Reinforcing a metal-based composite with a percentage of MgO particale to improve some of its properties and its relationship to conventional heat treatment

Shaymaa M.F.
Physics Dept. , College Sciences , University of Tikrit , Tikrit , Iraq
E-mail: shymafaydh@tu.edu.iq

Abstract

This research involved the manufacture of three compounds using powdered metallurgy technology through the reinforcement of the AlNi with addition percentage (40%), (35%) and 30% (MgO) ceramic reinforce phase to compound of A , B and C respectively and thermally treated In the traditional way

In order to study the effect of the MgO addition and heat treatment, the mechanical tests (Diametrical compressive strength and hardness) were conducted.

In order to determine the possibility of using the models produced for the attenuation of β particles, The linear attenuation coefficient and half thickness were examined for all models, The mechanical properties and the linear attenuation coefficient of all compounds have been improved, It was observed that the effect of the chemical composition was greater on the properties under study. We obtained the value of the compressive compressive strength of C (29) MPa before the a heat treatment, while the same compound had the MPa (32) After the heat treatment, in case of change in the addition ratio, we obtained the highest values of the mechanical properties and the linear attenuation coefficient of C, (29) MPa, (39) and (19.6)cm-1 respectively., And the lowest value given to the thickness of half (0.035)cm compared with (0.078) given by the A compound with the lowest mechanical properties and the linear attenuation coefficient (26.5)Mpa, (34.5) and (8.8)cm^{-1}respectively before thermal treatment.

Key words: overlapping material, chemical composition, heat treatment, mechanical properties, linear attenuation coefficient.

1- Interdiction

The progress made in materials science is the result of an attempt to meet the requirements of technological development in all fields. The emergence attempts of an urgent need to provide materials suitable for the use of multiple industrial for the manufacture of new materials have specifications that fit and meet the purpose in all aspects (lightweight, appropriate cost, durability…. etc.) so a new material appeared[1]. The overlapping material results from the physical bonding of two substances to represent each phase material separately in the system so as not to produce a new chemical[2].

But act on the basis that the new material is a single block properties combining the characteristics of the two basic articles and perhaps the possibility of avoiding the disadvantages of the articles by controlling the all conditions of manufacturing [3]. Chart (1) shows the most important types of materials that interrelate between them to be a new material .
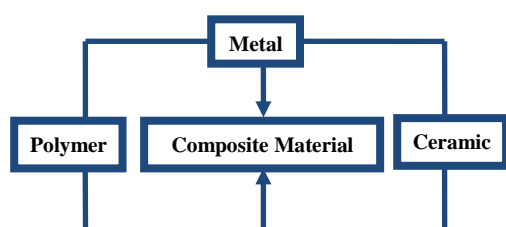

Chart (1) Interaction between materials for the production of overlapping materials [4]

One of the most common overlapping materials is the overlapping material with an aluminum basis for its extensive applications that are involved in the manufacture of motor vehicle parts (automobiles, airplanes and satellites) and in many other fields[4]. The most common manufacturing technology for the production of overlapping materials is powder metallurgy technology to control the properties of the produced part by controlling and changing the manufacturing conditions (weight ratio, compression pressure, particle size, sintering, sintering time and cooling method after finishing the sintering process) In order to fit the produced pieces with their field application[5]. This research aims at the possibility of manufacturing models in the applications of radioactive fields, which at the same time require good mechanical properties by adding different percentages from the phase of the MgO to the metal base AlNi and the effect of heat treatment on the properties of the product.

2-Expermental details

2-1 Mechanical Properties

One of the most important characteristics that determine the quality of the produced models is the mechanical properties because they determine the possibility of using the product in the field that requires good tolerability of stress [2]. Important way to improve mechanical properties is to choose either a good reinforcement phase and variable proportions or to procedure thermal transactions (conventional heat treatment, laser heating, plasma or isothermal heating), and the cooling method that follows the heating to the required temperature (cooling inside the oven, In the air and cooling in liquid oil or water)

and many mechanical properties are numerous, including the properties following [2,5] .

