REALIZATION OF THE MOULDS REINFORCED BY HARD SINTERED ALLOYS WITH SPECIAL UTILIZATION

Coman (Ciovică) E.

University VALAHIA, Târgovişte, E-mail: emilia_ciovica@yahoo.com

Abstract: *The fabrication of assembly mechanisms is usually based on cold plastic deformation of half-finished steel products in moulds reinforced by hard sintered alloys. A special category of moulds are those used in cold plastic deformation of car pivots and tappets, where the deformation ratio and the products configuration generate maximum stresses upon deformation tools-resulting in their premature failure. The paper presents some particularities of the technology of manufacturing the moulds reinforced by hard sintered alloys the improved technology results in a perceptible increase of their reliability.*

Keywords: *efficient utilization, energy system, energy*

1. INTRODUCTION

The manufacturing process of assembly mechanisms is based on the cold or hot plastic deformation process of half-finished steel products, a method, which provide improved mechanical properties, due to more homogenous and dense resulted after processing.

This method provides a higher processing accuracy and makes possible the obtaining of complex shapes with a minumum amount of operations and simple manual work.

The equipment consists in automatic operated high speed presses, fitted with several workstations, depending on the geometry of the product to be obtained and the deformability ratio of the used raw material.

The tools and control devices (SDV) were initially made from tool steel, but due to their low operation durability, they were gradually substituted with high wear and shock resistant materials [1].

WC-Co based hard alloys belong to this category of materials being known from literature as sintered metallic carbides (CMS). By using in the cold plastic deformation process tools with active elements from CMS, it can be obtained usually a 10 to 15 times higher durability, in special cases even a 100 times higher one as compared with the durability of similary steel tools.

The composition, which mostly satisfy the current requirements, is a binary alloy containing 70-85% WC and 30-15% Co with low amounts of additives such as TiC and TaC, in order to improve the toughness and the abrasive wear resistance [2].

These alloys are characterized by the fact that with the increase of Co content, toughness and shock resistance also increase, but on the other hand with the increase of the WC-content, the wear resistance increases and the shock resistance decreases.

The fabrication technologies of products by cold pressing require an adequate WC-Co composition, which has to comply with an as rational as possible tool utilization. Although, the WC is extremly hard, it shows a low tensile resistance, and cannot resist to radial stresses during the plastic deformation process and thus, the carbide insertion must be installed in a steel case, which has to absorb the radial stress [3].

If one applies a sufficiently high primary radial pressure on the carbide core, the strain produced by the shock during the assembly mechanisms formation can be counterbalanced.

The compression load exerted by the case on the carbide core, serves a double aim:

- To avoid the CMS core breaking;
- To diminish the negative influence of stresses, which occur during the plastic deformation process of steel.

This precompression of the CMS core in a steelcase, lowers to a minimum the possibility of core decay due to fatigue [4].

These mould types are realized as well by various tool manufacturers as by users respectively assembly mechanisms producers.

2. EXPERIMENTAL CONDITIONS

2.1. TECHNOLOGICAL ASPECTS CONCERNING THE ASSEMBLY MECHANISMS

The fabrication process of assembly mechanisms is based on the cold or hot plastic deformation method, which:

- provides improved mechanical properties, due to a more homogenuous and dense structure resulted after processing;
- requires a minimum material amount;
- provides a high working accuracy;
- allows the obtaining of more complex shapes using a few operations and simple manual work.

The equipment consists in automatic operated and very accurate high speed presses, fitted with several workstations function of the product geometry, which has to be obtained and the deformability ratio of the used raw material [5].

The behavior of sintered hard alloys as concern their reliability during the cold plastic deformation operations is conditioned by:
- the quality of metallic carbides;
- the correct manufacturing of tools and supplementary devices respectively the working as close as possible to the required parameters, providing, thus, a high operation durability;
- installation, control and operation, under running conditions, which are proper to hard alloys.

During the use of hard alloys, which are sintered during the hot deformation processes, one has to take into account several factors, which can determine the decay of the active surface of the tool namely:
- thermal shocks;
- mechanical stresses due to the shearing strain;
- corrosion [6].

