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STUDY OF THE THERMAL EXPANSION COEFFICIENT OF SEVERAL SAND MIXTURES USED IN THE CASTING TECHNOLOGY

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Abstract: The casting technology is one of the most important production processes, because of its special characteristics and features such as the ability to produce complex shapes and a wide range of compositions. This work aims to study several mixtures of sand with different structures in terms of permeability, strength, thermal expansion coefficient, comparing them, study the effect of the elements involved in the composition of these mixtures on those parameters, and create a database that can be used both in modeling processes or mold design, as when designing the sand mold The value of the sand expansion of the mold must be taken into account, otherwise the designer will face the problem of the possibility of exit some dimensions of the final product from the permissible range and thus rejecting the product, Or the product is undergone to deformations resulting from the expansion of mold sands, which must be avoided when designing the mold

Knowing the characteristics of those sand mixtures helps the investor in choosing the most appropriate mixture for the required casting process in terms of engineering specifications or quantity, with the aim of less costly production by saving in choosing the most appropriate and least expensive sand mixture that serves the desired purpose

Keywords: Casting, Sand molding, porosity, permeability, coefficient of thermal expansion

دراسة معامل التمدد الحراري لعدة خلائط من الرمال المستخدمة في تقنية الصب

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المستخلص: تعد عملية السباكة من أهم عمليات الإنتاج المستخدمة لما لها من خصائص ومميزات خاصة كالقدرة على إنتاج الأشكال المعقدة وطيف واسع من الخلائط المعدنية، ويهدف البحث هنا إلى دراسة عدة خلائط رمال مختلفة من حيث النفاذية والمتانة وعامل التمدد الحراري والمقارنة فيما بينها ودراسة تأثير العناصر الداخلة في تركيب تلك الخلائط على تلك البارامترات وتكوين قاعدة بيانات يمكن الاستفادة منها سواء في عمليات النمذجة أو تصميم القالب إذ إنه عند تصميم القالب الرملي أو السيراميكي يجب الأخذ بالحسبان قيمة تمدد رمال القالب وإلا سيقع المصمم في مشكلة احتمال خروج بعض أبعاد المنتج النهائي عن المجال المسموح به وبالتالي رفض المنتج. أو تعرض المسبوك لتشوهات ناتجة عن تمدد رمال القالب يجب تفاديها عند تصميم القالب.

إن معرفة خصائص تلك الخلطات الرملية يساعد المستثمر في اختيار الخليطة الأنسب لعملية السباكة المطلوبة من حيث المواصفات الهندسية أو الكمية وذلك بهدف الإنتاج الأقل كلفة من خلال التوفير في اختيار خليطة الرمل الأنسب والأقل كلفة والتي تؤدي الغرض المطلوب.

الكلمات المفتاحية: المحاكاة، السباكة، تصلب، مسامية، نفاذية، معامل التمدد الحراري.

1- Introduction.

Generally, casting molds are classified into two types according to mold age:

1. Permanent molds: Molds are made of ferrous metals and steel alloys. This type is used for light metal castings. Cold room molds, hot room molds, centrifugal molds, gravity metal molds, and continuous casting molds are permanent molds.
2. Temporary molds: They are made of anti-refractory sand and other additives. This type is used for castings all kinds of metal alloys. Sand molds with additives (bentonite or sodium silicate……) or shell molds (sand + resin), wasted wax casting molds and lost foam molds are non-permanent.

The main material in the second type is sand, and according to the type of additives, the type of the mold changes.

Sand is a natural granular material consisting of fine fragmented rock particles and mineral crumbs. It is defined in size as the substance with grains smaller than gravel and larger than silt. The composition of sand varies according to the source of the local rock and its conditions, but the most common component in the continental regions inland and non-tropical coastal areas is silica dioxide, or SiO2, which is usually quartz metal.

The transition from alpha quartz to beta quartz which occurs at about 530 ° C is accompanied by a total volume expansion of about 2.5% which leads to length changes in the mold of about 1.5% (Campbell.John, 2015). This change is dangerous and could leads to many problems of mold failure and loss of control over castings dimensional accuracy. To overcome this problem, sand additives are used to act as a binder and enhancer to weaken the previous effect (such as bentonite, coal, dextrin and sodium silicate…….).

There are also other kinds of sand where the linear expansion coefficient is low, such as chromite, zircon, and olivine, but obtaining them is more expensive than silica sand, so its use is limited to cast special-use pieces.

It is worth noting that the size and the shape of sand grains have a direct impact on the properties of sand which plays a major role in the quality of the castings.

The need to produce castings of high precision and low cost has become a necessity imposed by global competition among production companies, and the pursuit of international standards.

2- Reference studies:

(sun & Long -sun Chao, 2009)Hsien –Chi sun et al. measured the temperature distribution profile in a sand mold for cylindrical aluminum castings. Thermometers have been distributed symmetrically to obtain feasible readings. They used their results to calculate the heat transfer coefficient for mold/metal interface in four different formulas. The important role in calculating the effective heat transfer coefficient for mold /metal interface was the use of extrapolation techniques and reverse schemes. The lumped-capacitance model has also been used to determine the effective values of the heat transfer coefficient. A good accord has been found between the numerical values of the heat curves of the sand and the experimental values. Finally, the heat transfer coefficient obtained was used to perform a finite element simulation for modeling the evolution of the temperature distribution during solidification, and it was found an acceptable accordance between simulation time for casting stiffness with real time.

(Munusamy, R. Balaje , & C. Sivakandhan, 2017)P. Munusamy et al. focused on examining green sand mixed with ash and clay in terms of strength and permeability. Standard samples were used in different concentrations of ash and clay and tested their permeability and compression on testing devices. The following was concluded:

1- The compression strength of the sand increases with increasing ash ratio up to 14%, and it increases with increasing clay.
2- The permeability increases with sand by increasing ash ratio up to 2%, then decreases with increasing ash ratio.
3- The permeability increases with increasing clay ratio up to 3%, and then decreases with increasing clay ratio.
4- The above values are ideal for pouring.