2-1-1 Diametrical Compressive Strength

This is a measure of the resistance of the body to the external load applied on it. The method of applied the load for testing is determined by the dimensions of the manufactured models. If the height of the model is equal to its diameter or higher, the pressure applied on the surface of the sample, but in case the height of the model is less than the sample diameter, pressure or load is applied to the diameter of the sample as shown in Figure (1) . In order to avoid friction generated by the increase of the upper and lower surface area of the model, which affects to the results obtained from the test, the resistance of the Diametrical compression is denoted by σ and given in the mathematical formula following [2,7] :

$$\sigma = \frac{2F}{\pi h d} \quad ------(1)$$

Whereas :-

F is the applied force(N)

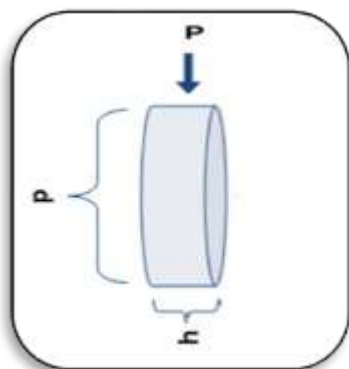h is the height sample (mm)

d is the diameter Sample (mm)

Figure (1) shows the method of applied the load

2-1-2 Hardness

Hardness is a measure of the ability of materials to resist scratching and plastic deformation. There is more than the way to procedure a hardness test based on the tool that is applied to the sample surface like (Brinal , Vickers , Knoop) the Brinal method was used in this research [8,9].

2-2 Reaction of charged particles with matter

The charged particles interact with the material mainly through a series of Colom reactions , with atomic electrons or atomic nuclei in the material, the energy lost by the charged particles in a single collision and the number of collisions it engages so large that the particle seems to lose its energy continuously and undergoes a gradual slow down [10] .

When the particles (N_o) of a charged particle thickness (dx), the number of particles (dN) is directly proportional to the number of particles falling and the thickness of the material.

$$dN = -\mu N_o dx -------------- (2)$$

The negative sign means that the number of photons that penetrate the material decreases as the thickness increases, and the intensity of the radiation or particles (I) can be used instead of (N). Thus can be written equation (2) as follows [11]:

$$dI = -\mu I_o dx ---------- (3)$$

Where μ represents the linear attenuation coefficient defined as the intensity lack of the unit area and its measurement unit is cm^{-1} .

I_o is the intensity of elementary particles count/sec.

Figure (2) shows the exponential decay curve as a result of obtaining a curve between the penetrating intensity and thickness when changing the thickness of the absorbed substance[12].
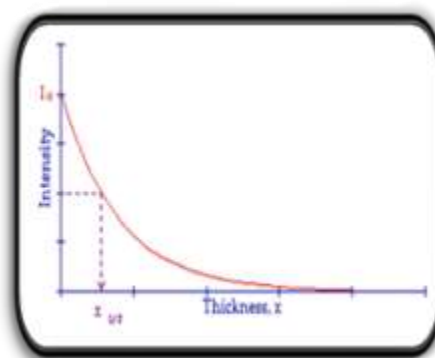

Figure (2) Curve of exponential decay [12]

The half thickness $X_{1/2}$ represents at which half the particles of the falling beam are removed on the material and measured in cm and can be calculated using the following equation [11]:

$$X_{1/2} = Ln\ 2\ /\ \mu --------- (4)$$

3-Experimental Part

In this part of the research we will discuss several items in which we describe the raw materials, the average size of their particles, the method of preparation of the models used in this research, methods of measuring the mechanical properties, the linear attenuation factor of beta particles and the half thickness , as well as the examination of crystalline structure using X-ray diffraction.