During the period of contact with the hot half-finished product, the temperature of the active surface amounts to cca. 550^0C, at the same time the tool being also compressed. The cooling of the surface generates supplementary stresses due to important differences between the thermal expansion coefficient of WC grains and the binder phase of Cobalt. This phenomenon induces and propagates thermal fatigue cracks. After the initiation of thermal fatigue cracks, the microscale emphasizes other factors too, which accelerate the rate of decay as concern the active surface of the tool [7].

Thus, corrosion influences the binder (Co), weakening the bond between the WC grains from the crack edges, thereafter they will be dislocated from the surface and the cracks widened.

If the decay continues, the cracks will be more deep and wide and deformation will occur between adjacent cracks.

These cracks occur mostly intergranulary and are proportional with the gradient of temperature. Later, due to mechanical forces resulting from deformation processes, at the base of these prominences will propagate transgranulary cracks, which will break the prominences and form a lot of pits, the surface appearance being also called "snake skin" [8-9].

If one continues to use such tools, these will be out of service due to their fracture.

In order to emphasize the great importance of the durability of the used tools as well as their special working conditions, one presents futheron the relative position of the tools made from hard alloys within the screws and nuts cold upsetting device (Fig.1) respectively (Fig. 2), and the operation of various tools used during the cold upsetting process.

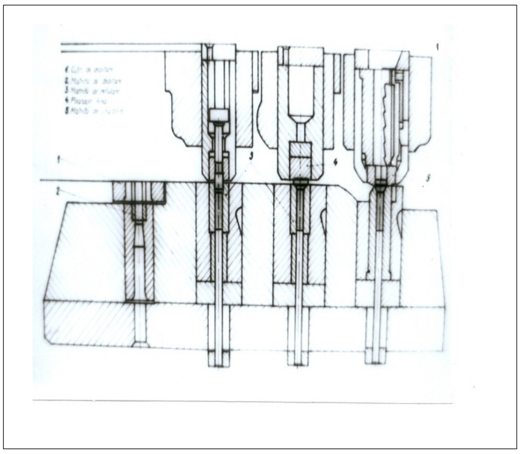

Figure 1 – The relative position of the tools reinfirced with sintered hard alloys for screw fabrication.

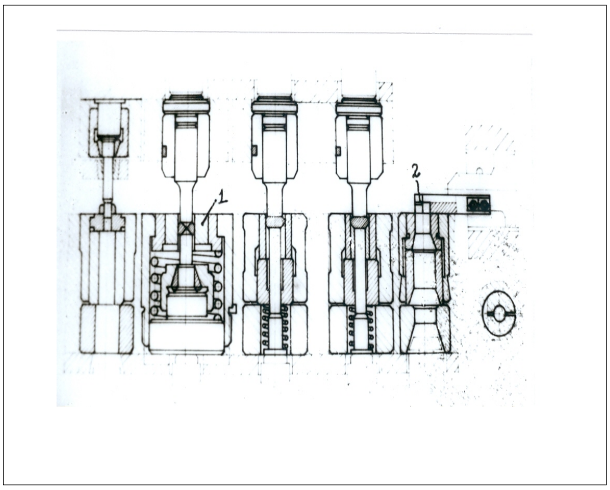

Figure 2 – The relative position of the tools reinforced with sintered metallic carbides for nut mnufacturing
1.Mould reinforced with CMS rings
2.Cutting tool reinforced with CMS

2.2. EXPERIMENTAL CONDITIONS

A primary element required by the obtaining of a high working durability of moulds with active elements from sintered hard alloys, is the proper selection of the chemical composition function of the deformation strains acting on the part during the deformation process of half finished steel products.

The properties of sintered hard alloys from the WC-Co system variates within large limits by modifying the composition (nature and ratio between binder material and carbides) and the structure (mean diameter of WC grains, shape of grains, distribution, composition and binder phase structure).

The wear resistance, provided by their remarkable hardness, high compression resistance, elasticity modulus, shock resistance ns well as the capacity to obtain an outstanding surface finish, recommend the sintered hard alloys with high Co content for the fabrication of reinforced moulds providing the plastic deformation operations of steels.

