Copper Metal Matrix Composite [CMMC] Behavior at Cold Compaction

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Abstract: Cold compaction of metal matrix composed powders [MMC] is extensively utilized in the manufacturing engineering materials for various utilizes in mechanical, chemical, electrical and petroleum industries. The ability to produce the required size and shape of a component with so small or not moreover machining is a basic advantage over other production processes. The production of a powder compact can be approximately divided into two phases. The primary level is the density of the metal powder, and the focus of the existing work is nearly the density of the cold mold in which the plastic deformation of the powder particles is the basic deformation process. The term "composite" in general indicated a material system that comprises of a discrete material (amplifier) distributed in a continuing phase (matrix) and has its concern distinctive profile from the properties of its component, geometry and also acquires structure of ingredients, and of the characteristic of the boundaries (interfaces) between various constituents. Composite materials are almost categorized depend on the physical or chemical nature of the matrix phase, as a case in point polymer matrices, metal, and ceramic matrix composites. Additionally, a few reports propose the rise of metal matrix and also carbon matrix composites like the polymers.

Keywords: Composite Materials, Cold Compaction, Manufacturing New Materials and MMC System

1. Introduction

The aim of composite reinforcement, intensity, toughness, and other mechanical characteristics is to main other properties as a coefficient of thermal process, conduction, and heat transfer. Failure mechanics have been agreeable as a beneficial discipline to describe the rigidity of materials that are macroscopically homogeneous and isotropic-universal, involving metals and also alloys. Particle composites are most vulnerable and stiffer than continuous fiber composites but are mostly a lot cheaper. Particle-reinforced composites mostly have less strengthening (maximum 40 to 50 percent volume) because of processing and also brittleness issues (Wan, Wang, Cheng, Tao, & Cao, 1998).

The compared with most polymer matrix composites, MMCs have superior mechanical characteristic, i.e. greater buckle strength and stiffness, higher shear and compressive strength, and higher temperature capability. There is further interest to some of the physical characteristic of MMCs, involving important feature in moisture absorption, non-flammable, high electrical and thermal conductivity, and greater resistance to radiation (Shehata, Fathy, Abdelhameed, & Moustafa, 2009) MMCs in general include of at least two ingredients: one is a metal matrix, and the other is a strengthening. In every case, the matrix is finding out as metal, but pure metal is rarely utilized: it is almost an alloy.

