

**Plasticity investigation of Medium Carbon Steel ( AISI CK<sub>45</sub> )  
treated by Quenching media .**

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**Abstract:**

This paper goals to investigate the plasticity of Medium Carbon Steel (AISI CK<sub>45</sub>) treated by three of Quenching ( Salty . Acid and Base ) media , the sample was selected with length (100 mm) and (10 mm) diameter , has been prepared in the form of a shaft , (24) samples were immersed in different media for (100) hours, the conclusion that the quenching process of ( AISI CK<sub>45</sub> ) at salty (NaCl) media at a concentration of (5%) will give a high plasticity .

**المخلص :**

يهدف البحث الحالي الى دراسة تأثير ثلاثة اوساط تقسية ( ملحية ، قاعدية ، حامضية ) على لدونة الفولاذ المتوسط الكربون نوع ( فولاذ سي كي 45 ) والبنية المجهرية له من خلال استخدام معادلات النسبة المئوية للنقص في مساحة المقطع العرضي والتغير في الطول لعينة شد اعدت لاغراض البحث بواقع 12 عينة لاختبار الشد و12 عينة لفحص البنية المجهرية ، وكانت استنتاجات الدراسة الحالية اثبتت ان المحلول الملحي هو المحلول الذي يعطي لدونة اكبر .

**Keywords: Plasticity, Quenching, salty, acid, and Base medias.**

**1- Introduction**

Plain carbon steels are widely used for many industrial applications and manufacturing on account of their low cost and easy fabrication [1] . Plain carbon steel is the one in which the only alloying element is carbon. Carbon being a powerful alloying agent can give a variety of strength and hardness by varying its composition in the steel. It is in this regard that carbon steel can be classified as low, medium and high carbon steel [2] . Plasticity is defined as the property of material to be deformed repeatedly without rupture

by the action of a force, and remain deformed after the force is removed [3] . Plasticity is an important property and widely used in several mechanical processes like forming, shaping, extruding and many other hot and cold working processes. In general, plasticity increases with increasing temperature and is a favorable property of material for secondary forming processes. Due to this properties various metal can be transformed into different products of required shape and size.[4] . Heat treatment is the heating and cooling of metals to change their physical and mechanical properties, without letting it change its Heat Treatment shape. Heat treatment could be said to be a method for strengthening materials but could also be used to alter some mechanical properties such as improving formability, machining, etc.[5] . The cooling rate of quenching media depends on some things. The size, composition, and initial temperature of the part and final properties are the deciding factors in selecting the quenching medium. A quenching medium must cool the metal at a rate rapid enough to produce the desired results.[6] . Mass affects quenching in that as the mass increases, the time required for complete cooling also increases. Even though parts are the same size, those containing holes or recesses cool more rapidly than solid objects. The composition of the metal determines the maximum cooling rate possible without the danger of cracking or warping. This critical cooling rate, in turn, influences the choice of the quenching medium.[7] .

Therefore, some researchers interested with the field of Quenching Media and its effects on the different sides of medium carbon steel to obtain the optimized opinions to improve some properties in it .such as Lee and Kim (2001) [8] studied the effect of some heat treatments on mechanical properties of medium carbon steel AISI 1050 alloy steel , Meriam L.T . ( 2005 ) [9] presents study to evaluate the microstructure of medium carbon steel after quenching process with salty water . Li, S.; Bourke, *et al* .(2005 ) [10] studied plastic deformation zone and working load in equal channel angular extrusion by using Finite element analysis .

In this study , which described the first study in this field . The plasticity of Medium Carbon Steel (AISI CK<sub>45</sub>) was investigated when treated by three of Quenching (Salty . Acid and Base ) medias to show the effect of these media upon the plasticity property and microstructure , to choose the optimum media which will be used to improve them .