(IHOM & Johnson AGUNSOYE, 2011) Paul Aondona et al. studied the effect of moisture content on the industrial properties of natural Yola sand, within values ranging from 1 to 9%, and the compressive strength, permeability, and bulk density were investigated. The distribution of sand particle sizes, the degree of smoothness and the clay content were also examined. Aluminum casting was then casted at the ideal value of moisture content (5%) and tested. It was concluded that:

1. Moisture has a major effect on the industrial properties of Yola sand.
2. For optimum compressive strength, the moisture content is 5%.
3. The permeability increases with increasing humidity until it reaches the point of saturation.
4. The apparent density decreases with increasing humidity until it reaches the point of saturation, then it increases with increasing humidity.
5. This type of sand is used to cast aluminum samples with good surface.

(Rao & M.Srinivasa, 2016) M. Srinivasa Rao aimed to study the effect of bentonite content on sand mixture with common additives, and to determine the independent effect of bentonite apart from other sand additives.

In the beginning, he determined the properties of sand without special additions, then determined the same properties by adding each element separately, and through these steps the independent effect of the sand additions was obtained. In his research, the content of the bentonite was changed and the resulting properties were studied.

The purpose of the last experimental procedure was to create a sand mixture with a suitable composition that meets the required properties on one hand, and an economic usage for the other, then to cast several products with that mixture and create a statistical database in order to explore the results.

(Abbas, Falak, Samir, & Ezzat, 2005) Falak Abbas et al. studied the possibility of improving the specifications of homegrown sands by adding various materials other than water and bentonite, such as phenol, boric acid, alumina and coal. The resulting mixture was used in the casting process and tests for permeability and strength had been carried out on the prepared standard samples. The results indicated an increase in compression strength with an increase in the ratios of these additives, and vice versa for permeability, with the exception of alumina. Permeability was increased with increasing it.

(Prabhu & W. D.Griffiths, 2001) K. Narayan Prabhu et al. studied the heat transfer on mold/metal interface during the solidification of an iron casting in a sand mold. A cylindrical mold of sand and another of ceramic cylinder with sand blocks at the bottom were investigated.

Then inverse method was used in solving the one-dimensional heat transfer equation to determine the metal-mold interface heat flux transits and heat transfer coefficients in the modified conductivity equation. Taking into account the packed bed nature for the sand mold, the effect of the convection of mold gases, and the evolution and absorption of heat as a result of a mold reaction, the following results were found:

1. The heat transfer was analyzed on mold/metal interface during the solidification of the cast iron using a reverse analysis taking into account the nature of the packed mold and the thermal transformations in the sand mold.
2. the sand mold heat flux transits show double peaks during solidification.
3. The first due to the solid initial shell of the cast, and the second due to the improved contact results from graphite precipitation causing expansion.
4. The principle of heat transfer mechanism was determined at mold/metal interface namely of conduction through the interfacial gas and radiation.

(al, 2013) Liping Chen et al. chose a cylindrical geometry to determine the interfacial heat transfer coefficient between a magnesium alloy and silica sand mold.

Coefficients were calculated in the inverse method based on an experimental data. Results show that the coefficient subjects to three distinct different stages as a function of the temperature of the cast during (mushy zone region.

We note that previous studies focus on the following themes:

1. Studying heat flux in the mold sands and its effects and modeling it numerically.
2. The effect of the concentration of each element of the sand mixture on the properties of the mixture on one hand, and the properties of the casting product on the other.
3. The effect of sand particle size on the properties of sand and castings.

In the current study, we choose several sand mixtures used for casting in order to study their thermal expansion. We explore the effect of several parameters on thermal expansion coefficient in some mixtures, such as the degree of packing and the size of the sand grains.

3- Research objective:

This work aims to establish and verify correlation between the degree of smoothness of the sand, the composition and the degree of compact (ramming) and the corresponding thermal expansion of the mixture.

4- Research materials and methods:

Several mixtures of casting sands were prepared and the expansion of samples made from these mixtures were tested as a function of temperature, and then the thermal expansion scheme was drawn. We use the following experimental equipment:

4.1-Sand sieving device:

This device is consisting of eleven copper sieves: 200 mm diameter and 40 mm height, arranged above each other's according to the following table1.

Table (1) Nominal aperture of used sieves

Sieve No.	Diameter [mm]
1	3.35
2	1.7
3	0.85
4	0.6
5	0.425
6	0.3
7	0.212
8	0.15

Sieve No.	Diameter [mm]
9	0.106
10	0.075
11	0.053

Figure (1) Sand screening device in the laboratory

4.2-Rammer device:

Rammer is light weight compaction equipment used to prepare standard DIN test samples in order to determine their compression, tensile, and shear stresses. The principle is to press a specific amount of sand in a tube or core box to form the desired shape. Compacting is achieved by dropping a known weight (6350 g) from a fixed distance

three times, and using the energy produced to compress the sand.

Figure (2) Rammer device in the lab

4.3-Electronic balance:

Shown in Figure 3

Figure (3) Electronic balance in the laboratory

4.4-Permeability measuring device:

Permeability is defined as the physical property of molded sand that allows gases to pass through it. It is determined by measuring the rate of air flow through a standard sample installed under standard pressure. It is expressed in the following mathematical formula:

$P = (v.h) / (p.a.t)$

Where P = Permeability number.

v = Volume of air passing through the

specimen in ml

h = Height of test specimen in cm.

p = Pressure of air (in cm of water).

a = Area of cross-section of specimen in cm2.

T = Time in minutes.

Figure (4) Permeability test device

4.5- Green compression strength device:

It consists of a metal body with a spiral screw rotating by a lever, and a metallic mass is fixed at the other end. During the rotation, a metallic piece is moved along a graduated ruler (in which unit pascal) in order to show the value of applied force necessary to achieve balance with the metal mass. The sample is placed between the jaws and the spiral rotates until the sample is broken, and the value given by the indicator is wrote down.