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Some MMC groups, like Cermet, diamond instruments, and solid metals, have a broad variety of applications and are always changing, even if they can be regarded traditional materials (Gaboriault, 2003; Wagih & Fathy, 2018). MMC metal matrix compounds have been studied for several years, the major uphold of the aerospace industry for aircraft and spacecraft components. Recently, the automotive, electronics and entertainment industries have been working widely with composites. MMC amplifiers can commonly be divided into five major groups: ongoing fibers, discontinuous fibers, shells, wires, and particles (including platelets). With the exception of wires, which are metals, reinforces are commonly ceramic. Usually, these ceramics are oxides, carbides, and nitrides that are utilized because of their good combination of strength and toughness at ambient temperature also high temperatures (Bach, Van Thuan, Thu, Phan, Vu, & Nam, 2019). Aluminum and its alloys have the highest interest as a matrix material for MMCs and the most commonly reinforcement is SiC. Applications of MMC motor for car engine cylinders are create of carbon fiber-aluminum-Al_2O_3 material and utilized. Therefore, these titanium alloys have a higher tensile strength to tensile strength ratio and a better strength at 400-500. C than aluminum alloys (Bach, Van Thuan, Thu, Phan, Vu, & Nam, 2019). Numerous studies have been carried out to specify the mechanisms linked with the compaction process. Thus, the pressure distribution model is usually linked with experimental functions connected to pressure and density to give the green density distribution in all nodes in the green sum. This model deals with the effect of frictional forces representation on the powder and interfaces of dead walls, which disperses the applicable pressure throughout the compression. The impact of compact geometry has the same affected on the uniformity of green pressure distribution and density distribution through compactness (Wagih & Fathy, 2018). It existed that the ratio of little dimensions give rise to a more uniform division than the ratio of higher dimensions. Hence, it looks like that this model works better for few aspect ratios. The industrialization with caution predicts the distribution of pressure and density during the compaction process (Bach, Van Thuan, Thu, Phan, Vu, & Nam, 2019). Justification, from the scientific and also the practical point of view, the growth of research in this scope and the following point has been drawn as the scope of the around work. The Cu-CuO-Al_2O_3 composite benefits the most augur well applications - mechanical machines, degrading electrical contacts, electrically disposal machining electrodes, and electric welding. No previous study in the literature to specify the mechanical properties of the new Cu-CuO-Al_2O_3 composite powders. To produce the cold compaction of Cu-CuO-Al_2O_3 composite powders, create a mold cylinder and show how the compact infrastructure can be manipulated by varying the composite powders utilized in the ultimate properties and the possibility of producing new Cu - CuO-Al2O3 composite powders which has beneficial mechanical properties. Recently, a few searchers have studied a hot-slope method determined to survey the mechanism of isothermal reaction of nickel and solid liquid isothermal reactions at 700 o C, 800o C and 900 o C for 0-40s. Solid nickel dissolution conduct in liquid aluminum was achieved. Constant dissolution rate, KNi, and dissolution activation energy, EA, were computed. Microstructural analysis through scanning electron microscopy (SEM) and transient electron microscopy (TEM) explained that the melted thickness of solid nickel in pure aluminum had a linear relationship with reaction time. The microstructure of the reaction interface involved a solid solution of nickel, nickel, nickel, Al3Ni2 layer, adhesive Al3Ni layer, free Al3Ni, eutectic structure Al3Ni + Al and Al. The structure of a nickel-based solid solution is primarily composed while the holding phase. Nanoscale Al_3Ni_2 and randomness Al_3Ni appeared in the interface across the quick cooling mode (Wagih, Abu-Oqail, & Fathy, 2019; Yu, Wang, Chen, Wei, Huang, Yang, & Zhao, 2020).

2. Experimental

We utilized two ceramics powder copper oxide and aluminum oxide powders with the copper metal powders as metal-matrix. Nearly 25 grams of powdered Cu-CuO- Al2O3 were placed in a plastic cup which was spilled inside the die. The piston was established in the die hole and the Instron was loaded in compression. The compacting applied pressure is fixed [50 kN] and less than after evicted the specimen of powder compact from the die, it was measured and also weighed. The densities of each the specimens were specified from mass divided (scale- ±0.1 g) by the computed volume determined from gauge with a dial caliper. Pure copper powders are widely used in the electrical and the electronic industries because of its excellent electrical and thermal conductivities. Pure copper powders may be given for these demands by electro deposition. The Copper (Cu) of high purity type, 99.7%, with an irregular dendrite's particles shape (50 mesh) as explained in Figure (1),

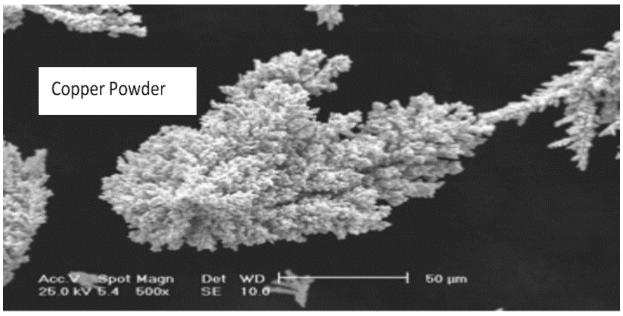

Figure 1: Copper powder by scanning electron microscope SEM

A Copper Oxide (CuO) powder with purity of 98.0%, and no uniform particle shape as explain in fig (2), and Blei (pb) < 0.01%, iron (Fe) < 0.03%, chloride (Cl) 0.2%, and sulphide (SO4). The purity of the product based on that of the raw material since refining of the melt prior to atomize is usually not practiced as explained in figure 2. Purity is usually over 98%. The powder can be made either spherical or irregular in shape. Particle size and shape, apparent density, flow, and green strength are influenced not only by atomization variables but also by controlling oxidation during atomization, subsequent reduction through annealing, and by final processing.

