EFFECT OF THE SAND MOULD ADDITIVES ON SOME MECHANICAL PROPERTIES OF CARBON STEEL CK45 CASTS

Asst. Prof. Dr. Hani Aziz Ameen
Technical College / Al-Musaib
Pumps Eng. Dept.

Khairia Salman Hassan
Institute of Technology - Baghdad
Mechanical Dept.

ABSTRACT

The research targets study of influence of additives on sand mold's properties and, consequently, on that of carbon steel CK45 casts produced by three molds. Three materials were selected for addition to sand mix at weight percentages. These are sodium carbonates, glycerin and oat flour. Sand molds of studied properties were produced to get casts from such molds. The required tests were made to find the best additives with respect to properties of cast. ANSYS software is used to demonstrate the stresses distribution of each produced materials. It is shown that the mechanical properties of casts produced is improved highly with sodium carbonates and is less with oat flour and it is seem a few with glycerin additives. It can be concluded that the sodium carbonates let to get the cast produced with highly mechanical properties.

الخلاصة

يهدف البحث الى دراسة تأثير الاضافات على خواص القالب الرملي وبالتالي على خواص مصبوبات الفولاذ الكربون CK45 المنتج في هذه القوالب. اذ تم انتخاب ثلاثة مواد اضيفت الى المزيج الرملي وبنسب وزنية مختلفة وهي كاربونات الصوديوم والكليسرين والشوفان . تم انتاج قوالب رملية ذات خواص تم دراستها والحصول على مصبوبات من هذه القوالب واجراء الفحوصات اللازمة وايجاد افضل مادة مضافة من حيث الخواص التي تم الحصول عليها . وتم دراسة توزيع الاجهادات على المسبوكات الناتجة ببرنامج ANSYS. وقد لوحظ ان الخواص الميكانيكية للمنتوجات قد تحسنت بشكل كبير في حالة اضافة كاربونات الصوديوم واقل تحسنا في حالة الشوفان وظهر تحسن قليل بالخواص في حالة الكليسرين. ومن هذا نستنتج ان اضافة كاربونات الصوديوم الى القالب يؤدي الى حصول منتوج ذو مواصفات ميكانيكية عالية .

KEYWORDS: casting, additives, mechanical properties, finite element method, ANSYS software , metallurgy .

INTRODUCTION

Casting is an operation for fabrication of the important and essential metals concerned with metal forming in the liquid state, i.e. casting the molten metal in a mold with a cavity whose form coincides with part to be produced.

Sand casting is considered as the most extensively used method of casting due to its low cost, ease of dealing with it and adequacy for repeated use in spite of importance of use of metal molds at casting. Its use is limited due to high cost and difficulty of fabricating the small and large forms. Thus, casting by use of sand molds is the trend . Such molds must possess the required specifications (strength, permeability , thermal properties ..etc)(Abid Al-Razaq I. Khdiar,2000). The sand is mixed with suitable binders and additives to improve its mechanical properties which determine the stability of the cast and type of its surface (St. dobosz. D. Drozyuski and A. chojecki,1997). The determination of the required percentages for mixing should be conducted according to scientific consideration for obtaining the optimum result with least possible costs (Asaad K. Mezher,2004). A group of factors influence the selection of a suitable casting method, the most important of these factors are:

- Design of the product to be fabricated .
- Form and size of the cast.
- Properties of the produced cast .
- The economic feasibility for the operation compared with forming operations
- Cost of tools and devices used .
- The required surface quality of the cast.

Few papers studied the effect of mould on the cast produced . Abbas A. A. Al-Raid ,1978, studied the Iraqi sand properties which is used in casting process. Najia Yousif Khaiou ,2005, studied the effect of additives on properties of sand moulds and then on the properties of cast iron. The effect of additives on sand moulds is studied in this research, in which three types of different additives is used, then their effects on the properties (mechanical and chemical) of the cast is investigated. Also the finite element analysis via ANSYS program is used to show the difference in the stresses distribution in the product's cast.