3-1 Stage of Sample Preparation

The models are manufactured by powdered metallurgy using the following steps:-

3-1-1 Preparation of The powders

From Table (1) we can Recognize the material. In the processing of mixtures and size of addition to the manufacturer and purity of each material. After the process of sieving and install the particle size in Table (1) we can move to the composition of each compound mixtures, following the weights shown in Table (2) using a sensitive electrical balance type Denver accurately (±0.0001) gm for example 1gm of the mixture of a compound A was placed in a container and the material was then well milled by the mill for half an hour to avoid the volatilization of the powder Ethanol alcohol was added and the

material was then placed in oven the maximum temperature is 250 °C The drying process was carried out at 100 ° C for half an hour to remove the alcohol and excess moisture. The grinding was then repeated after drying to ensure the required smoothness and uniformity of the mixture. The process was repeated for the rest of the mixtures mentioned in table(1).

Table (1) The powders used in the manufacture of the current study models and the average size of their particles and manufacturer

Type of powder	Purity %	Average size of Granules (µm)
MgO	99.90	≤200
Al	99.99	≤75
Ni	99.50	≤150

Table (2) Chemical composition of each compound

% Chemical composition			Models
MgO	Ni	Al	
30	10	60	(A)
35	10	55	(B)
40	10	50	(C)

3-1-2 Compressing the Samples
Take 1gm of the mixture, put that quantity in the cylindrical cylinder Diameter (4.15mm).

3-1-3 Sintering
The process was done using a manual plunger with a maximum of (10 ton). The models under study were compressed by the pressure of (4 ton) for a period of 60 seconds. The models resulting from the compression process were in the form of tablets with a diameter of (4.15) mm and a height of 4.15 mm. After the compression process . All The models had been put in furnace type (Prothrm) models and sintering at 1000 °C and raised to a desired temperature according to the steps described in chart (2) .
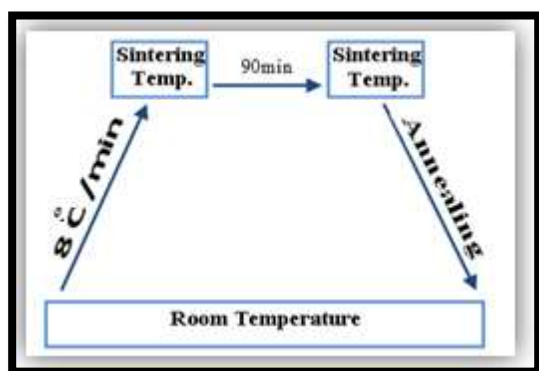

Chart (2) Method of sintering process

Before starting the tests, we prepared the samples by cleaning, smoothing, and fine-tuning the paper with SiC grades (1000,1200,2000)µm for all samples to be ready examination.

3-2 Heat Treatment
Has been conducting heat treatment using an electric oven. It was conducted at 500 ° C for a period of 30min. The samples were then cooled slowly and spontaneously until the room temperature reached .

3-3 Examinations
3-3-1 Mechanical Examinations
As noted above, the mechanical properties under study include both hardness and compressive strength. The first property was tested using the Bernell method for measuring hardness and using the Equotip2 digital hardness device with a rate of 5 readings per model.

As for the Q compressive strength, we measured the height of model h and diameter R to determine the mode of loading, where the load was raised diagonally because the height of the model was less than diameter using device measurement of hydraulic pressure resistance type Hoytom maximum load can reach up to 15 ton) After the determination of the value of the assumed power of the failure, the compressive strength value of the model was calculated using equation (1).

3-3-2 Measurement of linear attenuation coefficient and half thickness
For the purpose of verifying the validity of the use of manufactured models for the purpose of preventing β particles, measurements of the linear attenuation and half thickness were performed using the system described in Figure (3) which consists of the Geiger-Muller Counter, which has a voltage of 450V and counter for calculate the value of the radiation intensity and particles And parts of bullets designed to protect and reduce the harmful radiation and nuclear particles as well as the use of a holder, after running the system we follow the following steps to complete the measurements:

1- Determine the distance between the source used and the Geiger-Muller Counter .We measured the radiation background of the laboratory (I_b count / 100sec) before extracting the radioactive source for the purpose of subtracting the radiation background value to eliminate the radiation intensity and secondary nuclear particles present naturally and very minuscule in the laboratory.