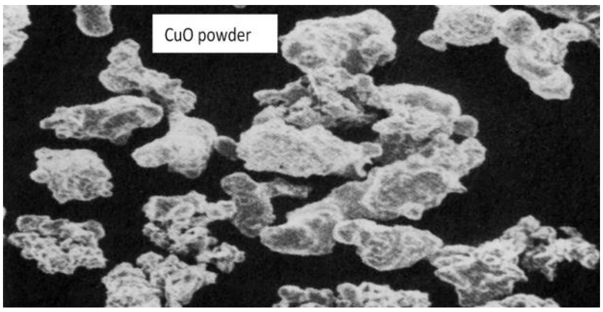

Figure 2: Dendrites Shape of Copper Oxide by SEM (100 MESH)

Aluminum Oxide (Al2O3) powder has a purity type (100 mesh), 99%, and no uniform particle shape as shown in fig (3), chloride (Cl) < 0.1%, sulphide (SO4) < 0.1%, and water-soluble matter < 0.5% has a rough shape.

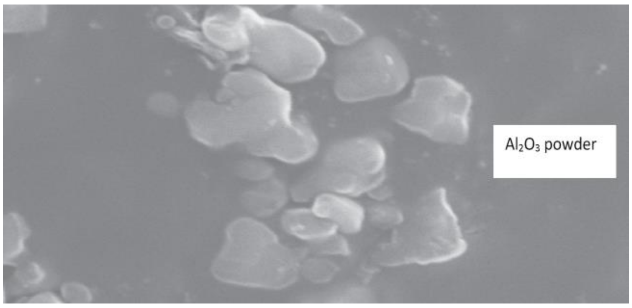

Figure 3: The rough shape particles of Al2O3 powder (100 mesh)

It is decided to utilize hardened steel (57%) for the punch and die cylinder to withstand the great applied pressure and abrasion. Usual die cylinder is explained in Fig. (4). By honing the die-wall with a fine stone, the grooves in the surface had a depth of less than 0.7 μm and 0.9 μm at the end of experimentation. After every compaction measurement the die is demounted, and if harm to the die-wall perceptible to the naked eye, The die honed, honing oil deleted by rinsing with methyl ethyl ketone (MEK) followed by ultrasonic. Cleared in ethanol and acetone in turn. The clearance between the die-wall and the punches is 0.3mm in the predominantly of tests. A hollow cylinder of steel from the inside, 11.70 cm in length and also inner diameter 2.45 cm and 5.00 cm outer diameter and has a high mechanical characteristics like toughness and hardness to withstand the pressure through the pressing powders inside and was smoothing the surface by a fine sandpaper (P400). For nice finishing of the surface so that it is smooth and to give a specimens softly high surface, and lower friction during the compaction powders, as well during the output model of the die, and are cleaned the die after each specimen to delete residual adhesive die from the previous specimen.

Figure 4: Die assemble for produce a composite powder compact the rough shape particles of Al2O3 powder (100 mesh)

The physical characteristics of the materials utilized in this research works are brief in this table.

Table 1: Physical properties of materials used

Material	Density [g/cm^3]	Elastic Modulus, GPa	Melting Point ^oC
Copper, Cu	7.83	110-128	1085
Copper Oxide, CuO	6.31	85-96	1201
Aluminum Oxide, Al2O3	3.95	380	2072

3. Results and Discussion

Experimental program includes cold compacting the following composites of [Cu-CuO-Al2O3)] [CMMC] powders are about 7 (seven) specimens at the similar weight (25 gm), as brief in Table 2 but at various composite. Every compound was happening again three times for checking the mechanical characteristics.