EXPERIMENTAL PART

It includes the following:

Sand Preparation

Sand *Arthoma* from Al-Anbar governorate was chosen for many reasons. Most important of which are its content of higher percentage of silica SiO_2, the dominating sub- angular grain shape and its high strength and binding force. The chemical composition is shown in **Table 1**

Sieve Analysis

The sieve analysis of sand was conducted to determine the distribution of grain size and fineness number by mechanical vibrating sieve consisting of (11) sieves starting with no. of 2000 microns hole up to the last sieve of (53) microns.

The test was conducted on 100 grams quantity for 15 minutes. After determination of finesses number, sand was used which passes from grid no. 44 of grain size (35-355) microns. Sizes (500-2000) micron were excluded for coarseness .

Preparation of the Binding Material

Iraqi Bentonite was chosen. It is the traditional binding material for moist sand mold casting, type Calcium . **Table 2 ,** shows the chemical composition for the percent bentonite binding material .

The total percentage is 91.5% and the rest is clay.

Additives

The following materials were added.

A- <u>Glycerol</u>

It is a pure chemical. Its trade name is Glycerin. Its pure composition is
(CH_2OH)- $(CHOH)$ – (CH_2OH) .

B- <u>Oat Flour</u>

It is a cereal crop, when water is added becomes a slurry of high viscosity. (Douglas Doehlert,2000). **Table3 ,** show its consistent.

Also there are other elements in the oat flour consistent as shown in **Table 4.**

C- Sodium Carbonates ($Na_2 CO_3$)

Most crude bentonite in the world is of calcium bentonite. It is capable of swelling, viscous, low heat resistance. It can be transformed to sodium bentonite by chemical treatment of adding sodium carbonates. The following equation illustrates it [J.G. Sylvia,1972 ; K.strauss ,1970).

Calcium bentonite + Sodium carbonate Na_2CO_3 $\rightarrow$ Soduim bentonite + calcium carbonate $CaCO_3$

Preparation of Sand Mixture

Regulation of mixture percentage require a little flexibility (stability) between the high strength to be evidenced by the mold during casting and fragmentation / breakage without which the sand can not be returned to preparation units for reuse a new, therefore, to attain the required properties (moist permeability, moist hardness, strength to moist compression and strength to dry compression), the optimum mixture percentage (sand, water, bentonite and additive) are to be chosen, therefore, the effect of sand (mixture percentage change was tested as follows:

Bentonite Percentages

Bentonite was added by 15% weight , and water was added at 5% .

Additives

The mentioned materials were added by weight percentage as shown in **Table 5**

Preparation of sand Sample

After mixing the materials by a mixer, a quantity was taken for standard samples (5x5 cm) making for testing for compressibility and permeability. **Table 6** , illustrated the properties of the sand mold The sand casting was made. The metal was melted for casting to acquire castings (50 mm diameter x 30 cm long specimen each) .

RESULTS OF CASTINGS INSPECTION

A casting is considered to have achieved its purpose only after the casting is ascertained of being up to the required specifications. This entails the following tests:

1- Chemical Composition

The chemical composition of steel CK45 was tested. **Table 7** , illustrated it.

2- Non- Destructive Tests

(a) *Visual inspection*

An inspection was conducted for any apparent defect (tears and cracks) .

(b) *Penetration Inspection* This penetration inspection used to detect surface defects which can not be determined visually.

(c) *Radiographic*

(a) x-ray (short wave ray) was used for inspection of the casting to detect internal defects. These rays can penetrate metal, passing via the casting to be inspected. It records on a photographic film, indicating the passing ray's density. Defects appear as opaque spots. Thus, their locations are determined. Inspection time was 2.5 min at 200 KV by German Feifer1 Apparatus No. 020386-17 .

(b) *Ultrasonic inspection*

This inspection was implemented to detect minute defects, inside the metal, which can not be detected by x- ray. USK7-5 apparatus with SEB2H probe and electronic oscillograph was used. The same prepared surface is inspection (3-15-2-2) was used . A gelatinic materials was used. A gelatinic material was used to facilitate movement of the probe along the surface.

Above inspections were conducted at State Company for Heavy Engineering Equipment / Quality Control.