The metallic carbide powders compositions used currently for manufacturing moulds in the plastic deformation processes of screws, nuts, rings and heading tools, as well as the physico-mechanical properties of the sintered half-finished products obtained from these powders, are shown in Table 1.

The raw material used for the realization of experimental lots was represented by the grades G40, G56 respectively G60, with the chemical composition and physical characteristics emphasized in Table 1; in Table 2 one presents the mechanical properties of the analyzed grades.

Table 1 – Thhe physico-chemical chracteristics of the sintered powder grades (paraffine binder)

Powder grade	Chemical composition				Pressing binder [%]	Granulation µm	Free apparent bulk density[g/cm^3]
	C_{tot} [%]	$C_{lib.}$ [%]	Co [%]	W [%]			
G40	5,05	0,15	19,9	rest	2	5,5	2,58
G56	4,46	0,14	27,8	rest	1,5	5,5	2,44
G60	4,66	0,11	28,9	rest	2	5,5	2,50

One established for these materials the definitive technological processing conditions of raw materials, thus allowing the fabrication of sintered benchmarks emphasizing physico-mechanical properties, which can be compared with those of the benchmarks obtained worldwide and which are specified by the powder-raw materials suppliers.

Table 2 – The mechanical properties of the grades G60, G56, G40

Physico-mechanical properties		
Specific density γ [g/cm^3]	Vickers Hardness HV_{50}	Bending resistance σ [N/mm^2]
12,8	740	2480
12,85	775	2650
13,52	890	2800

In order to characterize the raw materials and sintered products one used standard methods.

The realization of products from sintered hard alloys by using current methods of the powder metallurgy consists in following stages:

- pressing of compacted parts;
- debinding-presintering of compacted parts;
- sintering of compacted parts;
- control of physico-mechanical properties of sintered products by using tcontrol devices and standard methods;
- working of blanks made from sintered metallic carbides.

The raw materials compaction is realized in steel moulds, at specific pressures amounting to 15000N/cm2, using $200*10^3$-$1000*10^3$N manual hydraulic presses.

On assessing the thermal conditions for the debinding-presintering operation, one took into account the selected powder grade (the Co-content in the alloy) and the gauge dimensions of the compacted parts.

For dewaxing-presintering one uses low heating rates and a hydrogen flow rate, which is high enough to remove the paraffine vapors and to provide the necessary protection atmosphere.

As concern the physico-chemical phenomena, which occur during the processes of dewaxing and presintering, these continue the diffusion processes in solid state, being still incipient during compacting, thus, providing the first surfaces of close contact between Co-grains and WC.

The maximum presintering temperature is restricted to the temperature, which generates the liquid phase respectively to the forming and melting temperatures of the eutectoid W-Co-C, because there are two undesired phenomena occuring with the liquid phase during this operation: a sudden increase above the level of allowed values for the physico-mechanical properties of the compacted parts and the building up of a relatively stiff carbide skeleton, phenomena, which have a negative influence on the mechanical processing operation (if it is necessary) of the presintered compacted parts.

The parameters, which influence the alloying and presintering process are following:

- Heating rate;
- Presintering temperature;
- Threshold time at presintering temperature.

In order to obtain presintered compacted parts by removing the whole amount of paraffine, which is sufficiently resistant to further mechanical processing and is deformation and contraction-free, one selected after performing the experiments, following debinding presintering graphic, as shown inTable 3.

Dewaxing is performed under vacuum in argon atmosphere (20-35 torr). The intermediate thresholds as 380^0C, 450^0C and 900^0C provides the uniformization of temperature within the mass of the furnace charge and the slow and total removal of the paraffine vapors from the furnace, before they are decompressed on the parts or furnace walls.

At 550^0C, the binder is completely removed and the presintering process begins, which is realized under vacuum conditions (0,2 torr). The intermediate thresholds provide the temperature uniformization and the slow removal of paraffine.