Figure (5) Green compression strength device in the lab

4.6-Heating furnace:

Electric furnace to heat samples up to about 1100 °C.

Figure (6) Warming oven in the lab

4.7- caliper and Micrometers:

Instruments used to measure the dimensions of samples during experiments.

4.8- Contact thermometer:

to measure the accurate temperature of samples during experiments.

Figure (7) Contact thermometer in the lab

4.9- caliper and Micrometers:

Instruments used to measure the dimensions of samples during experiments.

4.10- Contact thermometer:

to measure the accurate temperature of samples during experiments.

5- Experimental procedure:

Samples are prepared using several sand mixtures with standard dimensions (cylinder of 50 mm diameter, 50 mm height), and they are installed in the rammer device. According to the standard procedure, ramming is to be done three times, then we measure their permeability and strength. After that, we put samples in the furnace in order to register their dimensions and the corresponding temperature, arrange the results into tables, and create the corresponding charts according to the following:

5.1-Mixture A: (mold + core - complex castings):

- Silica sand 95 ~ 96% (grain size of sand is between 0.6 to 0.2 mm)
- Sodium silicate (bonding material) 4 ~ 5%. It is a chemical compound with the formula Na2O3Si, used to increases the strength of the mixture. The resulting mixture is rammed then in the mold and immediately hardened by passing CO_2 gas.

Five samples (of 147 g average weight) are tested to determine their strength and permeability and to create diameter changes vs temperature diagram.

Table (2) Permeability and strength values of the A mixture

Sample symbol	parameter	The value				notice
		1st value	2ed value	3ed value	ava	
A3	permeability	250	250	280	260	Three ramming's
	Strength (0.1Mpa)	2.8	2.5	2.4	2.56	
A1	permeability	390	390	390	390	one ramming
	Strength (0.1Mpa)	2	2	2	2	
A6	permeability	250	250	250	250	six ramming's
	Strength (0.1Mpa)	2.4	2.4	2.4	2.4	

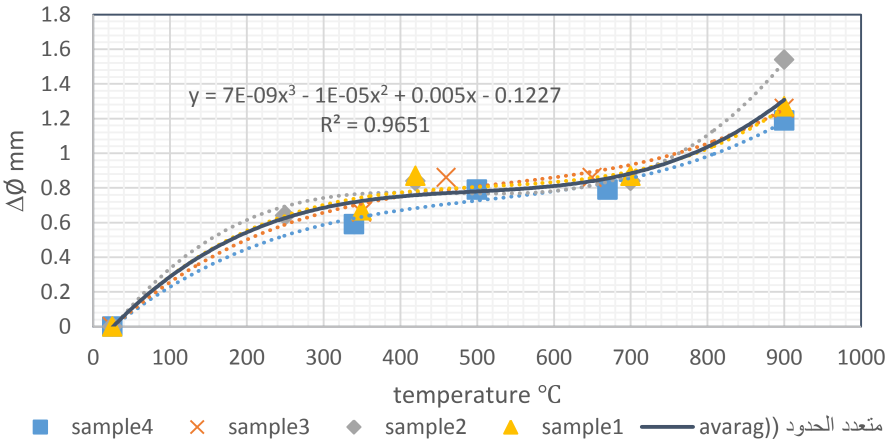


Figure (8) Temperature change diagram with the diameter change of the A3 mixture samples

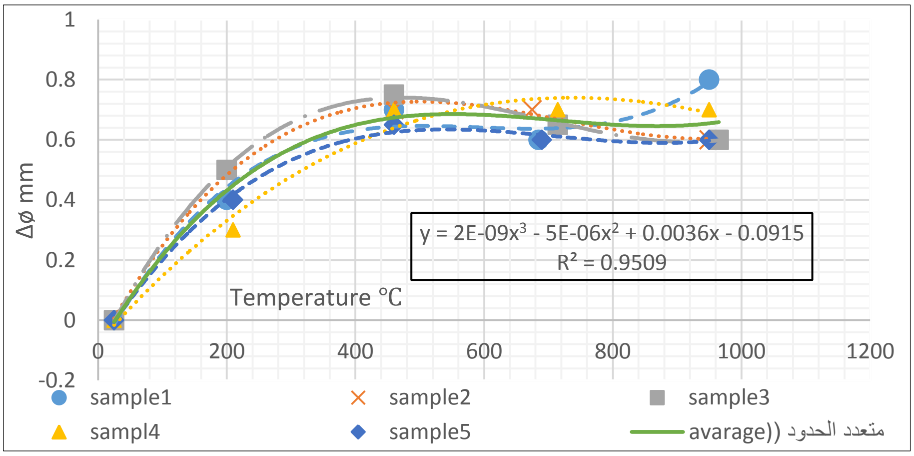


Figure (9) Temperature change diagram with diameter change of mixture A1 single ramming samples

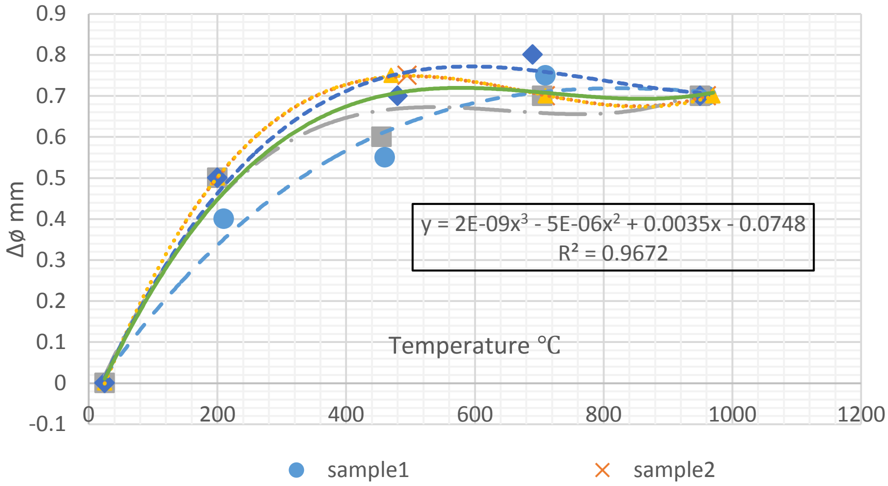


Figure (10) Temperature change diagram with diameter change of mixture A6 six ramming's samples

5.2-Mixture B: (die + core - complex castings):

- Silica sand 95 ~ 96% (grain size of sand is less than 0.2mm)
- Sodium Silicate 4 ~ 5%.

