ABOUT THE STRUCTURE AND PROPERTIES OF SINTERED Cu-Ni ALLOYS

L.A.Sorcoi*, V. Constantinescu*, I. Cârceanu**, N. Jumate*, D. A. Perneş*

*Technical University of Cluj-Napoca, Romania
**Metallurgical Research Institute Bucharest, Romania

ABSTRACT: Five batches of powder mixtures with various copper and nickel concentrations were prepared for the study of Cu-Ni alloys. Powder compacts were sintered at 800, 900, 1000°C in an hydrogen-reducing atmosphere. The mechanical properties and the compacts structures were put under analysis. The 600 MPa compacting pressure is the most adequate for as low porosity parts as possible, according to the pressability curves The structure of the Cu-Ni alloys obtained by sintering is one-phased, with polyhedron-shaped α solid solution crystals with annealing macles. The Cu-Ni sintered alloys have resistance to fracture R_m dependent upon nickel concentration. Its maximum values are reached at 208.2 MPa for the Cu80Ni20 alloy and at 318.3 MPa for the pure nickel as compared to cast alloys, where R_m=460 MPa (50-70% nickel alloys). The flow limit was evident only for the Cu100 and Cu80Ni20 alloys. For the Cu-Ni alloy the microhardness values have been determined in the α solid solution; no significant differences were noticed for the measurements on the same sample, because of the only phase, as expected. The microhardnesses of the α solid solution increase with the nickel content, ranging from 82.3 $HV_{0.02}$ to 138 $HV_{0.02}$.

KEYWORDS: copper alloys, nickel alloys, structure, mechanical properties

1 INTRODUCTION

Cu-Ni alloys have difficult moulding properties, a high gas adsorption tendency, bias towards void and slag inclusions, low fluidity, etc.

When alloys are made by moulding, large non-homogeneities and seggregations can also appear in the structure.

Having all these in view, the author chose to study if these materials could be obtained by powder metallurgy methods in order to prevent seggregations, inclusions or void from appearing.

Lower mechanical properties are typical of powder metallurgy materials, but these properties can be improved by compacting, wiredrawing, extrusion [1, 2].

2 FORMING Cu-Ni ALLOYS

Copper powder of 99% purity (made electrolitically) and nickel powder (obtained from carbonyl) were used to obtain sintered alloys.
The particle shape is dendritic with the electrolysis-based copper powder and almost spherical for the carbonyl nickel..

The powder grain size distribution was obtained after meshing (Table 1).

The nickel carbonyl powder ranged from 5 to 22 μm in size, the measurement being done with an electronic microscope.

Table 1. Particle size distribution of powders

Refuse [%]	Particle size range [μm]			
	<40 [μm]	40-63 [μm]	63-80 [μm]	80-90 [μm]
	30.2	35.1	25.1	10.2

Five batches of powder mixtures of various copper and nickel concentrations were used for the Cu-Ni alloys made with powder metallurgy methods (Table 2).

Table 2. Powder mixtures of various copper and nickel concentrations

Powder	Alloy				
	Cu20Ni80	Cu50Ni50	Cu80Ni20	Cu100	Ni100
Cu [%]	20	50	80	100	-
Ni [%]	80	50	20	-	100

The determined apparent density is 3.9 g/cm^3 for the carbonyl nickel powder and 4.4 g/cm^3 for the electrolitical copper powder.

The samples formed during the following stages: a. the powder mixtures were made homogeneous with a lubrifier (0.8% zinc stearate) and b. the bilateral press compacting.

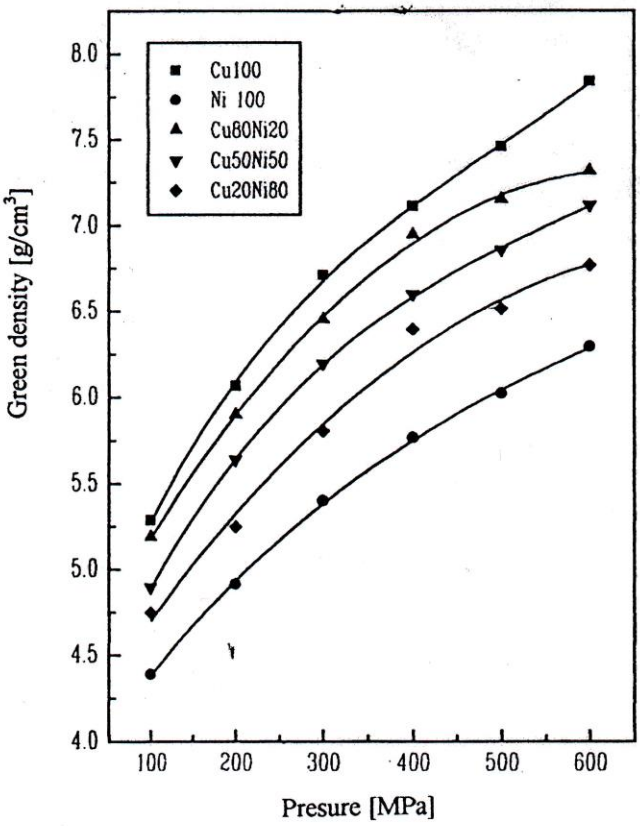
The samples were compacted in a cylindrical mould at a constant height and structure, hardness, microhardness, green density were determined.