(d) *Surface Roughness Inspection*

Talysurfu Apparatus of Technology University – Production and Metals Dept. was used to inspection the surface roughness.

(e) *Mechanical Properties inspection*

(1) Tensile Strength

Tensile specimen castings were obtained according to ASTM-A48-83, whose axsymmetric dimensions are specified in **Fig.1.**

(2) A tensile test by Instron 1195 apparatus was conducted. Fig.(2) shows the stress- strain curves for the steel CK45 in the three cases

(i.e when the Sodium Carbonate, Oat flour and Glycerin are used)

Table 8, illustrates the results of tensile test .

(3) Impact Strength

The specimens which were prepared of the same casting according to ASTM-A48-83 specifications was chosen for impact strength by Charpy method. The dimensions are as shown in the **Fig.3** , the apparatus used was Heckrt type.

Table 9, illustrated the results of impact test .

(4) Hardness Tests

Brinell method for hardness test was used , implementing a quenched steel ball , 5mm diameter and load 750 Kg, by Leybod Harris apparatus .Table-10- illustrated the results of hardness test .

MICROSCOPIC TEST OF SPECIMEN

Casting specimens were microscopically tested as follows:

- The specimen is made fine by smoothing apparatus of different grades (120, 200, 350, 500, 800, 1000).
- It is then polished by a polishing cloth with alumina solution of 0.3 micron. It is then washed and dried .
- Chemical treatment by Nital solution (1.8 nitric acid, 0.98 methyl alcohol)
- It is tested by optical microscope (Nikon73346) at X27 magnification, then photographed by a digital camera attached to the microscope. The photos of microscope are shown in the **Fig.4** .
- **MODEL GENERATION BY ANSYS**
- The ultimate purpose of a finite element analysis is to re-create mathematically the behavior of an actual engineering system. In other words, the analysis must be an accurate mathematical model of a physical prototype. In the broadest sense, the model comprises all the nodes, elements, material properties, real constants, boundary conditions and the other features that used to represent the physical system.
- In ANSYS terminology, the term model generation usually takes on the narrower meaning of generating the nodes and elements that represent the special volume and connectivity of the actual system. Thus, model generation in this study will mean the process of defining the geometric configuration of the model's nodes and elements. The program offers the following approaches to model generation (Saeed Mouveni ,1999).
  - a) Creating a solid model
  - b) Using direct generation
  - c) Importing a model created in a computer-aided design CAD system.
- The method used in this research to generate a model is solid model. In solid modeling some one can be described the boundaries of the model, establish controls over the size and desired shape elements automatically, i.e. drawing the two dimensional specimen model and meshing using meshtool and express the axsymmetrical condition . Solid modeling is usually more powerful and versatile than other modeling, and is commonly the preferred method for generation models. The Two Dimension model of specimen is done by drawing and meshing two dimensional axisymmetry specimen with element plan82. **Fig.5**, shows the specimen model in ANSYS. (ANSYS on-line-help,1996).

Fig.6, shows the stresses distribution and the deformed shape in the specimen when the glycerin additive is used to the mould sand. **Fig.7**, shows the stresses distribution and the deformed shape in the specimen when the sodium carbonate additive is used to the mould sand. **Fig.8** , shows the stresses distribution and the deformed shape in the specimen when the oat flour additive is used to the mould sand. From these figures it can be get that, in the case of glycerin additives the max. stress is (0.359 GPa) and with sodium carbonate additives (0.328 GPa) and for oat flour additives (0.321 GPa), from these results it can be concluded that the sand mold with additives glycerin is produced specimen bearing stresses more than the other additives.

CONCLUSIONS

1- The additives to the sand made improvement in impact, tensile strength and hardness for the carbon steel CK45 casts produced

2- It found that sodium carbonate was led to high improvement in these properties of casts and after that the addition of oat flour which also effect in improvement the mechanical properties of casting compared with the casting without additives.

3-Also it’s found that the stresses distribution in case of sodium carbonate additive is more efficient than the other two cases and the cast produced bearing more stresses than the others.