Table (3) Permeability and strength values of the B mixture

Sample symbol	parameter	The value				notice
		1st value	2ed value	3ed value	ava	
B3	permeability	55	54	55	54.66	Three ramming's
	Strength (0.1Mpa)	2.8	2.8	3	2.86	
B4	permeability	50	50	50	50	four ramming's
	Strength (0.1Mpa)	3.1	3.4	3.5	3.33	

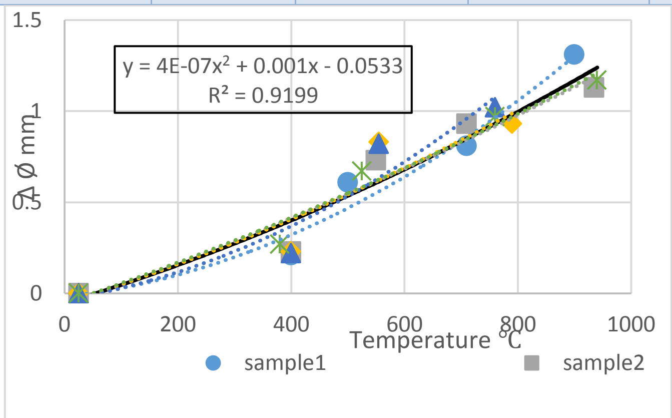


Figure (11) Temperature change diagram with diameter change of mixture B3 three ramming's samples

Samples B4 are from the same as the previous mixture, but the number of ramming's is four. Here we satisfied with four strokes because there was no significant change in the dimensions of the sample after the fourth stroke.

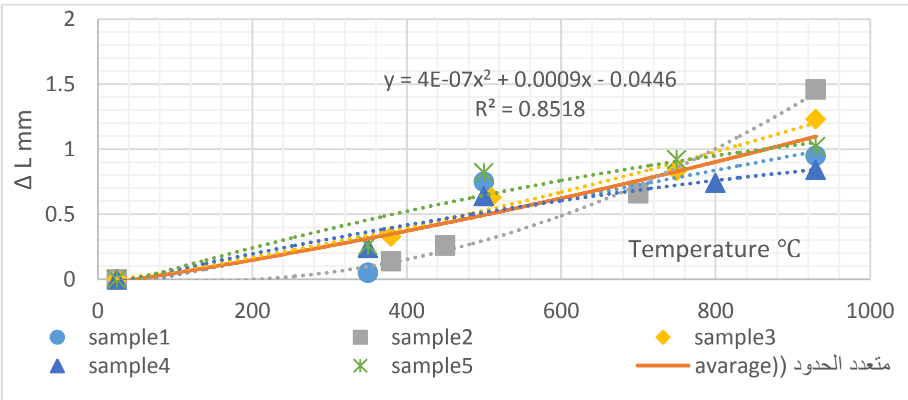


Figure (12) Temperature change diagram with diameter change of mixture B4four ramming's samples

5.3-Mixture C: (die + core):

- Silica sand 90 ~ 92% (grain size of sand is between 0.6 to 0.2 mm).
- Sodium silicate 5% (bonding material).
- Vegetable oil 3 ~ 5% (bonding material).
- Bentonite 1 ~ 2%.

Vegetable oil is added to the sand mixture to delay the drying of sand mixture in hot and dry climates, while bentonite and sodium silicate increase the strength of the mixture.

Table (4) Permeability and strength values of the C mixture

Sample symbol	parameter	The value				notice
		1st value	2ed value	3ed value	ava	
C3	permeability	260	260	280	266.7	Three ramming's
	Strength (0.1Mpa)	2.9	2.8	2.7	2.8	
C6	permeability	210	220	200	210	Six ramming's
	Strength (0.1Mpa)	3	3.3	3.2	3.16	

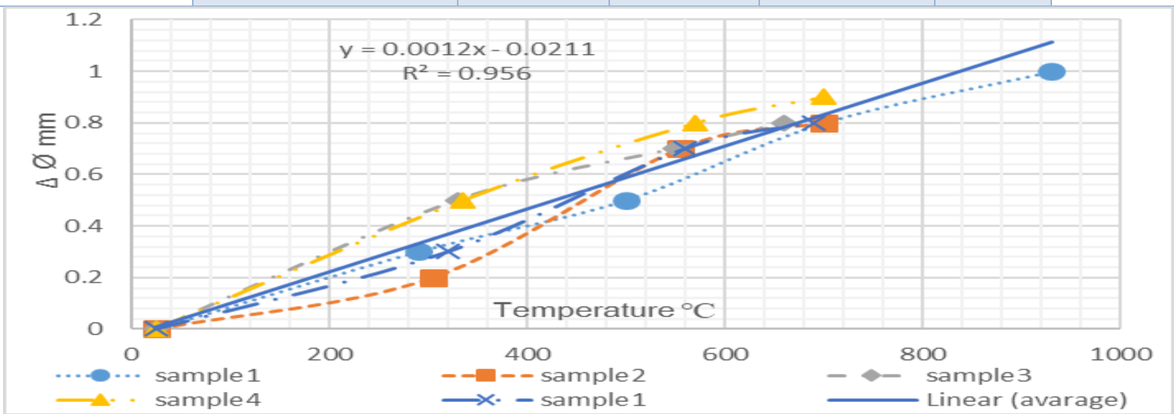


Figure (13) Temperature change diagram with diameter change of mixture C3 three ramming's samples