2- We used the radioactive source of the Sr ^{90} particles, which had an activity value of 25µCi. After that, the primary particle intensity was measured before installing the sample ($I_\circ$ count / 100 sec). The measurements were made for three attempts for each model.

3-We measured the thickness of the model using the vernier and then placed the model in the space allocated between the source and the detector. The intensity of the particles from the model (I count / 100 sec) was then measured for three attempts to reduce the error rate.

4-The linear attenuation coefficient value was calculated using equation (3)

5- applied to the slope of the graph between Ln I / I and the thickness value (X mm).

We also calculated the thickness of half $X_{1/2}$ using equation (4) .

Figure (3) attenuation measurement system

4- Results and discussion

4-1 Effect of the process on the mechanical properties

From the observations of Figures (4) and (5), the effect of heat treatment led to improve the compressive pressure and the hardness. All the values of all the compounds were higher after the process of heat treatment than before, This corresponds to other materials[13] , due to the removal of stresses from the models and the increase in bonding between the granules resulting in a decrease in porosity and a consequent improvement in mechanical properties.

4-2 The effect of the heat treatment process on both the linear attenuation coefficient and the half thickness

The effect of annealing on both the linear attenuation coefficient and the half thickness is illustrated by the figares (6) and (7), respectively, where we observe the relationship is positive for the linear attenuation coefficient and the opposite of the half thickness, It is worth mentioning that the improvement in linear attenuation coefficient is somewhat less than the improvement in mechanical properties as well as the inverse relation with the thickness of the half, as opposed to effect chemical composition the on noticeable improvement in properties all compounds, This effect is attributed to the fact that the linear attenuation coefficient and the of the half thickness depends on the density of the sorbent [11]. So chemical change has a greater role than the heat treatment, which we will discuss in more detail in a later paragraph.

4-3 Effect of chemical composition on mechanical properties

Table (3) shows that the chemical composition has a very large role before and after the annealing to improve the mechanical properties where we observe the lowest values of compressive resistance given by the compound A before and after the meld with values (26.5) MPa (27.5) MPa, respectively The increase in the ratio of the addition of Magnesium in Compound C compared with the ratio of addition to the compound B, A had a significant role in improving the properties even if the process of annealing was not a result of the phase as shown in figurs (8), (9) and (10) resulting from x-ray diffraction testing .We conclude that the improvement of mechanical properties results from increasing the ratio of the phase of the ceramic reinforcement to the metal base phase, which is consistent with [14,15] for other materials.

4-4 Effect of chemical composition on both linear attenuation coefficient and half thickness

The significant increase in the linear attenuation coefficient values and the decrease in the values of the half thickness as a result of the increase in the rate of the reinforcement phase can be observed by reviewing the values of Table (4) , In, both cases before and after the annealing, Multiply µ values of the added ratio of 30% in compound A through the 35% additive in compound B to the maximum addition of 40% for compound C It is worth mentioning that the process of heat treatment has an effect but is weak compared to the role played by the added rate as mentioned earlier, Note that A has a value of (8.8) cm^{-1} for the linear attenuation coefficient before annealing and it has a (9.5) cm^{-1} after the treatment while C has a value of (19.6) cm^{-1}.

5- Conclusions

1- Effect of heat on both compressive resistance and hardness was positive effect All values for all vehicles were higher after the heat treatment process than before the operation.

2-The increase in the addition rate in the consolidation phase before and after the heat treatment process results in an increase in the linear attenuation coefficients values, which is offset by a decrease in the thickness values of the half .