REFERENCES

Abbas A. A. Al-Raid, “Study the Iraqi Sand Properties by CO_2 Method”, M.Sc. Thesis, Univ. of Technology, 1978.

Abid Al-Razaq I. Khdiar , “Casting Technology” , University of Technology Published, 2000.

Asaad K. Mezher, “Stresses Analysis of the Casting Dies by Finite Element Method”, M.Sc. Thesis, Univ. of Technology, 2004.

Basic Structural Non-linearities, Training Manual, (ANSYS Inc., (ANSYS on-line-help),1996.

Douglas Doehlert, “www.Fargo.ars-usda.gov/cer.Acl.htm”, 2000.

J.G. Sylvia, "Cast Metals Technology", Canada, 1972.

K.Strauss, "Applied Science in the Casting of Metals" , Pergamon Press, NewYork 1970.

Najia Yousif Khaiou, “Effect of Additives on Properties of Sand Moulds”, M.Sc. Thesis, Technical College , Baghdad , 2005.

Saeed Mouveni, “Finite Element Analysis - Theory and Application with ANSYA”, 1999.

St. dobosz. D. Drozyuski and A. chojecki, “Mechanical Damage Mechanism of Moulding Sands”, Engineering University of Mining and Metallurgy, Krakow, Poland, 1997.

www.egsma gov.eg/bentonite, 1998.

www.flauqnart.com, Oat, Oat flour, December, 2000.

Table-1- Chemical composition of the used sand

Loss on Ignition	K_2O % Max.	MgO %	CaO%	Fe_2O_3 % Max	Al_2O_3%	SiO_2% Min
0.6	0.1	0.3	0.8	0.2	0.3	97.7

Table-2- Chemical composition of the bentonite binding material

% Loss on Ignition	CaO % Max.	Fe_2O_3 % Max	Al_2O_3% Min	SiO_2% Max
10.5	5.5	5.5	13	57

Table -3- Oat Flour consistent

Moisture	Fat %	Starch and Glucose %	Protein%
8.5	8	66	10

Table- 4- Elements in Oat Flour consistent

Phosphore	Magnesium	Potassium	Sodium	Calcium
405 mg/100g	17 mg/100g	268 mg/100g	6 mg/100g	54 mg/100g

Table – 5 – The weight percentage of the additives

Sodium Carbonate	Oat flour	Glycerin
0.5	0.25	0.25

Table – 6 - Properties of the sand mold

Strength of dry compression (MPa)	Strength to moist compression (MPa)	Moist hardness No. B. scale	Permeability No.	% of Addition	Additives
1.7	0.035	65	70	---	None
0.425	0.045	73	55	0.5	Na_2CO_3
0.325	0.032	56	80	0.25	Oat flour
0.43	0.04	72	51	0.25	Glyceral

Table – 7 – Chemical composition for Carbon Steel CK45

Element Wt%	C	Si	Mn	P	S	Cr	Mo	Ni
Standard Value	0.4-0.5	0.4	0.5-0.8	0.035	0.035	0.4	0.1	0.04
Actual Value	0.4	-	0.573	-	-	0.051	0.018	0.077

Table – 8 – Tensile test results

Mech. Properties of steel CK45 / cast Type of Sand Additive	Yield strength MPa	Ultimate Strength MPa	Elongation %	Yonug Modulus GPa
Sodium Carbonate	297.27	743.18	9.58	3.100
Oat flour	258.57	790.6	12.03	2.154
Glycerin	331.788	683.09	7.5	4.43

Table – 9 – Impact test results

	Oat flour	Sodium Carbonate	Glycerin
Impact Stress N/mm^2	169.13	209.75	171.1

Table –10 – Hardness test results

	As received	Oat flour	Sodium Carbonate	Glycerin
Hardness Kg/mm^2	162.4	168.8	172	153

