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Studying of the properties of composite materials (powder mixtures) during complex laboratory work

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***Abstract*—The article deals with the methodology of complex laboratory work on related technical disciplines of the two departments of the University. There are presented difficult moments in the organization of such works are noted and positive results allowing students to master methods of research work.**

***Keywords*— composite materials, Engineering technology, design**

I. INTRODUCTION

The study of the problems of ensuring the quality of engineering products leads to the conclusion that the quality of products is provided by a high level of training of specialists working at enterprises. We need a systematic approach to solving quality management problems. A scientific approach is needed to address the issues of production technology and quality control at all stages of production [1].

Therefore, the issues of training of young professionals and advanced training of managers of enterprises have been and remain in the first place.

The quality of training and retraining of engineers is the main task of higher education institutions. Quality assurance methods are associated with many disciplines studied at the University, starting from the first year: "Technology of structural materials", "General production technology", "Technical measurements and devices", "Methods of quality assurance of engineering products", "quality Management", "Metrology, standardization and certification". All of these courses have laboratory sessions.

One of the main tasks of the departments - to give laboratory classes research orientation. Naturally, there are certain organizational difficulties associated with the adjustment of the schedule, the number of hours in the curriculum. Most departments have outdated equipment; there are difficulties with the acquisition of materials, the manufacture of samples and parts, and the lack of technicians.

With all these difficulties, we benefit from the fact that all 100% of students participate in research and most of them are interested in the results of their own research.

The above disciplines are assigned to the departments of engineering technology (DET) and innovation management and organization of production (IM and OP). On the basis of these departments complex laboratory works are carried out more than 12 years [4]. At the same time, depending on the curriculum, laboratory work is carried out either in parallel or sequentially during one or several semesters. If you correctly set the task in the laboratory, the students will be engaged with great interest, and when they receive the final results of the research, the conclusions are interesting analogies and even recommendations for use in industrial production.

II. METHODS

At the I or II courses, students majoring in "Engineering technology" (now the design and technological direction) and students of "innovation" study the discipline "Technology of structural materials". Laboratory work is carried out in the laboratory of powder metallurgy and foundry of the Department of IM and OP, where students perform the first part (4 hours) of interdepartmental complex work "Study of the relative density and dimensional accuracy of the pressing force and the composition of the powder mixture." The second part of this work is related to the study of dimensional accuracy, performed on the II or III course in the laboratory of Metrology and interchangeability of the Department of DET.

The teacher explains the goals and objectives of the work. At the same time, attention is drawn to the fact that the aim of the work is to obtain high-quality samples from the given compositions of powder mixtures that meet the requirements of the technological process (relative density and porosity). It should be noted that the three-stage process of obtaining materials of products by powder metallurgy includes:

1) production of powders and their mixtures at metallurgical and specialized enterprises. This forms the technological properties (particle shape, particle size distribution, compressibility);

2) forming blanks. The end result of the second stage is to provide optimal characteristics of the work pieces (relative density, porosity, dimensional accuracy) for subsequent sintering. The determination of these characteristics is the task of the study;

3) sintering (diffusion annealing). Changing the volume and size of the sample during heat treatment is not the task of this work.

The first part of laboratory work on the compression of samples of metal and non-metal powders and their mixtures includes the following technological operations that affect the accuracy of the dimensions of the product: dosing, mixing of powders, filling and uniform distribution of the powder by the volume of the mold, pressing and removing from the matrix the resulting work pieces (samples) – fig. 1.

Manufacturing errors in size are possible in case of violation of high-speed modes of sample pressing at manual control, which can lead to a typical marriage in powder metallurgy – a hidden layer of pressing due to elastic deformations of the sample after pressing.

Students are given individual assignments. The composition of the mixture sets the teacher: iron-copper, iron-graphite, iron-aluminum, copper-aluminum, and copper-zinc.

The technological process of pressing includes the mixing of powders, filling them into a mold, pressing according to the specified modes and pressing the sample out of the mold.

The thoroughness of mixing of the powders, the uniformity of their distribution by volume ensures stability, strength, dimensional and operational characteristics of the material.

After filling the powder into the mold (fig. 1), it is necessary to eliminate the irregularity of filling the volume of the matrix. The reason for this unevenness is the angle of the natural slope of the bulk solids. At the first stage of pressing, the main process, due to which the relative density of the sample increases, is the physical compaction – the movement, reversal and convergence of the particles. Along with this process, plastic deformation of the particles takes place and becomes the predominant process at the second stage, providing partial filling of the pores. The final stage may result in the destruction of brittle or riveted particles and filling them with fragments of pores.