The plasticity property of the materials depend upon the reduction in cross-sectional area and the elongation of the tested specimen , So, The reduction in cross – sectional area ( $\psi$ ) experienced by equation form,[11]

$$\varphi = \frac{A_o - A_f}{A_o} * 100 \dots\dots\dots ( 1 )$$

When :

$(\psi)$  = reduction in cross – sectional area ( mm <sup>2</sup> )

A<sub>o</sub> : Original cross – sectional area ( mm <sup>2</sup> )

A<sub>f</sub> : Final cross – sectional area ( mm <sup>2</sup> )

The elongation of the tested specimen can be calculated by the equation :

$$\delta = \frac{L_f - L_o}{L_o} * 100 \dots\dots\dots ( 2 )$$

When :

$\delta$  = the elongation in the length of the tested specimen ( mm )

L<sub>o</sub> : Original length ( mm )

L<sub>f</sub> : Final length ( mm )

So , the plasticity can be determined by the equation : [12]

$$P = \frac{(\delta_o - \delta_f) + (\varphi_o - \varphi_f)}{\delta_o + \varphi_o} \dots\dots\dots ( 3 )$$

## 2 – Methodology

### 2 – 1: Material:

Medium Carbon Steel , defined by (DIN CK<sub>45</sub>) according to Germany Standard , (AISI CK<sub>45</sub>) according to American Society Standard [11] , was used as engineering material in this paper , Modulus of Elasticity ( 200\*10<sup>3</sup> N/mm<sup>2</sup> ) , Tensile Strength Ultimate (585) MPa and the Tensile Strength Yield (450) MPa , table ( 1 ) shows the chemical analysis for medium carbon steel (AISI CK<sub>45</sub>) which was used in the current paper and investigated in laboratories of the college of engineering.

**Table ( 1 ) : Chemical analysis for medium carbon steel (AISI CK<sub>45</sub>)**

Element	Mo	P	S	Si	Mn	C
Standard	-	0.035	0.03	0.4	0.5-0.8	0.42-0.5
Tested	0.027	0.005	0.005	0.277	0.61	0.458

Element	Fe	Ni	Cu	V	W	Cr
Standard	Rem	-	-	-	-	-
Tested	98.1	0.157	0.23	0	0.14	0.15

## 2 – 2: Samples preparing:

The sample was selected with length (100 mm) and (10 mm) diameter [13] , has been prepared in the form of a shaft of medium carbon steel (AISI CK<sub>45</sub>), by using a frequently chainsaw, have been carried out treatment rims and clean appendages sticking of shearing process using handle files , with a good cleaning of the surface of the sample surface from the oxidation using machine grinding up (25 microns) to ensure uniformity accuracy of dimensions for all samples. The (24) samples has been tested according to the planning operation, then encoded samples using effective chisels at the tip of each sample for the purpose of controlling the sort after testing. Fig. (1) shows the used dimensions of the sample in the current research .

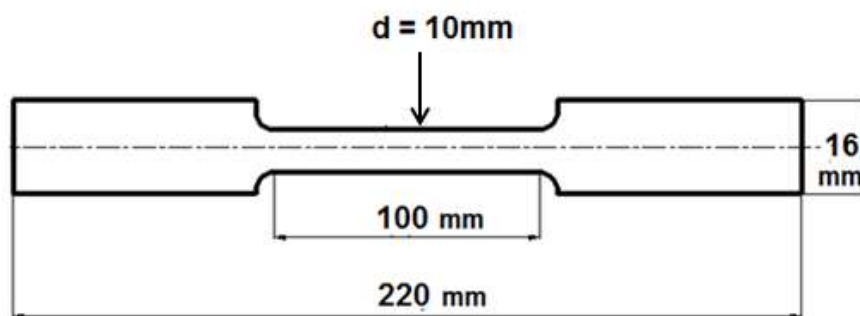


Fig. (1) The dimensions of the sample used in the current study.

## 2 – 3: Testing Procedures:

**Quenching operation:** (18) samples of medium carbon steels (AISI CK<sub>45</sub>) were carried out to (800) ° C and stay at this temperature for (30) minutes for the purpose of homogenization, then cooling with water, the samples were immersed in different solutions for (100) hours, (6) samples for each of following solutions: [13]

- Salty NaCl solution at a concentration of ( 5 % )
- Base solution (NaOH) concentration ( 20% )
- Acid solution (HCl) concentration ( 20% )

**Tension** : (12) samples of medium carbon steels (Article of current search) [3 samples before quenching operation , 9 samples after quenching operation ] were used according to applied measurements accredited laboratory for the purpose of testing them prior to determine the value of the reduction in the cross- sectional area and the elongation using a device (Universal Testing Machine) Capacity (5 tons) .

**Microstructure**: (12) samples of engineering material [3 samples before quenching operation , 9 samples after quenching operation] used to know the microstructure, KELER reagent type of appearance solution was used to appear the samples , then wash the samples by water and alcohol and dried so that the sample will be ready to microstructure testing which was investigated by Olympus Bx 60M instrument with (10 X ) number of zooming force , So , the pictures transferred to the computer to save by video digital camera .