Table 3 – The presintering graphic

Range of temperature, [^{0}C]	Time, [min]	Protection atmosphere			Time threshold, [min]
		Argon flow rate[torr]	Hydrogen flow rate [l/h]	-	
20^{0}C-380^{0}C	90	20-35	200	-	-
threshold 380^{0}C	90	20-35	220		90
380^{0}C-450^{0}C	30	20-35	220		-
threshold 450^{0}C	90	20-35	220		90
450^{0}C-900^{0}C	90	De la 500^{0}C vacuum 0,2-1 torr	220		-
threshold 900^{0}C	45	20-35	220		45

The sintering operation was realized in the intermediate frequency induction vacuum sintering installation (4000 Hz) type IOV-16 Blazers, for the parameters presented in Table 4.

Table 4 – The parameters of the sintering cycle

Raw material	Temperature range, [^{0}C]	Time [min]
G40	0-500	90
	500-700	30
	700-860	30
	860-1080	30
	1080-1240	30
	1240-1360	30
	threshold at 1316	30
G56	0-500	90
	500-700	30
	700-860	30
	860-1080	30
	1080-1240	30
	1240-1360	30
	threshold at 1304	25
G60	0-500	90
	500-700	30
	700-860	30
	860-1080	30
	1080-1240	30
	1240-1360	30
	threshold at 1304	25

Generally, for grades with a Cobalt content being higher than 15% (it is valuable for all selected grades), the threshold time is the lowest one (20-30 minutes) in order to avoid the depreciation of the sintered benchmark due to ageing phenomena Oswald.

Also, in order to diminish the Cobalt losses by evaporation at temperatures higher than 1100^{0}C one worked in coarse vacuum conditions (4-7 torr).

In the inner of the furnace, the nets are placed on graphite plates. The WC-Co system emphasizes the tendency to take over Carbon from the supporting material, a more pronounced trend for alloys with alloys containing more than 15% Cobalt. In order to avoid this phenomenon, the benchmarks realized from the grades G40, G56, G60 were placed on an electrocorindon layer with 400 μm grain size.

The cooling was realized under vacuum down to 900^{0}C, then in stationary hydrogen medium (400 torr).

The sintering diagram Figure 4 was applied to benchmarks made from the above mentioned grades.

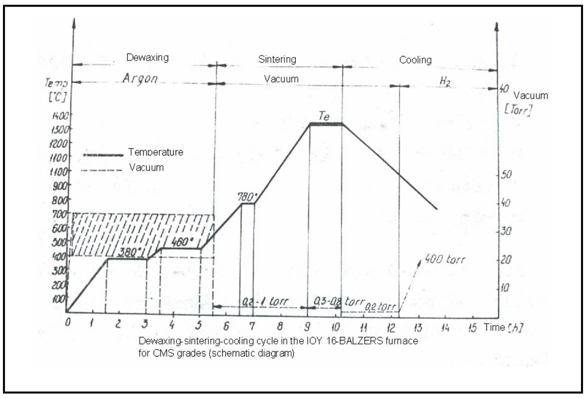

Figure 4 – The sintering diagram for the analyzed grades

One determined the physico-mechanical characteristics of the manufactured materials and namely:

- density;
- hardness;
- bending resistance.The determination was performed in compliance with the international standards in force, the values of the results obtained being presented in Table 5.

Table 5 – The physico-mechanical characteristics of experimental specimens

Name of the analyzed powder grade	Specific density γ [g/cm^3]	Vickers hardnessHV_{50}	Bending resistance [N/cm^2]
G40	13,51	907	2750
G56	12,94	758	2200

G60	12,8	785	2200

For the metallographical analysis performed as required by STAS 8264-68 one determined the:

- apparent porosity;
- presence and distribution of free Carbon;
- character and the distribution of the Co-phase;
- size and distribution of the phase-grain.

The apparent porosity and the metallographical structure of the studied carbides are presented in Figures no. 5-10. The porosity was studied on the nonetched sample using a diamond grain of 15-3 µm. One observes, that the porosity complies with the standard state, the sample emphasizing a porosity of maximum 10 µm. Also, there isn't any porosity produced by the free Carbon.