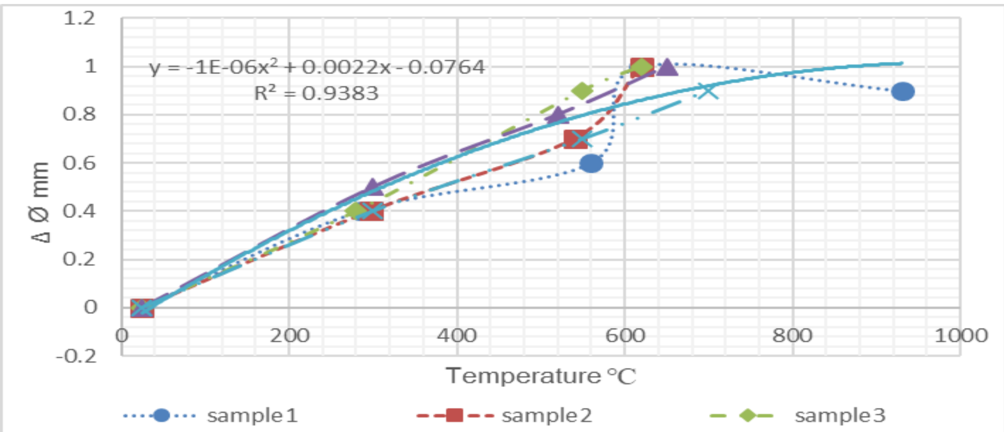


Figure (14) Temperature change diagram with diameter change of mixture C6sixramming's samples

5.4-Mixture D: (mold + core):

- Silica sand: 95% (grain size of sand is between 0.6 to 0.2 mm).
- Sodium silicate: 3% (bonding material).
- Vegetable oil: 1% (cannot be added)
- Molasses: 1% (bonding material).

Molasses is material from the sugar industry waste. Adding it to the sand mixture helps increase its strength. Also, during the casting process, it burns, leaving holes in it that increase the permeability of the mold.

Table (5) Permeability and strength values of the D mixture

Sample symbol	parameter	The value				notice
		1st value	2ed value	3ed value	ava	
D3	permeability	290	290	300	293.33	Three ramming's
	Strength (0.1Mpa)	2.7	2.6	2.7	2.66	
D6	permeability	220	230	220	223.33	six ramming's
	Strength (0.1Mpa)	3.2	3.1	3.3	3.2	

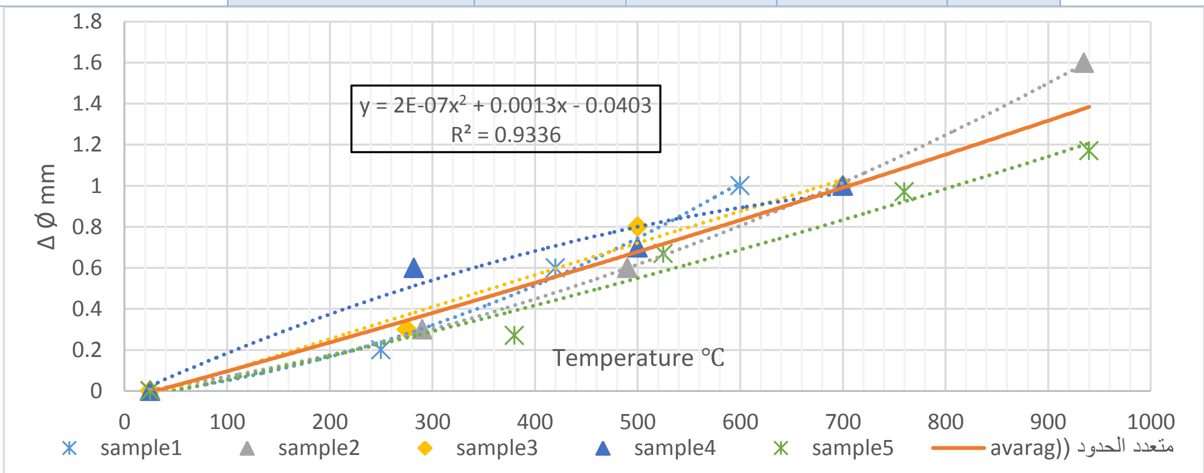


Figure (15) Temperature change diagram with diameter change of mixture D3 three ramming's samples

Samples D6 are from the same as the previous mixture D, but the number of strikes is six. It was noted that when the temperature reached about 700 degrees, the surface layer of sample began to crumble, and it became impossible to take accurate measurements, so we stopped testing at this degree.