3- chemical composition has a large role before and after heat treatment to improve the mechanical properties where we note that the highest values given by the compound C, which (29)Map and (32) Map before and after heat treatment, respectively.
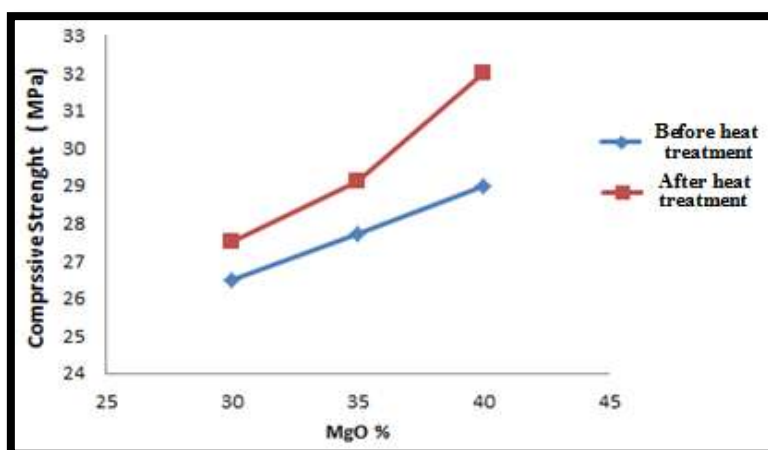
Figure (4) Effect of heat treatment on the Diametrical Compressive Strength
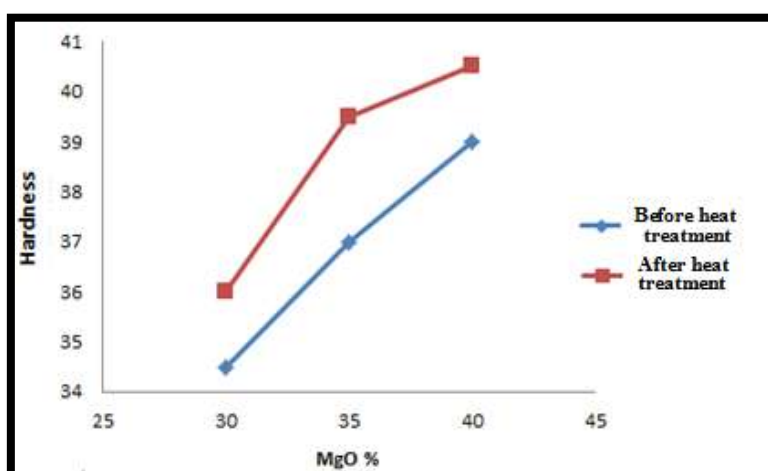

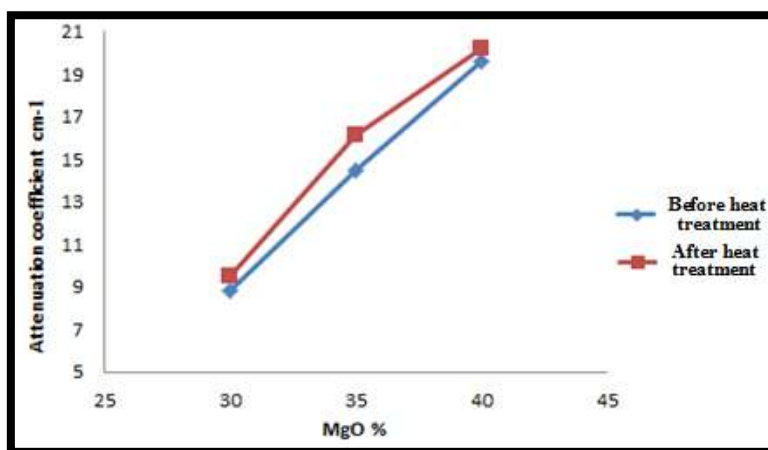**Figure (5) Effect of heat treatment on the Hardness**