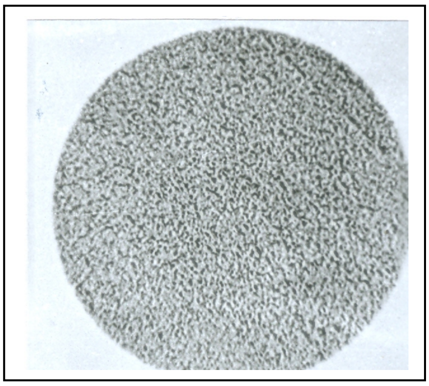

Figure 5 – The apparent porosity A2 complying with the standard scale of porosity for 10 µm pores, non-etched (composition G40) – Atac Murakami x1000

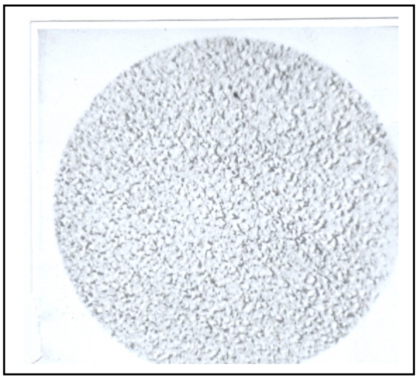

Figure 6 – The apparent porosity A2 complying with the standard scale of porosity for 10 µm pores, non-etched (composition G56) – Atac Murakami x1000

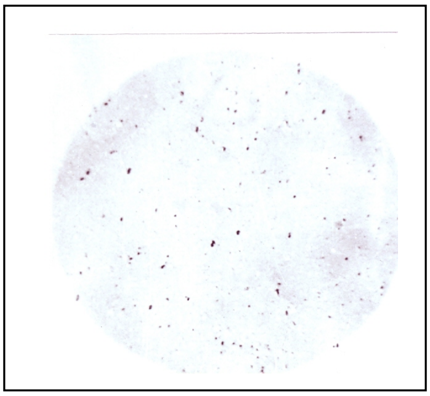

Figure 7 – The apparent porosity A2 complying with the standard scale of porosity for 10 µm pores, non-etched (composition G60) – Atac Murakami x1000

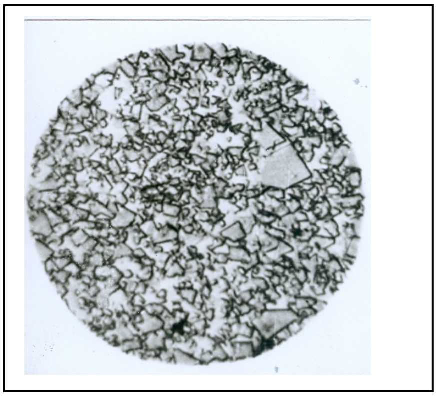

Figure 8 – The uniform distribution of the Co-phase. The apparent granulation of the mean WC-phase (composition G40) – Atac Murakami x1000

As concern the microstructure of the samples studied using a metallographical microscope with X 1500 magnification, one observes a structure with a mean and uniform grain size.

From the analyze of the obtained results, data and recommendations from literature, it resulted materials with adequate properties, thus allowing them to be used on experimental scale.

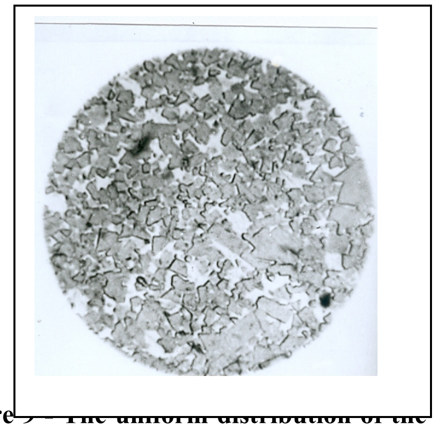

Figure 9 – The uniform distribution of the Co-phase. The apparent granulation of the mean WC-phase (composition G56) – Atac Murakami x1000

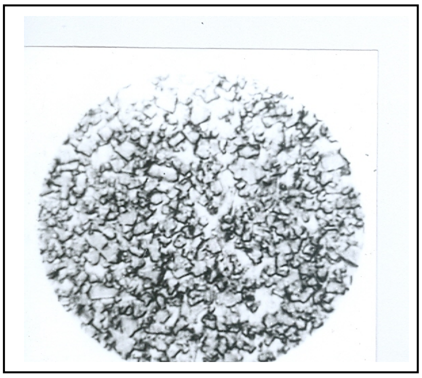

Figure 10 – The uniform distribution of the Co-phase. The apparent granulation of the mean WC-phase (composition G60) – Atac Murakami x1000

3. INDUSTRIAL EXPERIMENTS

One knows that the fabrication technology of screws and nuts requires tools made from materials and showing typodimensions function of the workphase sequence: cutters and cutting dies, upsetting moulds, finishing dies, stamping dies and segment moulds.