### **3– Results and Discussion:**

After the completion of the quenching process, tensile strength and the microstructure examined of the samples which carried in quenching process with the use of the same as the previous tests devices , so a package (office 2010) has been used to treat the results and draw relations in the light of the theoretical and practical results of tests, it has been found values of each of the percentage reduction in cross-sectional area and the elongation after using equations (1) , (2) and (3) , applied to practical results getting taking into account the use of the actual sample.

#### **3 – 1: Reduction ratio in cross-sectional area & Elongation ratio:**

Table (2) shows the results obtained from experimental work ,contains reduction in cross-sectional area & elongation for each types of samples .

Table (2)

Reduction in cross-sectional area & elongation for each types of tested samples

Type	Symbol	No. of samples	( $\psi$ ) Reduction in cross- sectional area (mm <sup>2</sup> ) %	( $\delta$ ) Elongation (mm) %	( P ) Plasticity %
Without Quenching	X 1	3	4.40	5.34	2.67
Salty (NaCl) solution at a concentration of (5%)	X 2	3	2.08	2.27	18.46
Base solution (NaOH) concentration ( 20% )	X 3	3	4.00	4.77	3.33
Acid solution (HCl) concentration ( 20% )	X 4	3	4.54	5.57	1.25

Illustrated by the table (2) that Reduction in cross-sectional area was increased in X4 comparing with the original (X1) in (0.14 %) while the types (X2) and (X3) was decreased in ( 2.32 %) and (0.40% ) respectively .

So , the elongation was increased in (X4) in (0.32 %) comparing with the original (X1) , at the same time , the types (X2) and (X3) was decreased in ( 3.07 % ) and (0.57 %) respectively .In other wise , the plasticity of the sample (X2) was increased in (15.79 %) comparing with the original (X1) while the sample (X3) was also increased but in little amount percentage (0.66 %) , but the sample (X4) was in decreasing by (1.42 %) .

These results can be illustrated by the following diagram showing the percentage of reduction ratio of cross – sectional area , Elongation ratio and plasticity ratio in three quenching media comparing with the original tested sample without quenching .

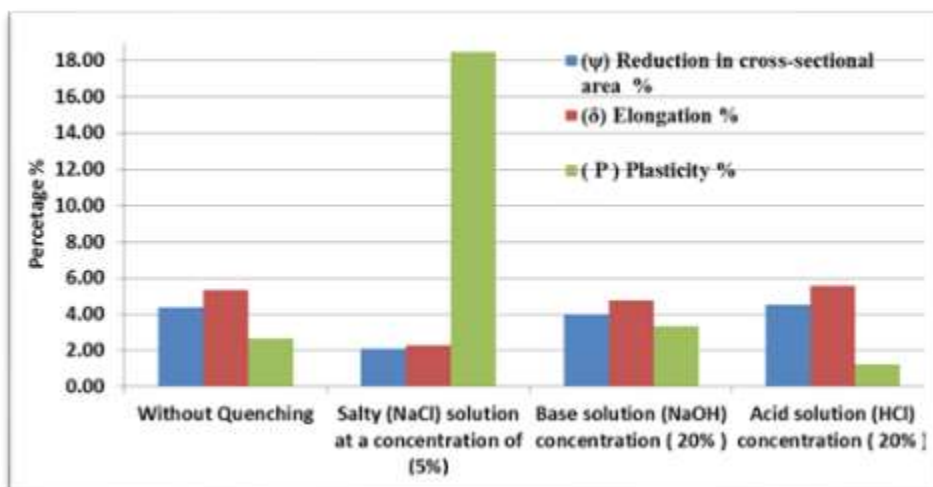


Fig. (2) The percentage ratio of reduction of area , Elongation and plasticity in three quenching media comparing with the original test without quenching

The sample (X1) shows that its mechanical properties were normal plasticity and large elasticity zone as noted in the figure .but the quenching media made it at high plasticity , specially the sample ( X2 ) with salty (NaCl) solution so the reason of this phenomenon returns to the ductility of the medium carbon steel ( AISI CK<sub>45</sub> ) which directly proportional to increased hardness because of quenching process .

### 3 – 2: The relationship between the quenching media and the microstructure:

In fig.(3) the structure of the samples is shown, (X1) without quenching process shows two colors , the first is white color represents the ferrite component distributed on the whole of structure , and the second is black color which represents the perlite component.