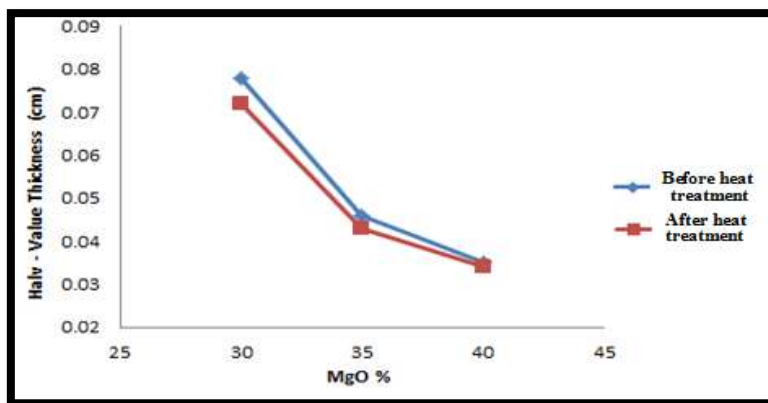**Figure (6) Effect of heat treatment on the linear attenuation coefficient**

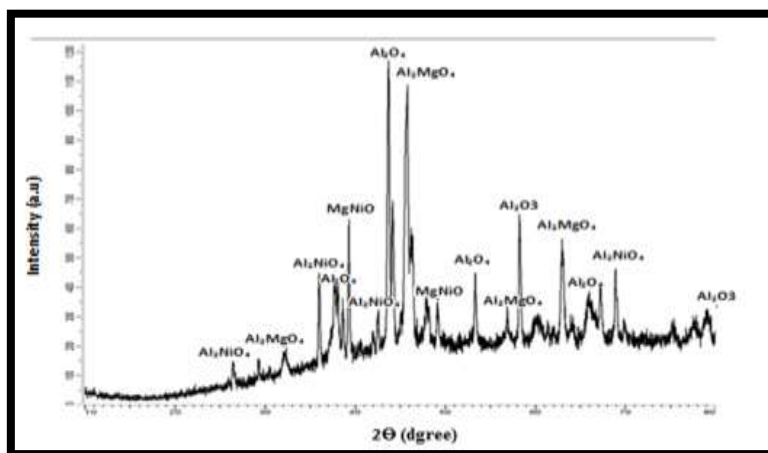**Figure (7) Effect of heat treatment on the half thickness**

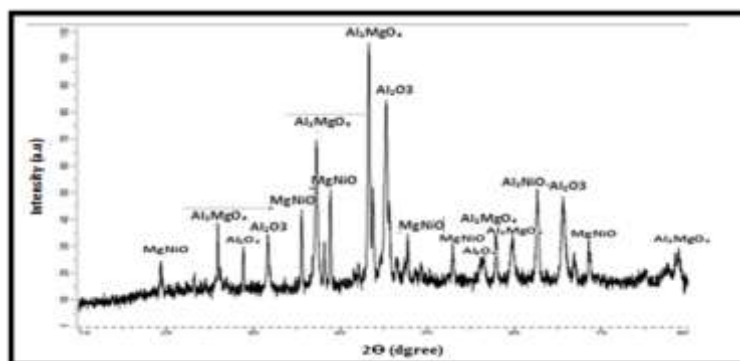**Figure (8) X-ray diffraction of composite A before of heat treatment**