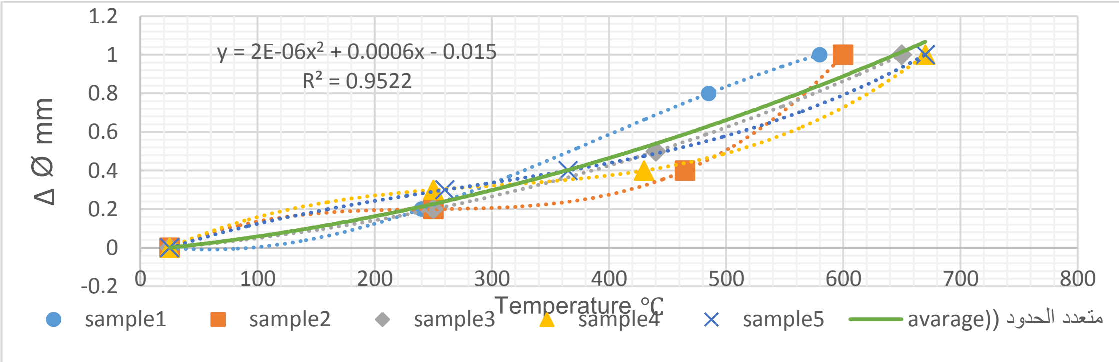


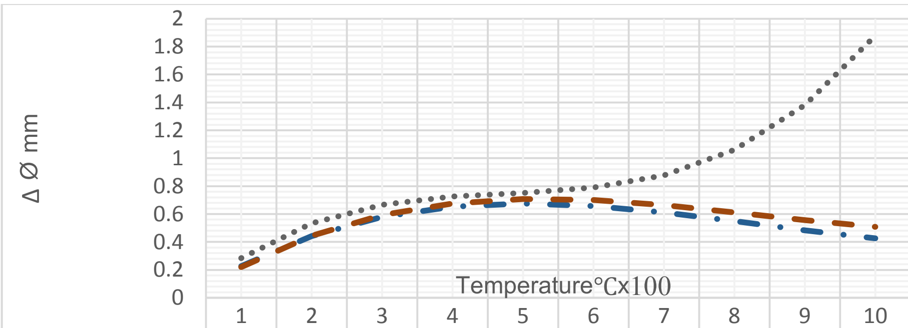
Figure (16) Temperature change diagram with diameter change of mixture D6sixramming's samples

6- Results and discussion:

6.1-Mixture A:

Comparing the curves of temperature and expansion of mixture A (one stroke - three strokes - six strokes), as seen in Figure (17), we note that sand expansion decreases in both excessive ramming and light ramming, where it is less in the case of excessive ramming. Permeability is high for light ramming since grains of sand find larger and more spaces when sand expand comparing to the standard ramming (three ramming's), so grains can move in these cavities without increasing of sample dimensions. Nevertheless, the strength of the sample here is less than other samples, so it is risked to deform the mold either transportation and handling, or during thermal and mechanical stresses during casting.

As for excessive ramming, it is clear that the increasing strength of the sample and its solidity reduce the effect of expansion, although the permeability is less comparing to other samples. Still this difference in this case is not remarkable, while the strength is greater, so we conclude that the last case is the optimal for practical use.



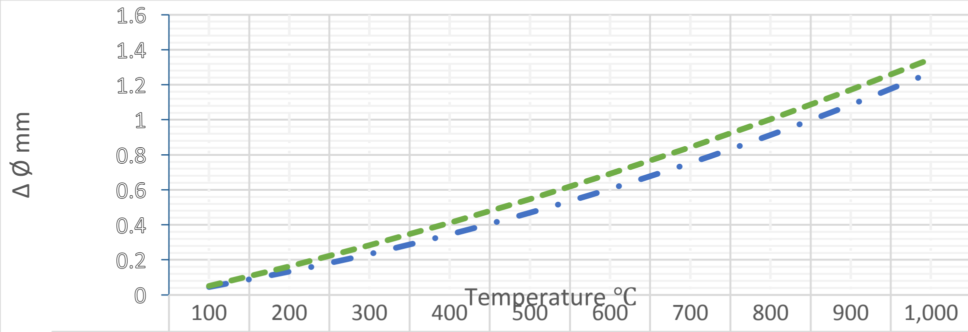
	1	2	3	4	5	6	7	8	9	10
A6	0.2272	0.4412	0.5792	0.6532	0.6752	0.6572	0.6112	0.5492	0.4832	0.4252
A1	0.2205	0.4445	0.5925	0.6765	0.7085	0.7005	0.6645	0.6125	0.5565	0.5085
A3	0.2843	0.5333	0.6663	0.7253	0.7523	0.7893	0.8783	1.0613	1.3803	1.8773

Figure (17) Temperature change diagram with diameter change of mixture A samples

6.2-Mixture B:

Mixture B is the same as mixture A in terms of composition but the grain size in mixture B is smaller. This increases the smoothness and quality of the casting surfaces, but it's negatively influenced the permeability to the point that gases will be trapped in the casting. So, Permeability can be increased either through using additives or through increasing the number of vents.

In this mixture we can’t make a single stroke sample because we can’t obtain a coherent body. As for why we were satisfied with four strokes instead of six because we did not notice a change in the length of the sample after increasing the strokes by more than four strokes. With regard to expansion and temperature, we note same as shown in mixture A.

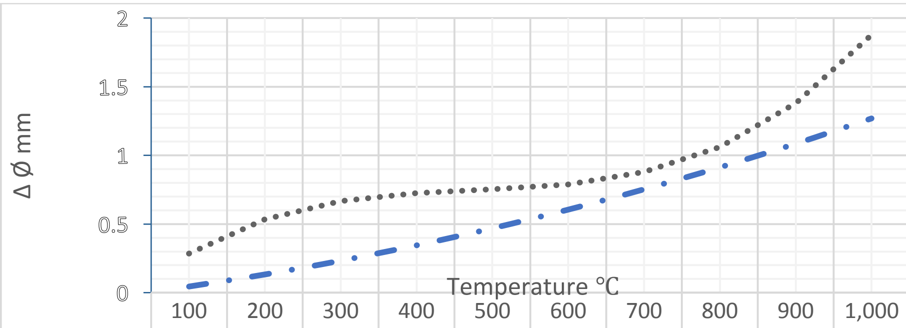


	100	200	300	400	500	600	700	800	900	1,000
B4	0.045	0.133	0.233	0.345	0.469	0.605	0.753	0.913	1.085	1.269
B3	0.0507	0.1627	0.2827	0.4107	0.5467	0.6907	0.8427	1.0027	1.1707	1.3467

Figure (19) Temperature change diagram with diameter change of mixture B Samples

6.3-Mixture A& B:

Comparing the two samples (A, B) having the same composition with different grain size, we notice that the expansion of sample B is less. Strength of sample B is greater despite the same number of strokes for both samples, therefore we can conclude that increasing the strength of the sand mixture reduces the expansion.