The industrial experiments performed on the sintered parts had in view the testing of:

- the durability of carbide grades used for the fabrication of moulds, as compared with those from imports or those realized from tool-steel;
- the Elements, which influence the durability of moulds.

For the interpretation of the obtained results, one took into account the influence of factors occuring in the industrial practice as: the mould processing degree, the state of the processing machines (adjustment, stiffness, etc.) the worked material quality (hardness, structure, plasticity, etc.).

Furtheron, one presents deducted on benchmarks, the experimental results and the conclusions deriving from these experiments.

Cutters and cold cutting moulds

The cutters and the cold cutting dies were obtained from the powder grade G40, after performing experiments on 192 moulds and cutters. The experiments were realized on A1822 machines as concern the fabrication of nuts and on CEVA, TPZ6, TPZ8, TPZ12 şi RPB 161 machines for the fabrication of screws.

a) the fabrication of nuts:

- by using cutting moulds, one obtained mean durabilities amounting to 1.000.000 pieces for M5, M6 and M8, as compared with 200.000 pieces, which were obtained with similary moulds made from tool steels;

- by usng cutters, one obtained mean durabilities amounting 300.000 pieces for the same dimensions as compared with 20.000 pieces, which were obtained with a similary cutter made from tool steels.

b) the fabrication of screws:

- by using cutting moulds, one obtained mean durabilities amounting to 2.000.000 pieces at dimensions M5-M20 as compared with 150.000 pieces, obtained with a similary mould from tool steels;

- by using cutters, one obtained mean durabilities amounting to 300.000 pieces as compared with 30.000 pieces, which were obtained with cutters made from tool steels for the same dimensions.

Thus, the use of hard alloys for this benchmark, besides a 5-10 times higher durability as compared with that of steel tools, is also advantageous, because it eliminates time waste for installation and adjustment.

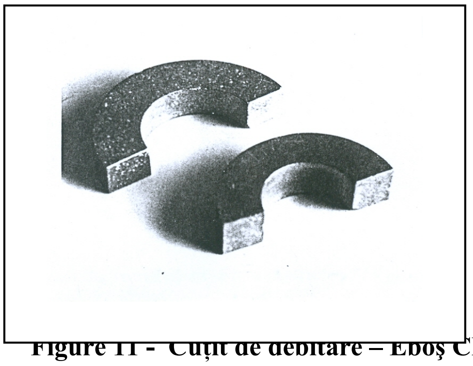

Figure 11 - Cuţit de debitare – Eboş CMS

Upsetting moulds and finishing dies

The industrial experiments using cold upsetting moulds were performed on a wide range of screws, e.g. from M4 to M16. The number of moulds observed amounted to more than 800 pieces, the blanks being realized from hard alloys (fig.12) at dimensions M4-M6 were realized from the grade G60, at M6-M16 from the grade G56, thus obtaining following results:

- for M4-M6, the mean durability amounts to 450-350 thousand strokes per mould;
- for M6-M10, the mean durability amounts to 350-250 thousand strokes per mould;
- for M12-M16, the mean durability amounts to 300-200 thousand strokes per mould.

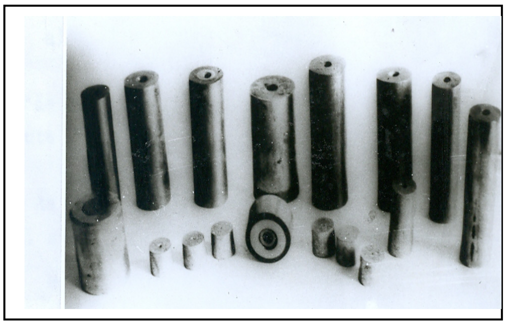

Figure 12 – Upsetting and cutting moulds–blank CMS

Segment moulds

As concern the IIIrd cold deformation operation of the nut manufacturing technology, one currently uses moulds reinforced with monoblock hard alloys emphasizing lower durabilities on the whole, due to the fact that some tools are out of service prematurely by breaking along the edge orientation of the hexagon.