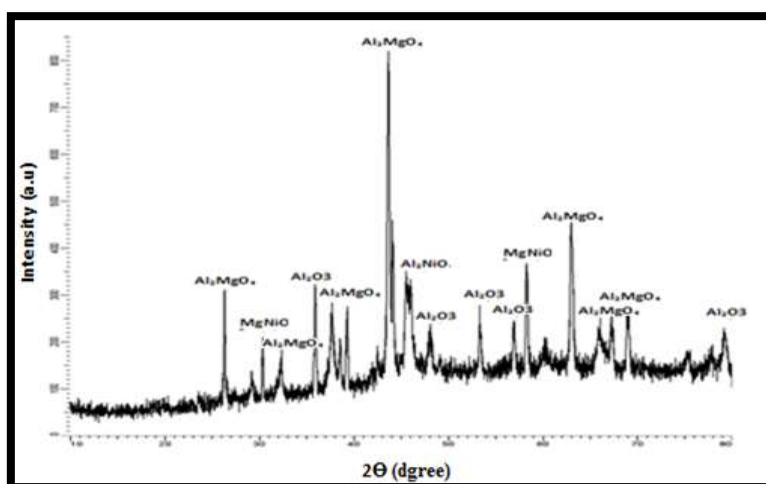**Figure (9) X-ray diffraction of composite B before of heat treatment**

Figure (10) X-ray diffraction of composite C before of annealing

Table (3) Mechanical properties and their relation to chemical composition before and after of heat treatment

models	Hardness HB		Compression Resistance MPa	
	Before	After	Before	After
A	34.5	36	26.5	27.5
B	37	39.5	27.7	29.1
C	39	40.5	29	32

Table (4) The effect of the chemical composition on both the linear attenuation coefficient and the half thickness a before and after of heat treatment

Model	Half thickness cm		Linear attenuation coefficient cm^{-1}	
	Before	After	Before	After
A	0.0787	0.072	8.8	9.5
B	0.046	0.043	14.9	16.1
C	0.035	0.034	19.6	20.2

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تدعيم متراكب ذات أساس معدني بنسب من دقائق أوكسيد المغنسيوم لتحسين بعض من خواصه وعلاقتها بالمعالجة الحرارية التقليدية

شيماء محمد فياض

قسم الفيزياء ، كلية العلوم ، جامعة تكريت ، تكريت ، العراق

E-mail: shymafaydh@tu.edu.iq

الملخص

تضمن هذا البحث تصنيع ثلاث مركبات بتقانة ميتالورجيا المساحيق من خلال تدعيم طور الأساس المعدني (AlNi) بنسب أضافة (40%) , (35%) و(30%) من طور التدعيم السيراميكي MgO لتكوين المركبات A,B,C على التوالي ومعالجتها حراريا بالطريقة التقليدية, ولدراسة تأثير نسبة اضافة MgO والتلدين تم اجراء الفحوصات الميكانيكية (مقاومة الانضغاط القطرية والصلادة) ولتحديد امكانية استخدام النماذج المنتجة لغرض توهين جسيمات بيتا تم اجراء فحص معامل التوهين الخطي وسمك النصف لكافة النماذج.

تم التوصل الى امكانية تحسن الخواص الميكانيكية ومعامل التوهين الخطي لكافة المركبات بالتلدين, لكن تم ملاحظة ان تأثير التكوين الكيميائي كان أكبر من التلدين على الخواص قيد الدراسة فحصلنا على قيمة مقاومة الانضغاط القطري للمركب C‏(29)MPa قبل التلدين بينما امتلك نفس المركب القيمة (32)MPa بعد التلدين بنما في حالة تغير نسبة الاضافة حصلنا على اعلى قيم للخواص الميكانيكية ومعامل التوهين الخطي للمركب C وهي (29)MPa, (39) و‏(19.6)cm^{-1} على التوالي, واقل قيمة اعطاها لسمك النصف (0.035)cm بالمقارنة مع القيمة cm (0.078) التي اعطاها المركب A الذي امتلك اقل قيم للخواص الميكانيكية ومعامل التوهين الخطي (26.5)MPa , (34.5) و ‏(8.8)cm^{-1} على التوالي قبل المعالجة الحرارية .

الكلمات الدالة: المواد المتراكبة, التكوين الكيميائي, المعالجة الحرارية, الخواص الميكانيكية, معامل التوهين الخطي.