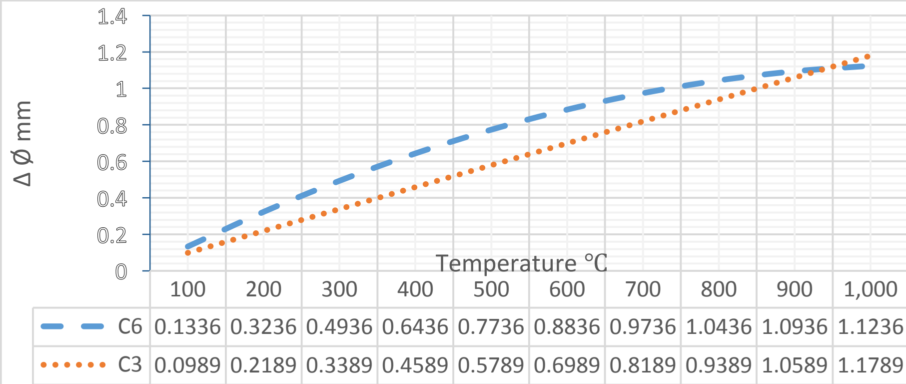


	100	200	300	400	500	600	700	800	900	1,000
B3	0.045	0.133	0.233	0.345	0.469	0.605	0.753	0.913	1.085	1.269
A3	0.2843	0.5333	0.6663	0.7253	0.7523	0.7893	0.8783	1.0613	1.3803	1.8773

Figure (20) Temperature change diagram with diameter change of mixture A3 & B3 Samples

6.4-Mixture C:

One can note that the expansion increases in this mixture by increasing the ramming number, this can be explained by noticing that both oil and bentonite have this effect, and One also note that the expansion exhibits a linear behavior by increasing the ramming.

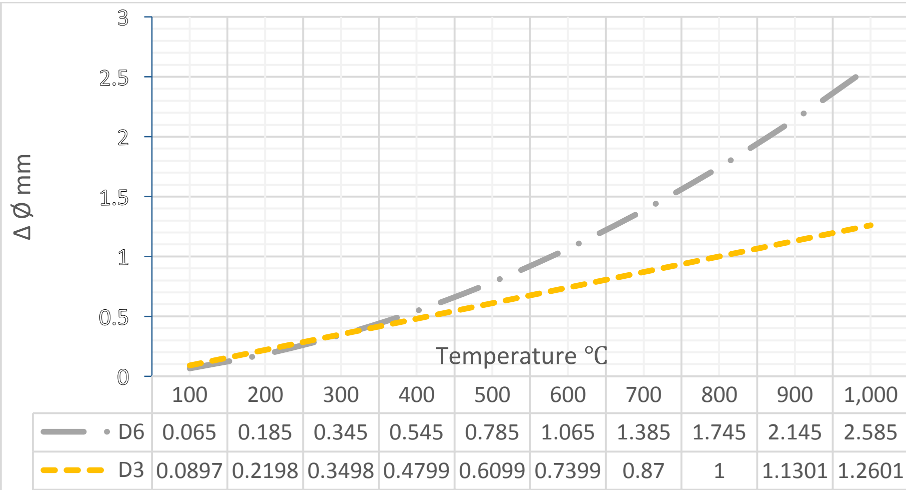


	100	200	300	400	500	600	700	800	900	1,000
C6	0.1336	0.3236	0.4936	0.6436	0.7736	0.8836	0.9736	1.0436	1.0936	1.1236
C3	0.0989	0.2189	0.3389	0.4589	0.5789	0.6989	0.8189	0.9389	1.0589	1.1789

Figure (21) Temperature change diagram with diameter change of mixture C Samples

6.5-Mixture D:

One can note that mixture D exhibits the same behavior as mixture C, with a difference in the expansion values.



	100	200	300	400	500	600	700	800	900	1,000
D6	0.065	0.185	0.345	0.545	0.785	1.065	1.385	1.745	2.145	2.585
D3	0.0897	0.2198	0.3498	0.4799	0.6099	0.7399	0.87	1	1.1301	1.2601

Figure (22) Temperature change diagram with diameter change of mixture D Samples

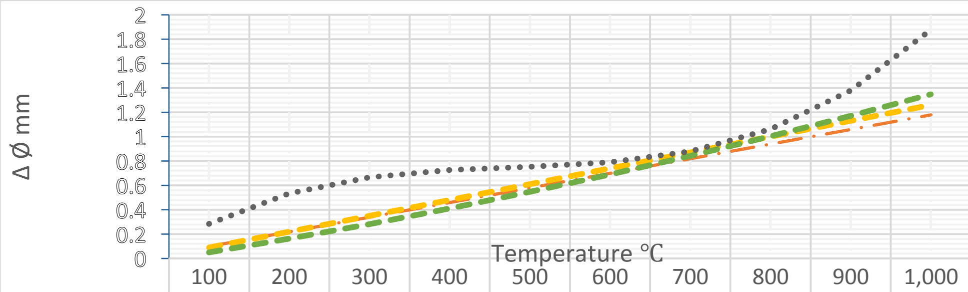
6.6-Mixture A& B & C & D:

Comparing the four mixtures, we notice that the mixture C has the least expansion values, then mixture B and mixture D come next.

The two mixtures C and D have two disadvantages; The first is that those mixtures are relatively more difficult in handling during the making the mold comparing to mixture A and B. in addition to the extra cost.

The other disadvantage is considered a disadvantage on the one hand and an advantage on the other hand, where when the sand temperature rises up about 700 degrees the mixture becomes fragile and fragmented easily therefore it is afraid of deformation of the mold and thus the deformation of the casting.

As for the advantage is the ease of cleaning the casting and taking out the sand.