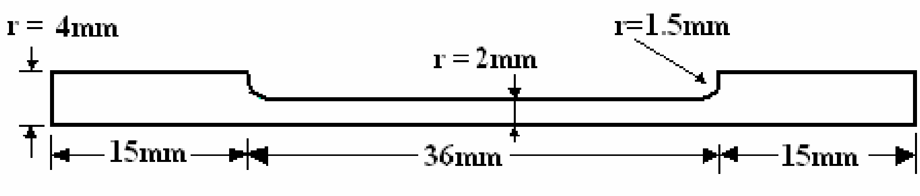


Fig.(1) Dimensions of tensile specimen

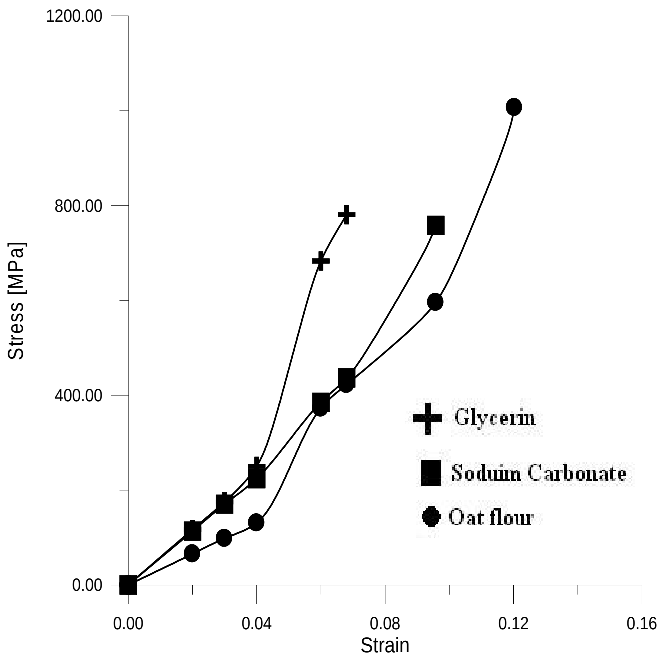


Fig.(2) Stress- Strain curves for the steel CK45 cast in the three cases (Sodium Carbonate, Oat flour and Glycerin)

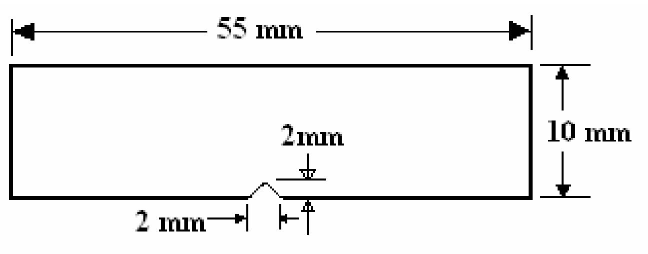
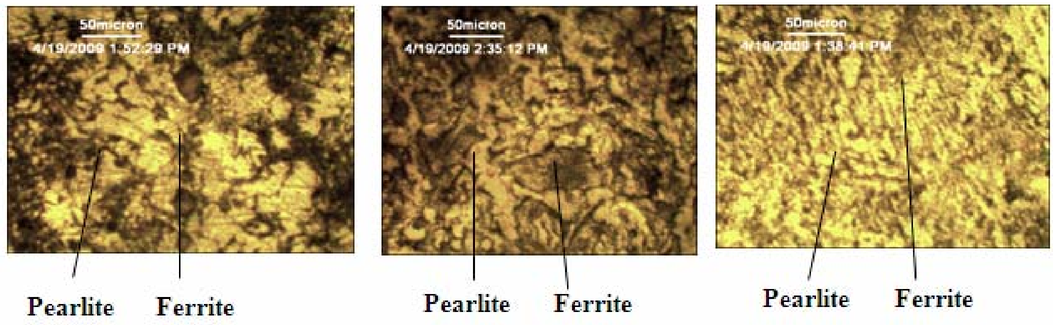


Fig.(3) Impact test specimen



-a- -b- -c-

Fig.(4) microscopic structure of the cast produced (a) mould sand with Glycerin (b) mould sand with Sodium Carbonate (c) mould sand with Oat flour