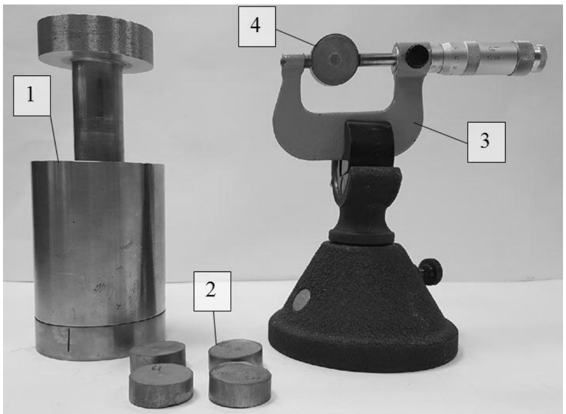

Fig. 1. Mold (1), samples (2), micrometer on stand (3), sample in micrometer (4).

Simultaneously with plastic deformations, elastic deformations take place in the sample, leading to an increase in the diameter of the sample during extrusion.

Note – violation of pressing modes, first of all, the speed of pressing the powder and pressing the samples, leads to their destruction due to the stratification.

When pressing iron powder, the effect of additives (the second component) of powders of other metals, alloys and non-metals on the relative density of the samples is different and can contribute to:

- increasing in relative density due to greater plasticity, smaller powder particle sizes, low strength or lower friction coefficient of the second component;

- lowering the relative density of the samples at high hardness and friction coefficient of the second component.

Students should take into account all these points in the conclusions after plotting the relative density of the samples from the composition of the powder mixture.

Finished samples (in powder metallurgy they are called "raw", i.e. untreated, blanks) are Packed and transferred to the Metrology laboratory for storage for the II part of the work.

Fig. 1 shows a mold, samples, and a sample mounted on a micrometer with a stand.

The second part of the work is carried out in the laboratory of Metrology and interchangeability and includes the following steps: the choice of measuring instruments with the filling of the metrological chart; familiarization with the measurement technique; measurement of the size of the manufactured samples, measuring the size of the mold (the diameter of the working cavity of the matrix and the diameter of the punch); calculation of the size change of samples from the mixture. The last stage of the work is to identify the dependence of the changes in the size of the samples on the composition and percentage of the components of the mixture presented in the report on laboratory work in the form of graphs and conclusions.

A. Filling in metrological card

In the metrological map [2] should enter all the devices and tools used in the first part of the work: electronic scales VEU-2 with a division price of 0.5 g for dosing powders and scales MW-120 with a division price of 0.01 g for weighing additives, press P-50 with a division price of 10 kN, caliper with a division price of 0.1 mm; and devices used in the second part of the work. To measure the diameter of the punch typically use micrometer smooth of class I, for measure the internal diameter of the die used caliper indicator (in this work it is recommended of into the caliper with a measurement error δ lim=±5 μm), with a scale division of 0.01 mm.

To measure the diameter of the sample, a class I micrometer (preferably with a stand) is required.

Thus, the metrological chart includes six measuring instruments. All measurements shall take into account the measurement error.

B. Measurement of the size of the mold

1) Measuring the actual diameter of the punch

Measurement of the actual diameter of the punch is necessary to identify the wear of the punch. The measurement is carried out by a class I smooth micrometer in two mutually perpendicular planes and in three sections in height. Then, the arithmetic mean of the six results is taken and recorded in the report, and the results of the measurement can identify the amount of wear and error of the form of wear.

2) Measuring the diameter of the die hole

The measurement of the diameter of the holes of the matrix necessary for determining the wear of the matrix. Measurements indicating calipers into. To measure you must have the clamp with the laterals and the unit tiles equal to the nominal diameter of the hole of the matrix (Ømatrix). The actual size of the matrix hole is recorded in the form of measurement results (table 1).

TABLE I. MEASUREMENTS' RESULTS

№ образца	Composition of the mixture, %		Diameter of the matrix hole ($Ø_{matrix}$), mm	Diameter of the sample d_1 (measurements in 3 sections), mm			Actual size (d_m) with Δlim $d_m = d_{1m} - Δlim$, mm	sample size change ($Δ_v$) *) $Δ_v = d_m - Ø_{matrix}$, mm
	K_I Cu	K_{II} Zn		1	2	3		
1	98	2	29.947	30.53	30.59	30.48	30.525	0.578
2	96	4	29.947	30.56	30.54	30.53	30.535	0.588
3	94	6	29.947	30.58	30.61	30.58	30.575	0.628
4	92	8	29.947	30.57	30.60	30.61	30.585	0.636

3) Measurement of sample diameter d1

The diameter of the sample was measured by a smooth class I micrometer on the rack (fig. 1) in 3 sections and the average value of d1m was calculated taking into account the measurement error of the class I micrometer Δlim= ±0.008 mm.

A class 0 smooth micrometer can be used with an error of Δlim= ±0.0055 mm [1].

As an example, the results of the study of samples of the mixture (Cu+Zn) are given in table 1.

d1m is the mean value of the 3 measurement results.