Where hi is the thickness or the height of the powder inside the die before compaction in cm presents (the initial height of the powder inside the die), the diameter of the die is 24. 5mm which is constant for all specimens before and after cold compaction. Some definitions are required:

- Specific Weight: δ = m/Vt ………….. (eqn. 1) (measured in g/cm3); m = mass of the material; Vt = true volume of the material or particulate powder volume.
- Density: ρf = m/Vb …………….…… (eqn. 2) (measured in g/cm3); m = mass of the powder resp. compact; Vb = bulk volume (enveloping volume).
- Theoretical Density: ρth = density of a (practically not attainable) pore-free powder compact (measured in g/cm3) after placed in the die.
- Porosity: □ = [(Vb – Vt)/ Vb] …. …. (eqn. 3)
- Compacting Pressure (die compacting):
  P = compacting force/face area of compact (measured in N/mm2 or MN/m2).

Density of a powder compact for composite curve [Figure 5] gives information about the frame within which a suitable compromise may be found. This curve is generally obtained from standard laboratory tests where a number of compacts are made at constant pressures in a stainless-steel die having a cylindrical bore of 25 mm diameter. It is clear from this figure that, the decreasing of compact density with growing the aluminum oxide powders weight percentage and rising the amount of copper oxide powder at the fixed weight percentage of Cu powder.

Table 2: for specimens when (Cu) is constant weight by 50% with different weight fraction for CuO and Al2O3

Specimen No.	Copper (Cu) %	Copper Oxide (CuO) %	Aluminum Oxide (Al_2O_3) %	hi, (cm)
1	50	45	5	2.78
2	50	43	7	2.89
3	50	41	9	3.02
4	50	40	10	3.14
5	50	38	12	3.31
6	50	37	13	3.36
7	50	35	15	3.48

A striking feature of these curves is the fact that their slope reduced considerably of the density of composite powders compact with growing the amount of copper powder, and that the density of massive pure copper powder is (7.83 g/cm3) obviously cannot be reached at feasible pressures as shown in the following table.

Table 3: The density and porosity of composite powders compact

Specimen No.	ρth., g/cm3	ρf., g/cm3	Δρ, g/cm3	Porosity, φ
1	1.95	5.25	3.3	0.628
2	1.88	4.78	2.9	0.608
3	1.77	4.47	2.7	0.6
4	1.72	4.19	2.47	0.589
5	1.63	3.96	2.33	0.572
6	1.56	3.89	2.33	0.596
7	1.48	3.81	2.33	0.607

