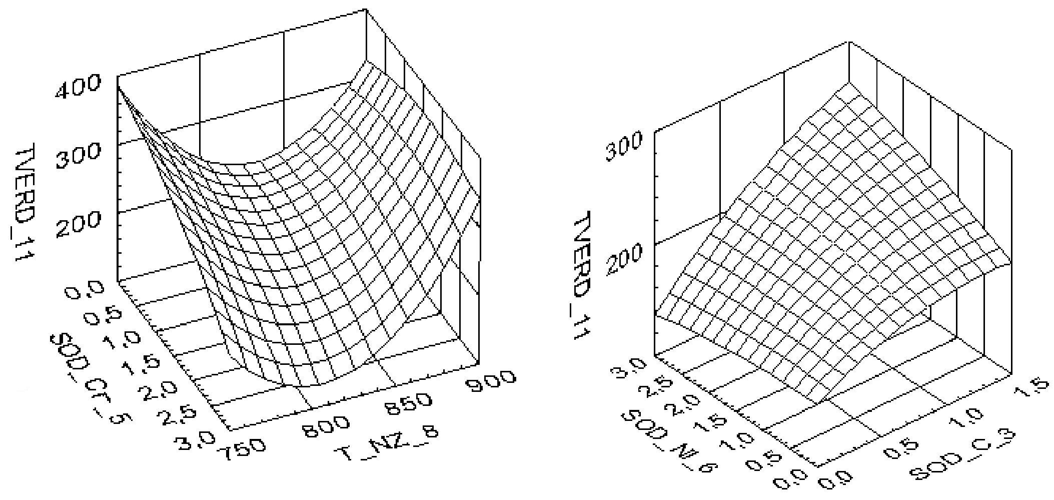
*Table 2. Correlation dependence powder metallurgy*

| variable | Cont. of C | Cont. of Cu | Cont. of Cr | Cont. of Ni | Poro-sity | Temp. of har-dening | Speed of coo-ling | Temp. of fur-lough | Hard-ness | Elongati on |
|---|---|---|---|---|---|---|---|---|---|---|
| Cont. of C | 1,0 | 0,47 | 0,61 | | 0,22 | 0,14 | 0,19 | 0,16 | | -0,37 |
| Cont. of Cu | 0,47 | 1,00 | 0,77 | 0,22 | 0,38 | 0,14 | 0,12 | | | |
| Cont. of Cr | 0,61 | 0,77 | 1,00 | 0,22 | 0,39 | 0,26 | 0,14 | | 0,11 | 0,23 |
| Cont. of Ni | | 0,22 | 0,22 | 1,00 | 0,35 | 0,15 | 0,15 | | 0,21 | 0,24 |
| porosity | 0,22 | 0,38 | 0,39 | 0,35 | 1,00 | | | | 0,17 | |
| Temp. of hardening | 0,14 | 0,14 | 0,26 | 0,15 | | 1,00 | | | 0,21 | 0,27 |
| Speed of cooling | 0,19 | 0,12 | 0,14 | -0,15 | | | 1,00 | | 0,24 | 0,16 |
| Temp. of furlough | 0,16 | | | | | | 0,24 | 1,00 | 0,47 | |
| Hardness | | | 0,11 | 0,21 | 0,17 | 0,21 | 0,16 | 0,47 | 1,00 | |
| Elongation | -0,37 | | 0,23 | 0,24 | | 0,27 | | | | 1,00 |




a) b)

*Fig.1 The schedule impact of the content on the hardness HB: a) carbon (C) and copper (Cu) in %, b) carbon (C) and chromium (Cr) in %.*




a) b)

*Fig.2 The schedule impact of the content on the hardness HB: a) carbon (C) and copper (Cu) in %, b) the content of chromium (Cr) in% and temperature of heating for hardening in $^0C$*

Analysis of the results presented in the form of graphs, should be held in conjunction with the correlation to avoid false, unfounded interpretation of graphs. According to Table 2, significant correlations between carbon and nickel is not observed, it can be assumed that they are independently affect the hardness. However, the graph shows that the alignment are: increasing the nickel content, with increasing the carbon content leads to a significant increase in hardness, almost a 70 HB.

## III. CONCLUSIONS

Thus, the empirical data obtained during the experimental studies shall be subjected to statistical processing and analysis to identify patterns of influence of independent factors on the physical and mechanical properties of powder materials. But the analysis should take into account all the results of statistical processing to prevent false interpretation of the results of experimental studies.

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