	100	200	300	400	500	600	700	800	900	1,000
C3	0.0989	0.2189	0.3389	0.4589	0.5789	0.6989	0.8189	0.9389	1.0589	1.1789
D3	0.08974	0.21978	0.34982	0.47986	0.6099	0.73994	0.86998	1.00002	1.13006	1.2601
B3	0.0507	0.1627	0.2827	0.4107	0.5467	0.6907	0.8427	1.0027	1.1707	1.3467
A3	0.2843	0.5333	0.6663	0.7253	0.7523	0.7893	0.8783	1.0613	1.3803	1.8773

Figure (23) Temperature change diagram with diameter change of mixture A3 & B3 &C3 & D3 Samples

- Another fact must be mentioned in all mixtures that the change in dimensions due to expansion is irreversible; In other words, as the temperature drops into ambient temperature, the sample does not retain its original dimension.

This can be explained by a phase transition in the sand, as shown in Figure (23) Previous studies (Munasir, 2018) report that the transformation mechanism of the crystal phase of SiO_2 is influenced by temperature and pressure. In the crystal phase of SiO_2, the transformations that possibly happen are α-quartz (trigonal), β-quartz (hexagonal), α-tridymite (orthorhombic), β-tridymite (hexagonal), α-cristobalite (tetragonal), and β-cristobalite (cubic). The phase transformation of α-quartz ↔ β-quartz occurs at 573 °C; β-quartz↔β-tridymite occurs at 870 °C; α-tridymite ↔β-tridymite occurs at 117 °C; β-tridymite ↔β-cristobalite occurs at 1470 °C, and β-cristobalit⟶liquid silica occurs at temperature over 1710 °C.

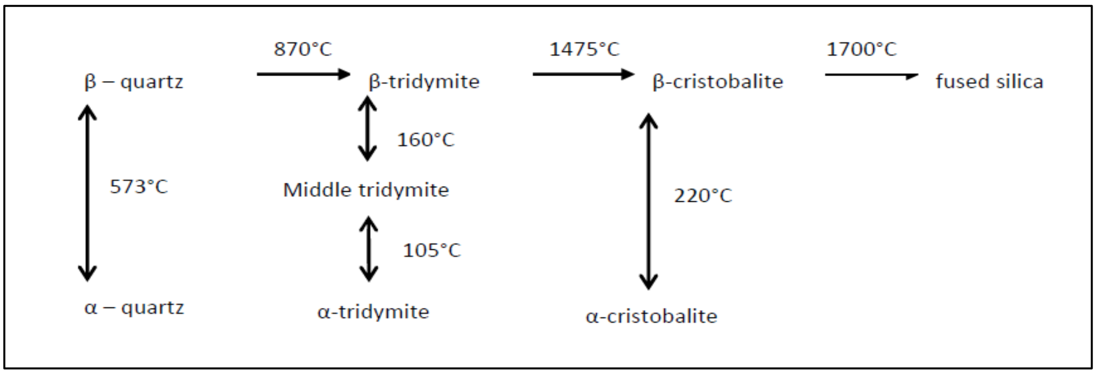


Figure (24) phase transition in the sand

6.7-suggested applications:

1. For the selection of the most appropriate mixture. Through practical and realistic experience in the casting workshop, we noticed that the same sand mixture changes its behavior during molding from one season to another according to the temperature and humidity of the air in the workshop. Therefore, we have to change the proportions of the materials included in the composition of the mixture or add other materials such as oil, molasses and others depending on the type of molten metal, the quality of the surfaces, the accuracy of the required dimensions, the number of pieces required, and the source of used sand.

Accordingly, we make a comparison between these parameters to choose the mixture that performs the required at the lowest possible cost.

2. We noticed that in the casting simulation programs, when choosing the mold material from sand or one of the ceramic materials, the program ignores the stress and displacement calculations of mold in the solution algorithm.

Also, when looking at the thermal properties of the sand used in the database of these programs, we note that the thermal expansion factor is not specified.

we believe here that it is necessary to add it in the simulation calculations because the expansion of the mold parts will lead to displacements that generate stresses which can lead to deformations, cracks, and even fractures in some metal alloys. This was observed while pouring these mixtures into our plumbing workshop.

3. The idea of designing a computer program that includes sand mixtures, its technical properties and its expansion factor, seems to be a great idea.

it is the basis of a scientific article that we are preparing for it based on Artificial Neural Networks (ANN), but the topic needs more sand mixtures. And we will add the shape and size factors, the thermal shock factor and other factors under study in the algorithm.

4. When starting to design a sand-casting model, the designer, based on the final design drawing of the piece, will add thicknesses to the product (machining allowance). These allowances will be machined

after the process of casting the product to achieve the exact dimensions of the product and the conditions of perpendicularity, parallelism, centralization and other engineering specifications that can be accurately achieved Through the machining but the casting process cannot achieve.

The designer also takes into account the heat shrinkage factor which is related to the type of metal, the shape, size, and the method of casting. Accordingly, the designer enlarges the dimensions of the product.

if we assume, for example, the shrinkage factor value is 1%. And the final dimension of a product is 100mm, it will be matched on the 101mm casting model. But the problem posed by this research that when designing a casting model in sand or wasted wax, the expansion of sand must be taken into account, which varies from one sandy mixture to another, according to what was shown in the research. Returning to our previous example, and if we assume that the expansion of the sandy mixture is 1%, a space of mold will also expand. The dimension of 101 mm in the mold become 101 * 1.01 = 102.1 mm. At the end of the casting process, after the product solidified, cools and shrinks, the final dimension of the product will be 101 mm, while the dimension required by design is 100 mm, which means that the product is rejected.

7- Conclusions:

From the above work and discussions, we conclude the following:

1. Sand expands within noticeable values and clearly affects the dimensions of the casting; Therefore, sand expansion must be taken into consideration during the mold phase.
2. The expansion process, according to what experiments have shown, is an irreversible process, meaning that the sand does not return to its original dimensions after cooling.
3. The dimensions of sand grains and additives to sand mixtures such as bentonite, molasses, vegetable oil and sodium silicate have a reducing effect on the expansion effect.
4. Any mixture type of previous can be chosen for use in the casting process. the mixture is chosen according to the investor's desire and capabilities.

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