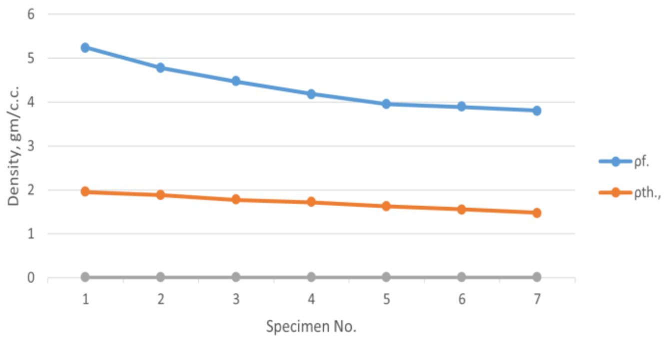

Figure 5: The Density of composite powder compact for all seven specimens

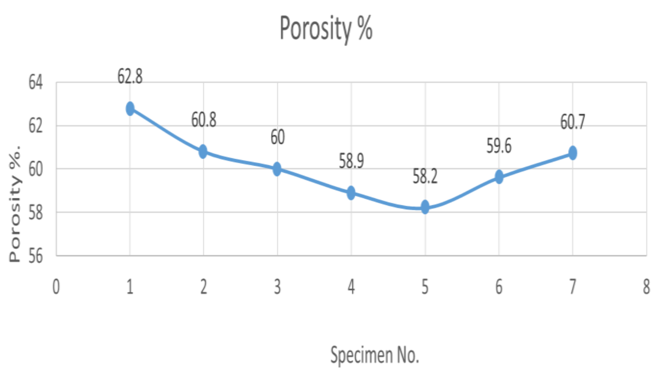

Figure 6: The porosity of composite powders before compaction

Table 4: The Mechanical properties of the composite compact powders

Specimen No.	Average of Micro-hardness test	Average of Surface roughness (µm)	Tensile strength, MPa	Compression KN
1	51.76	2.10	174	46.3
2	56.84	1.82	185	41.8
3	58.12	1.77	196	37.2
4	67.96	1.67	229	29.5
5	74.60	1.59	251	21.2
6	66.82	1.53	232	22.6
7	61.46	1.49	207	23.7

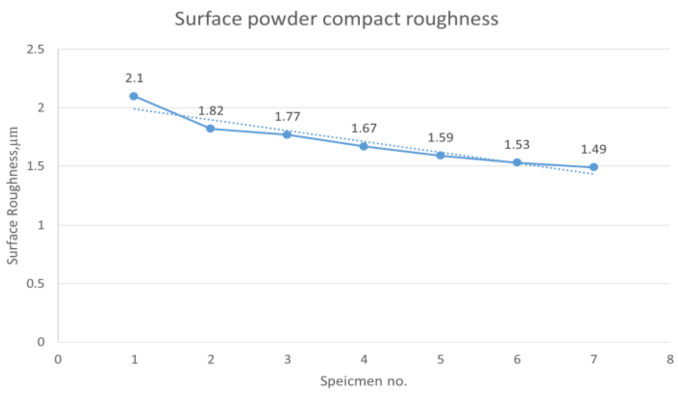

Figure 7: The average surface roughness of CMMC

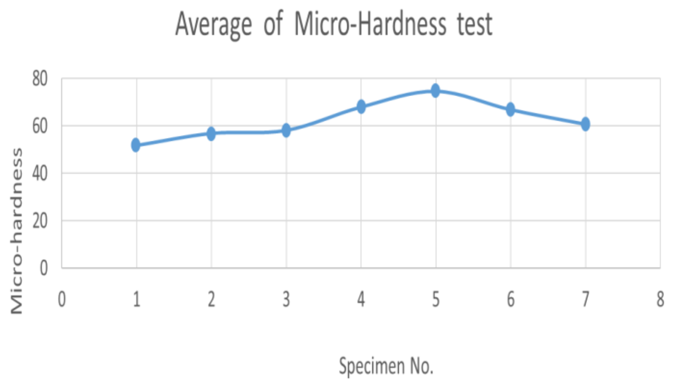

Figure 8: The average micro - hardness test for CMMC specimens

The surface roughness can influence dissolution, variability, and adhesion of coatings and films for powder compact. To explain, surface roughness correlated severely with the powder compact variations for composite powders (Cu-CuO-Al2O3). The surface roughness of particles furthermore has been correlated to powder flow and powder compaction, where the smoother particles giving rise to an enhancement of powder compaction and flow characteristic. The adhesion of particles to surfaces or other particles can also be greatly affected by surface roughness. Dry powder formulations are often composed of small drug particles and inert larger carrier particles. Interactions between these particles can be dominated by physio-chemical properties of the particle, such as size, shape, morphology, contact area. In particular, it has been shown that the surface roughness of the carrier particles has a significant effect on the adhesion and friction forces between the carrier and drug particles. Adhesion, blend homogeneity, and also stability have been directly related to the surface roughness of the carrier particle. The powder metal matrix [Cu-CuO-Al2O3] composite specimens were ground using surface grinder. They were polished using emery paper and then finished using diamond-lapping paste. The surface roughness on polished specimens was determined using Taly surf-6 surface roughness measuring instrument and the results are illustrated in Figure 10.