Mechanical tests required a powder pressing under the form of "biscuit" in the some conditions according to the Romanian standard STAS 8266-74.

The pressability curves of the mixtures in Table 2 are shown in Figure 1, indicating an increase in density before sintering when copper content was raised, in all mixtures.

Figure 2 presents the variation of compacts density with copper content increase at various compacting pressures.

The purpose of sintering was to check if the material was proper sintered and whether its structure could be modified by thermochemical treatment.



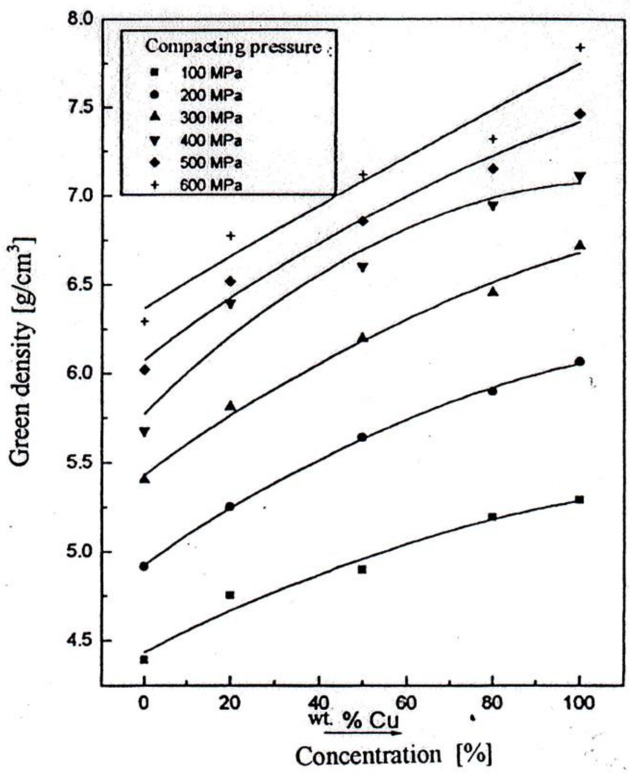


Fig.1. Presability curves for the mixtures in Table 2.

Fig.2. Green density vs.copper content.

The pressed compacts sintering at 600 MPa (i.e. the best densities) was carried out in a "DEGUSSA" type oven with automated feed, in a hydrogen reducing atmosphere, with an output of 280 l/h and a dew point at 0°C [2, 4].

The sintering cycle for the pressed compacts included:

- a 1 hour preheating up to 600°C to remove the stearate
- a 1 hour sintering at 800, 900 and 1000°C
- a 1 hour cooling at room temperature.

The Cu-Ni sintering occurs during the solid phase when the change of the pore shape and of their volume brings about an overall surface energy decrease.

The diffusion processes are principially responsible for sintering and densification, with volume diffusion playing the role of dominant mechanism. In the Cu-Ni diffusion couple, the diffusion coeficient has a high value and consequently sintering evolves without difficulty.

Table 3 presents the after-sintering of the 600 MPa pressed compacts. One can notice an increase of the density in time and with temperature, in general. However, some alloys behave exceptionally.

Table 3. Densities of sintered compacts

Alloy type	Density [g/cm^3]; τ=1 hour; P = 600 [MPa]		
	800°C	900°C	1000°C
Cu 100	7.0	6.9	7.5
Cu20Ni80	6.7	6.8	6.7
Cu50Ni50	6.8	6.8	6.8
Cu80Ni20	6.7	6.8	6.6
Ni100	5.7	6.3	6.2

2 THE MECHANICAL PROPERTIES AND STRUCTURE OF SINTERED COMPACTS

Table 4 presents the results obtained experimentally for the hardness of the alloys, calculated by averaging three results per hardness. The Rockwell method, scale G was used because of material softness.