When a heat treatment of the sample (X2) by quenching process , note that its microstructure is Martensite nature with a few percentage large grains of Austenite , as the tempering process led to the increased prevalence rate with increasing the movement speed of carbon atoms and melting Austenite and the emergence of a new phase in the microstructure consists of Trostite

which is a fine mixture of Ferrite and carbides that formed Martensite when heated at a temperature of (300) ° C, so microstructure is called the tempered Martensite which led to increasing of impact strength , toughness , the percentage of the elongation , decreasing of the internal stresses and tensile strength .

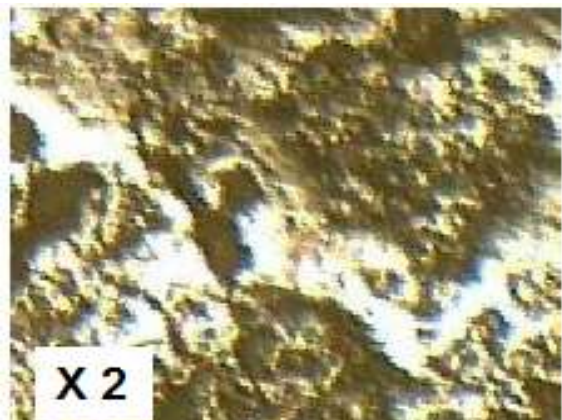
The chlorine ions (Cl-) presented in the (NaCl) media, which is characterized by its good conductivity of the electrical conductivity, causes corrosion and is a pure erosion due to the presence of chloride ions that cause this type of corrosion as shown in Fig(3) of (X2) sample .

The sample (X3), which is more martensite than the sample (X2) ,and little Austenite with less hardness. The sample (X4) shows that its microstructure is Martensite. because of the penetration of hydrogen in the microstructure where hydrogen gas continues in the inner surface as a result of the reduction reactions to the process of corrosion. The atomic of hydrogen performs to the microstructure of the small size of the hydrogen atoms.

Therefore , it can noted that the quenching process of medium carbon steel ( AISI CK<sub>45</sub> ) at salty (NaCl) media at a concentration of (5%) will give a high plasticity due to the collection of Austenite and make the Ferrite component in less limited areas of microstructure.

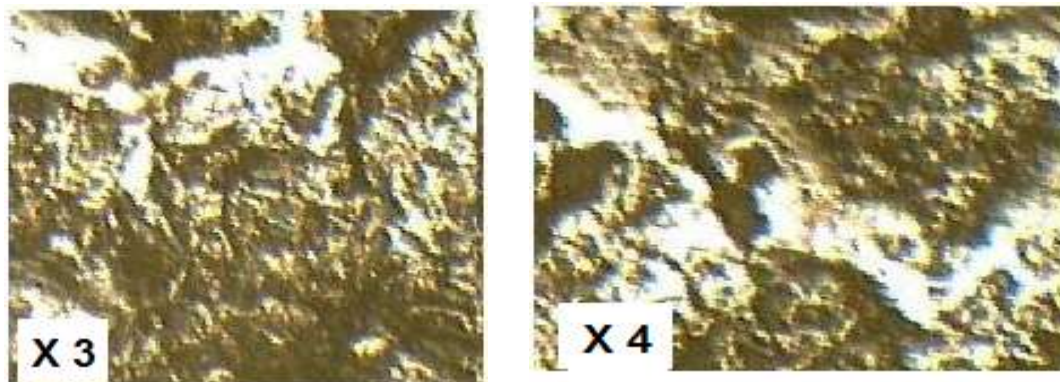


Without Quenching



Salty (NaCl) solution at a concentration of (5%)





Base solution (NaOH) concentration ( 20% )

Acid solution (HCl) concentration ( 20% )

**Fig.(3) : Microstructure of the samples**

### **Conclusion:**

- 1- Reduction in cross-sectional area was increased in Acid solution (HCl) concentration ( 20% ) so was the elongation.
- 2- The plasticity of the Salty (NaCl) solution at a concentration of (5%) was increased .
- 3- The quenching process of medium carbon steel ( AISI CK<sub>45</sub> ) at Salty (NaCl) media at a concentration of (5%) will give a high plasticity .

### **Recommendations:**

- 1- Using current research data to conduct similar studies to determine other mechanical properties such as creep and fatigue .
- 2- Develop the recent study to investigate the elasticity and plasticity for other steel alloys .

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