Vickers micro-hardness measurements progress at various locations on the surface of for all sample. Since the samples were metallographic bright to a great mirror finish, the al interred measured hardness values at various locations on the sample surface was less pronounced in the as compacted Cu-CuO-Al2O3 powder samples by utilizing Taylor-Hobson device as explain in Fig. 10 and the measured micro-hardness was noted to be near-uniform throughout each as-compacted sample, refer to uniform densification. Polishing of the sample surface facilitates lowering the spread into measured hardness values. Contributions from A Topical E micro structural heterogeneities and artifacts for example microscopic gaps, pores and fine microscopic cracks are official for the noted lower value of the micro-hardness of the sample in compared to the micro-hardness. We measured the micro-hardness for various distance nearly 4mm between the five dots at the specimens of cold composite powder, and then we adopt the average value for accurate results and the average value for this measurement are represented in Figure (11) for specimens no. 1,2 and 3.

Figure 9: Taylor-Hobson surface roughness test.

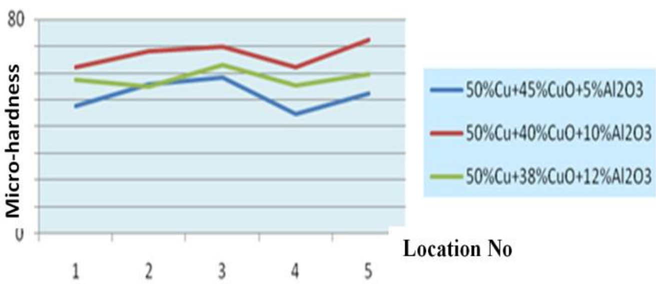

Figure 10: Micro-Hardness results for specimens 1,2&3 respectively at different locations

Contributions from A Topical E micro structural heterogeneities and artifacts for example microscopic voids, pores and fine microscopic cracks are responsible for the noted lower value of the micro-hardness of the sample in compared to the micro-hardness. It is obvious from the top results an average micro-hardness change with the composite of [Cu-CuO-Al2O3] cold compaction powders. The maximum values are found at specimen no. 5 (50% Cu- 38% CuO- 12% Al2O3) at 75 µm value of average micro-hardness as shown in Figure 10.

It is clear from top figure the range of surface roughness from 1.5 to 2.1 µm. The top height values of surface roughness are specimens no. 1 (5% Al2O3- 45% CuO – 50% Cu). This means the copper oxide powder has the predominantly to alter the surface roughness value in the cold compact composite powders.

The tensile strength, σ, which is the maximum tensile stress value of the material, is here identification as the horizontal tensile stress at the initiation of the large vertical crack in the center of the disc. Tradition the tensile strength of diametric compression testing is assessed by substituting the super load value into Eq. (4). For powder material the tensile strength is a density approved material parameter. The indirectly tensile strength of the compact powders Cu-CuO-Al2O3 composites with various weight % of Cu were measured. For this objective Cu-CuO-Al2O3 composite powder of right circular cylindrical shape was fabricated by a powder metallurgy process. The tensile stress σ is yield by

$$\sigma = 2P/ \pi.d.t \qquad [4]$$

Where,

P = Applied load (N), d = Specimen diameter (m), t = Specimen thickness (m).

In our work, we used the Germany specification [DIN 50 150] tables for measured the tensile strength as represented in table 3, by using the following equation (5):

$$\sigma \text{ (Mpa)} = 3.55 \text{ HB} \qquad [5]$$

When (HB < 175), HB = 0.95 HV

Remembered: σ is the tensile strength. HV is the Vickers micro-hardness and HB is the Brinell micro-hardest.