Table 4. The increase of handness with sintering temperature

Alloy type	HRG Hardness; τ=1 hour; P = 600 [MPa]		
	800°C	900°C	1000°C
Cu 100	32.5	38.5	46.3
Cu20Ni80	38.3	45.0	50.5
Cu50Ni50	40.5	48.2	58.0
Cu80Ni20	41.3	58.1	63.0
Ni100	78.1	84.3	86.4

The table shows the increase of hardness with sintering temperature and higher nickel content.

The behaviour of sintered compacts during traction is given in Figure 3 a, b, c, at various sintering temperatures.

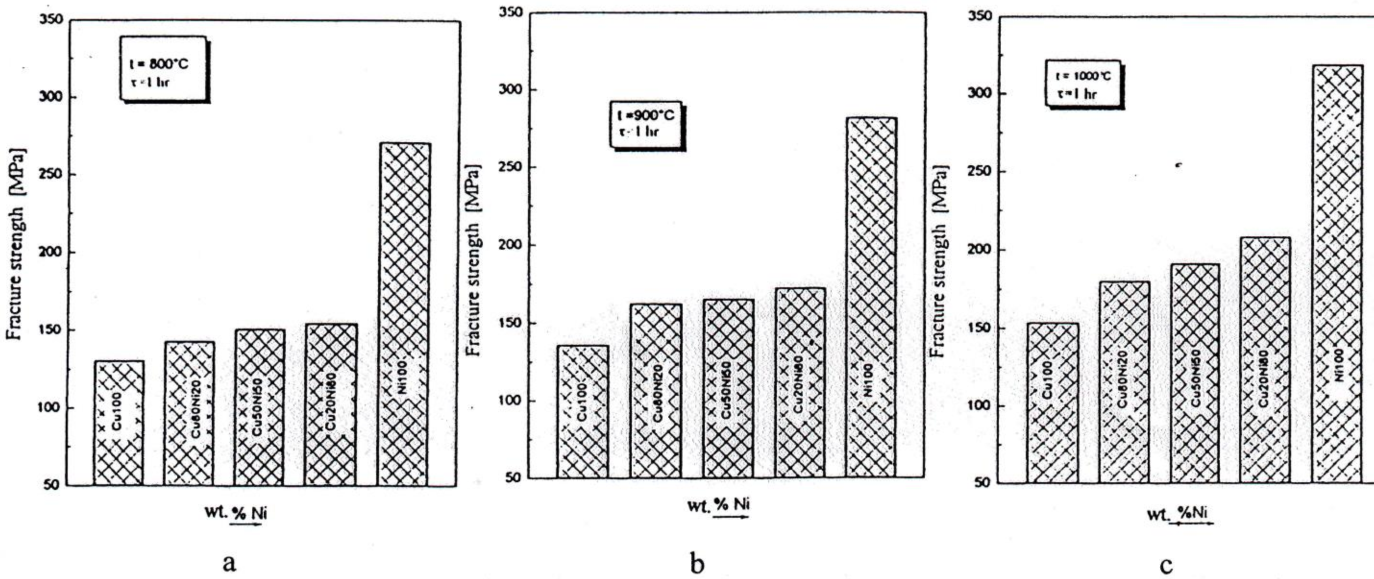


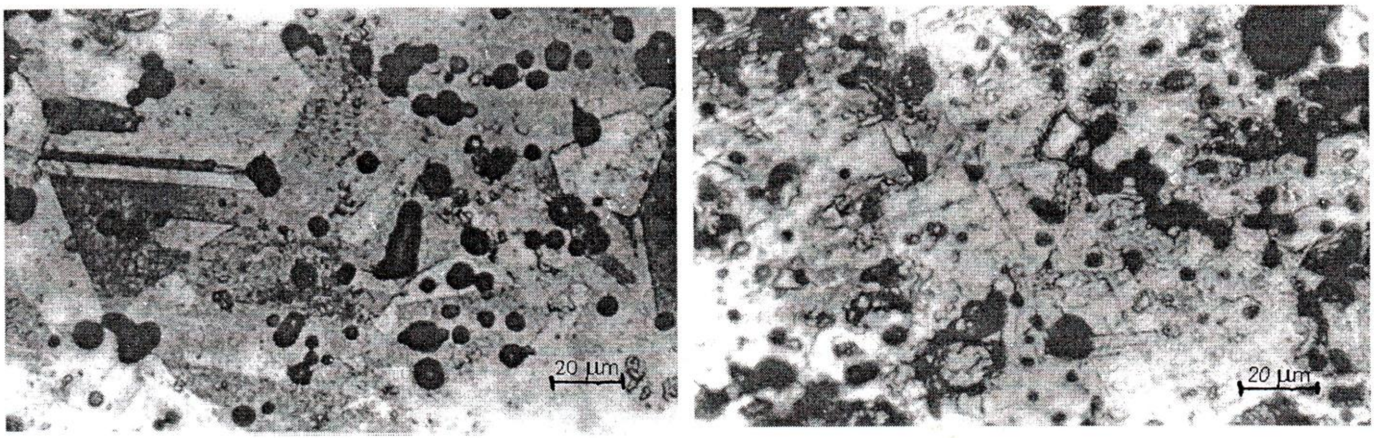
Fig.3. Variation of the fracture strength of sintered compacts.