In order to avoid this problem, one adopted the method of manufacturing these moulds from segments (Figure 13), thus being possible to use materials with higher wear resistance and also, to recover efficiently the carbide mould by the changing of only one segment.

In order to perform the experiments, one prepared upsetting moulds for screws sized as M10, M12, M16, due, in this case, to the occurence of maximum strains. These experiments were realized on TPM12, A3411, A1821, A1822 machines.

The obtained mean durabulities were:

- for M10 = 3.100.000 pieces;
- for M12 = 1.200.000 pieces;
- for M16 = 1.300.000 pieces.

These durabilities are similar to those obtained after using import moulds.

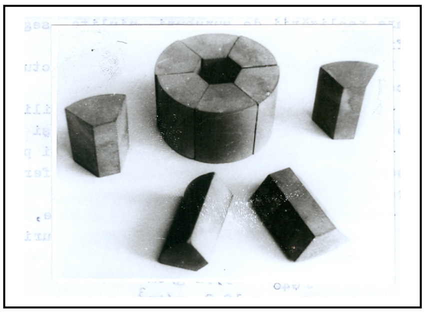

Figure 13 – Segments from sintered metallic carbides

4. CONCLUSIONS

The performed experiments targetted to emphasize the increase of plastic deformation reliability required by the manufacturing process of screws, nuts, segments and finishing dies.

The realized works consisted in:

- the characterization of the used granulated and non-granulated raw materials (powder mixtures) from the WC-Co system;
- the determination of technological parameters for the entire typodimensional range of blanks required by various working processes of assembly mechanisms;
- the characterization of the obtained products namely:
  - the mean density obtained for the blanks belonging to the experimental lot:
    $\rho_{G40} = 13,51$ g/cm^3
    $\rho_{G60} = 12,8$ g/cm^3
    $\rho_{G56} = 12,95$ g/cm^3
  - Vickers HV60 hardness (mean):
    $HV50_{G40} = 907$
    $HV50_{G56} = 758$
    $HV50_{G60} = 785$
  - Bending resistance:
    $\sigma_{î}$ G56-G60 = 220 daN/mm^2
    $\sigma_{î}$ G40 = 275 daN/mm^2
- the microstructural characterization aiming at the determination of porosity and microstructure by means of the optic microscopy, studying the realization of a homogenous and uniformly distributed WC structure.

The industrial experiments confirmed the good behavior of CMS compositions, which were considered to be optimal ones, and emphasized an increase of durability under running conditions as compared with that of tool steels in the case of plastic deformation moulds.

5. REFERENCES

[1] Domşa A. Tehnologia fabricării pieselor din pulberi metalice. Bucuresti: Ed.Tehnică, 1996.

[2] Herşcovici P. Materiale dure. Bucuresti: Ed. Tehnică, 1970.

[3] Gavrilaş L. Tehnologii de prelucrare cu scule din materiale dure şi extradure. Bucuresti: Ed. Tehnică, 1977.

[4 Kawachii. Special Alloy Industries Japonia –Starloz Tungsten Carbida Toolings

[5] Krupp V. Hartmetall für den Verschleißschutz

[6] Laszlo T. Csavangzartas - Nekezipari köyvkiado. Budapest: 1963.

[7] Rich M. Folosirea oţelurilor rapide şi a alijelor dure pentru scule destinate deformării plastice la rece ODPT-BIT: nr.5, 1973, pp.5-17.

[8] Tretiakov V.I. Metalokeramiceskie tviordîie splavî. Moskva: 1962.

[9] ***, Cercetări în vederea stabilirii tehnologiei de prelucrare-armare a sculelor de deformare plastică echipate cu elemente active din carburi metalice sinterizate.