Measurement of the tensile strength of powder compacts is interesting for determining the magnitude of the cohesive forces which cause powders to agglomerate. Generally, plots of average of tensile stress [σ] opposite the various composites cold compact of Cu-CuO-Al2O3 powders for [CMMC] system is explained in figure 12, which observed a big range from 170 to 255MPa. The altitude cohesive force and powder agglomerated found in the one specimen no. 5 (50% Cu- 38% CuO- 12% Al2O3). This specimen had a height value of tensile strength 251MPa for specimen no. 5due a perfect densification of powders particulates occurs.

The results for compression check to our composite cold compact powders (Cu-CuO-Al2O3) has a big range from 20 to 48 kN are illustrated in Figure13. The following specimens, no. 1 (50% Cu-45%CuO-5%Al2O3) has a height value, but specimen no.5 (50% Cu-38%CuO-12%Al2O3) has a lower value 21 kN. That is mean the compression check is based on the rising the weight percentage of the copper oxide powder and reducing the aluminum oxide.

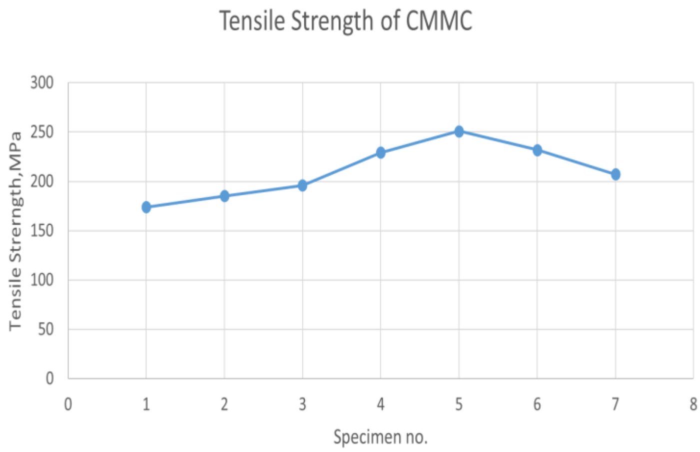

Figure 11: Tensile strength of CMMC system

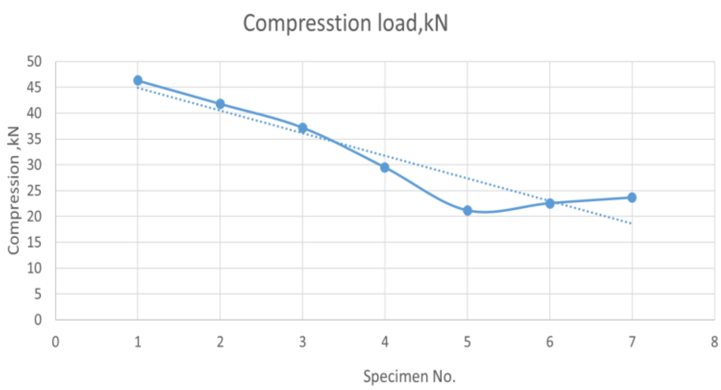

Figure 12: Compression test for composite copper metal matrix

4. Conclusions

Depending on the results given in an experimental survey target at understanding the influence of process conditions on mechanical characteristics of composite samples manufactured by cold compact composite powders of Cu-CuO-Al2O3, the following are the key observations.

1. The optimum composite found at specimen no. 5 (50% Cu – 38% CuO-12%Al2O3), which give as high value of mechanical properties for example tensile strength and micro-hardness than the others with least density of CMMC system.
2. It is found that is the surface roughness of compacts composite powder grow with growing the weight percentage of the copper oxide powder and reducing the aluminum oxide powder.
3. Machinability of the processed Cu-CuO-Al2O3 composites is in ordinary limits for this type of composites, guarantee, with moderate cutting forces, the giving of a nice surface quality.
4. Establishing of a competitive technology of Cu-CuO-Al2O3 composites elaboration, much inexpensive and more credible than those published in recent papers as being achieved.
5. Complex properties of the elaborated materials from both functional properties (electrical/thermal conductivity and mechanical properties) and machinability and for establishing the processing parameters - properties correlation as the key to their application.

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