The flow limit was evident only for the Cu100 and Cu80Ni20 alloys.

The Cu-Ni sintered alloys have resistance to fracture R_m dependent upon nickel concentration. Its maximum values are reached at 208.2 MPa for the Cu80Ni20 alloy and at 318.3 MPa for the pure nickel as compared to cast alloys, where R_m=400 MPa (50-70% nickel alloys) explained by the 87-90% compactness of the sintered materials, where pores act as fatique stress joints (concentrators) [3, 5].

Another cause for these lower values consists in the fact that porous sintered parts usually break along contact edges while cast alloys fracture along a trans-or intracrystalline plane.

Figures 4.a. and b present the microstructure of the sintered compacts: Cu80Ni20 (4.a) and Cu50Ni50 (4.b)



a b

Fig.4. The microstructure of the sintered compacts.

In the case of the Cu-Ni alloy the structure is one phased, made up of α solid solution polyhedron-shaped crystals (Fig.4.a and b). The polyheadrons have macles of the crystalized metals, arranged face to face in the cubic system. The macles are typical for annealing, being evident after the cold deformation of the powder grains followed by the annealing of the alloy during sintering. Solid solutions with minimum quantities of seggregations in a dispersed phase and a good resistance to coorosion were obtained.

For the Cu-Ni alloy the microhardness values have been determined in the α solid solution; no significant differences were noticed for the measurements on the same sample, because of the only phase, as expected. The microhardnesses of the α solid solution increase with the nickel content, ranging from 82.3 $HV_{0.02}$ to 138 $HV_{0.02}$.

3 CONCLUSIONS

The following conclusions can be drawn after the study of the Cu-Ni alloys subjected to sintering:

- the powder grain selection used was suitable as the copper and nickel alloying members diffused; the solid solution structures and a porosity of ~ 10% come to demonstrate it;

- the 600 MPa compacting pressure is the most adequate for as low porosity parts as possible, according to the pressability curves;

- the compact powders sintered at 900°C for 1 hr have the some α solid solution structure as with cast parts;
- the resistance to corrosion is very high, especially for 20-50% Ni compacts;
- the structure of the Cu-Ni alloys obtained by sintering is one-phased, with polyhedron-shaped α solid solution crystals with annealing macles;
- the HV hardness of the powder alloys is the some (according to experiments) on the compact (proving homogeneity), while with 50-80% nickel contents it is larger than for nickel (which is harder than copper) similar to cast alloys;
- after elongation tests, sintered compacts present a poorer resistance to fracture than cast materials with the same composition.

REFERENCE

1.*** Metals Handbook, Ninth Edition, Powder Metallurgy, ASM, Ohio, (1988), vol.7.
2.A.H. Kuhn, A. Lawley, Powder Metallurgy Procesing, Academix Press, (1978).
3. R. C. Ivănuş, S. Şontea, Cercetări privind forjabilitatea pieselor sinterizate din aliajele Cu-Ni, Comunicare la Conf. INGMEC'98, Craiova, 16-17 oct.1998, vol.III, pag.108-111.
4. F.V. Lenell, Powder Metallurgy - Principles and Aplications - MPIF, Princeton New Jersey, (1980).
5. Gh. Matei, L.A. Sorcoi, N. Jumate, Elaboration and Characterization of Copper Based Powder Produced by Rapid Solidification, Proc. 2th Int. Conf. Materials and Manufacturing Technologies, Cluj-Napoca , vol.2, (1998), p. 739 - 742.