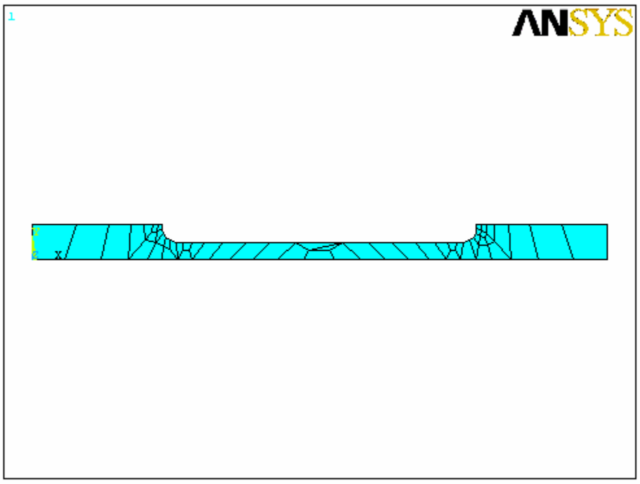
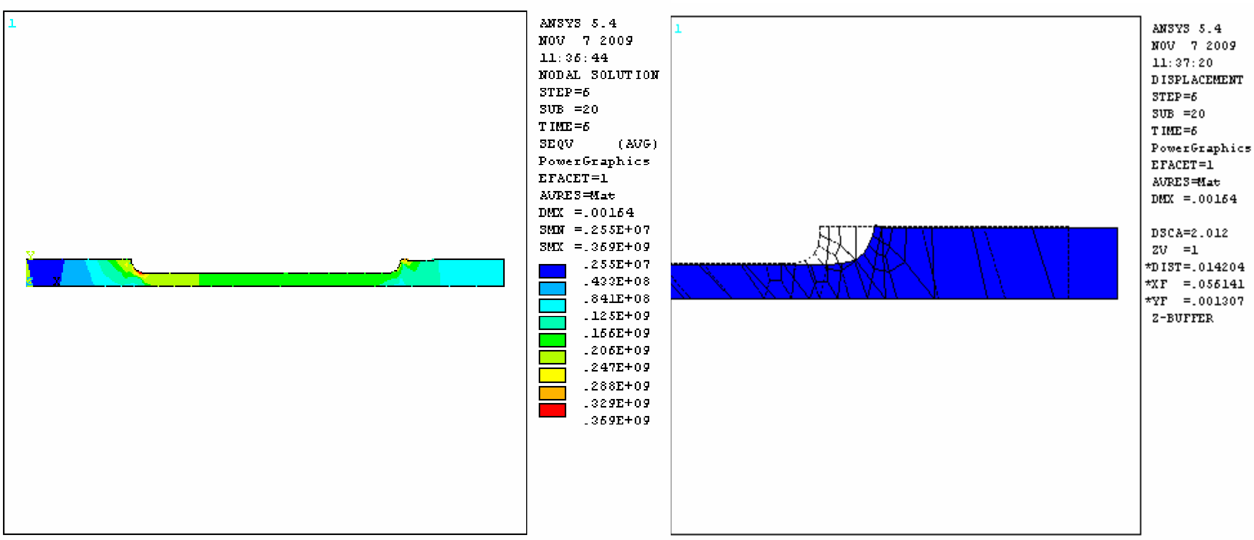
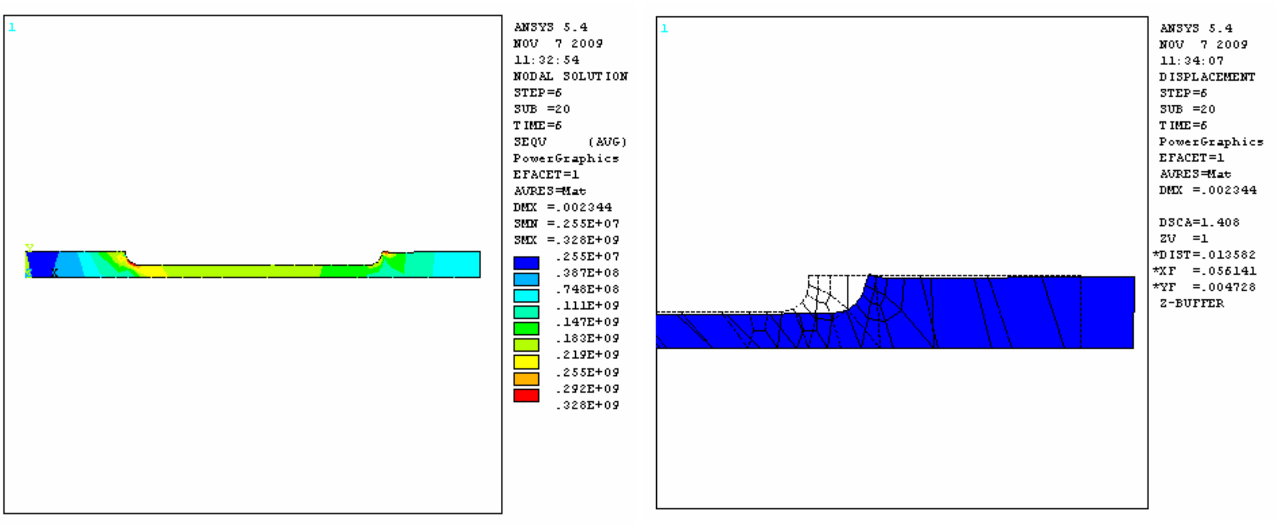