*)Δv – increasing the size of the sample after pressing out of the matrix as a result of elastic deformations, called in powder metallurgy "spring" or "elastic aftereffect".

4) construction of the graph

The measurement result is plotted the dependence of the change of the dimensions of the sample (Δv) of the composition of the mixture of powders. Fig. 2 shows the dependences of Δv on the composition of the powder mixtures. The values for plotting are given in table 2.

5) Analysis of causes and phenomena affecting the increase or decrease in sample size

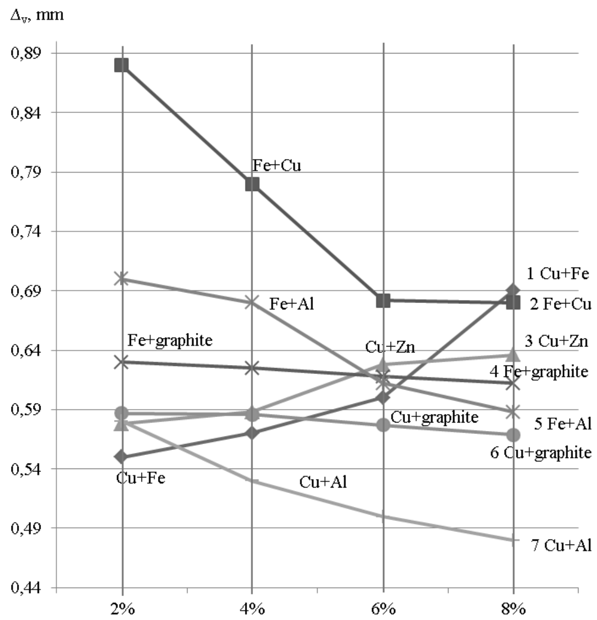

Fig. 2. Graph of the sample size change depending on the % Zn content in the mixture.

It is this moment of analysis of the results of their research is of great interest to students to the possibility of using the results. Table 2 is based on the results of studies conducted by students over the past 5 years [3, 4].

TABLE II. THE RESULTS OF THE MEASUREMENTS OF ΔV FROM THE COMPOSITIONS OF POWDER MIXTURES

№	Mixture composition	The values of Δv (mm) at different percentages of the input of additional component			
	Main component + Additional component	2%	4%	6%	8%
1	Cu+Fe	0.550	0.570	0.600	0.690
2	Fe+Cu	0.880	0.780	0.682	0.680
3	Cu+Zn	0.578	0.588	0.628	0.636
4	Fe+graphite	0.630	0.625	0.618	0.612
5	Fe+Al	0.700	0.680	0.612	0.588
6	Cu+graphite	0.587	0.586	0.577	0.569
7	Cu+Al	0.580	0.530	0.500	0.480

III. RESULTS

Results of experimental studies:

- the dimensions of the samples are determined by the degree of completeness of the processes occurring during compression such as: physical compaction, plastic deformation, destruction of particles; graphite is the only one of the materials studied, the low strength of which contributes to the production of non-porous samples;

- pressing of samples from the mold matrix is accompanied by an elastic aftereffect with an increase in size, which is primarily determined by the elastic modulus of materials; this leads to the conclusion that the design of molds for batch and mass production of parts made of powders, it is necessary to experimentally determine the diameter of the matrix and punch;

- when composing composite mixtures, it is necessary to remember three regularities of the volumetric expansion of the samples as a result of the aftereffect of elastic deformations:

1. with the increase in the content of components with a high modulus of elasticity (zinc and iron) in the mixture, the dimensions increase (curves 1, 3 fig. 2);

2. with an increase in the content of plastic components (aluminum, copper), the dimensions decrease (curves 2, 5, 7 fig. 2);

3. with the increase in the content of brittle components (graphite), the dimensions practically do not change (curves 4, 6, fig. 2).

Further research, i.e. the third stage of the process – sintering (heat treatment) in order to obtain finished parts requires not only special equipment, but also a large time-consuming (8-10 hours). The curriculum does not provide for such an amount of hours, so research can be continued at the next stage of training, for example, in the master's degree.

IV. Discussion

From the example of complex laboratory work we have considered, it follows that all students of the group not only carry out measurements, but build dependency graphs, and, most importantly, try to explain the results, draw conclusions and give suggestions on the use of their research.

Laboratory work of a research nature of the Department of TMS conducts in the disciplines of "Methods of quality assurance of engineering products", "quality Management". It is possible to develop laboratory works of this type on the discipline "quality Control of parts to the requirements of technical documentation" and a number of other disciplines.

The authors believe that the goals and objectives of the work are fulfilled. In the future, research skills will be needed not only in the performance of the final qualifying work, but also in the study of master's degree and work in the workplace, as students will come out of the walls of the University thinking specialists.

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