Fig.(5) Model of the specimen in ANSYS



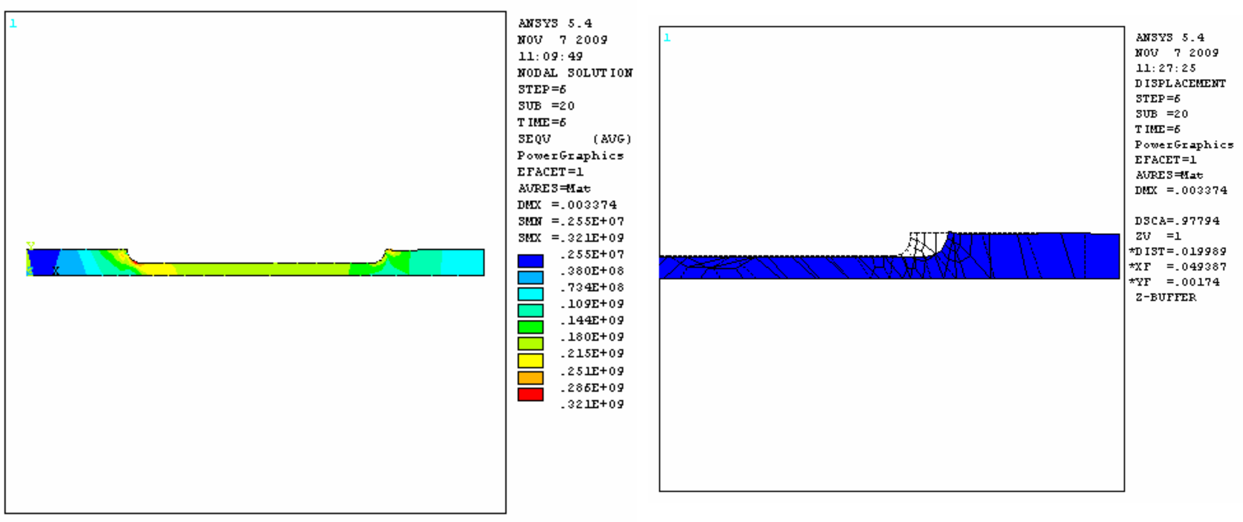
(a) Stresses distribution (b) deformed shaped

Fig.(6) Stresses distribution and the deformed shape in the specimen when the glycerin additive is used to the mould sand



(a) Stresses distribution (b) deformed shaped

Fig.(7) Stresses distribution and the deformed shape in the specimen when the sodium carbonate additive is used to the mould sand



(a) Stresses distribution (b) deformed shaped

Fig.(8) Stresses distribution and the deformed shape in the specimen when the oat flour additive is used to the mould sand.