The Effect of Tempering Heat Treatment on Some Mechanical Properties of Medium Carbon Steel (AISI 1045) Formed By Cold Forging Process

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Abstract

Current paper discuses the effect of tempering as one of heat treatment processes on some mechanical properties of medium carbon steel (AISI 1045) such as hardness, ultimate tensile strength, yield strength and strain rate , formed by forging hammers operation as one of cold forging process .Three values of loads (20, 30 and 40) kg were used in forging operation .The results show that the tempering and cold hammering forging increase the ability of medium carbon steel (AISI 1045) to resist the internal stresses produced by hardening process , so the ultimate tensile strength and yield strength of tempered MCS 1045 decrease with an increase in tempering temperature. Otherwise, the strain rate and hardness of tempered MCS 1045 increases with an increasing of tempering temperature.

Keywords: heat treatment, mechanical properties, tempering, steel 45, forging.

1 : Introduction :

Medium Carbon Steel (AISI 1045) is characterized by good weldability, good machinability, and high strength and impact properties in either the normalized or hot rolled or forged condition [1]. This grade of steel is used for axles, bolts, forged connecting rods, crankshafts, torsion bars, light gears, guide rods etc. [2] . Medium Carbon Steel is forged from around (1205ºC) down to a temperature in the range (900-925ºC.) to improve its mechanical properties. The actual forging and finishing temperatures depended on a number of factors, including overall reduction during forging and complexity of part being forged. Experience alone will determine near exact values for these two parameters [3]. Tempering is a heat treatment technique applied to ferrous alloys, such as steel or cast iron, to achieve greater toughness by decreasing the hardness of the alloy [4]. Cold forging is the process to form the metal according to required shapes by using a hummers with variable weights [5].

Either impact or gradual pressure is used in forging. The distinction derives more from the type of equipment used than differences in process technology. A forging machine that applies an impact load is called a forging hammer, while one that applies gradual pressure is called a forging press [6].

In open-die forging as shown in fig.(1) , the work is compressed between two flat (or almost flat) dies, thus allowing the metal to flow without constraint in a lateral direction relative to the die surfaces. In impression-die forging, the die surfaces contain a shape or impression that is imparted to the work during compression, thus constraining metal flow to a significant degree [7].

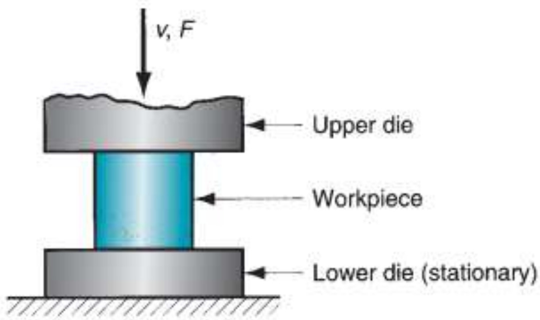

Figure (1) Open-Die Forging

Forging hammers operates by applying an impact loading against the work. The term drop hammer is often used for these machines, owing to the means of delivering impact energy [8] .

Opiela, *et al* (2013) [9] studied "The influence of hot-working conditions on the structure and mechanical properties of forged products of microalloyed steel ", while the researchers Hiroyuki Saiki, *et al* (2014) [10],were investigate "Effect of the surface structure on the resistance to plastic deformation of a hot forging tool " , and . Efreet (2014) [11] studied " the effect of falling loads on the mechanical properties , noted that there are some changes in the mechanical properties due to falling load on specimen of medium carbon steel plate. Tony (2016) [12] investigated the influence of forging processes on the reduction ratio in length of bars treated by normalizing heat treatment. AA 2219 alloys of 120 mm round bar are forged into various round bars (25, 50, 75mm) and subjected to T6 temper heat treatment to identify the peak ageing time for various round bars. The electrical conductivity of the round bars is also measured and correlated with the mechanical properties were experimented by Prabhu (2017) [13] . So, Quanshe Sun, *et al* (2017) [14] studied the effect rang of Annealing in various temperature on the mechanical properties of high toughness of titanium alloy under the effect of rolling process.

The current paper has focused on the investigation the (Hardness, ultimate tensile strength, yield strength, and strain rate) properties of the medium carbon steel (AISI 1045) formed by forging hammers operate as one of cold forging process, and treated by tempering as one of the heat treatment, since this type of metal is used in many applications, including devices and mechanisms of transfer of power and large hammers and parts of vehicles and others.

2 : Experimental Procedures:

2 : 1 : Selection of Engineering material :

Medium Carbon Steel , defined by (DIN CK_{45}) according to Germany Standard , (AISI 1045) according to American Society Standard [15], has been used as engineering material in this paper, modulus of elasticity ($200*10^3$ N/mm^2) , ultimate tensile strength 585 MPa and the yield strength 450 MPa. Table (1) shows the chemical analysis for medium carbon steel (AISI 1045) 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 1045)[15]

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 Preparation of Specimens :

The specimen is selected with long 210 mm [16], has been prepared in the form of a strips with thickness (0.5 mm), 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 specimen surface from the oxidation using machine grinding up (25 microns) to ensure uniformity accuracy of dimensions for all samples. It has been initialized (30) tested specimen, and encoded specimen using effective chisels at the tip of each specimen for the purpose of controlling the sort after testing.Fig. (2) shows the used dimensions of the specimen in the current paper .

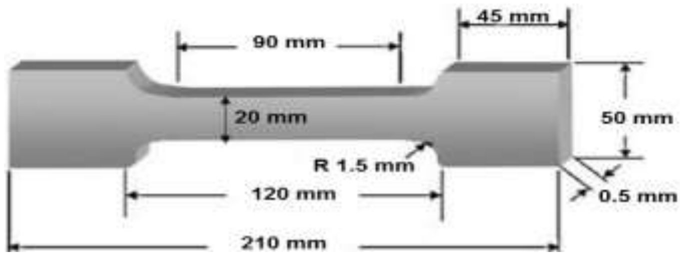

Figure (2) The shape and dimensions of the specimen used in the current paper[16]

2 : 3 Testing Procedures :

2 : 3 : 1 Tensile Test :

Three specimens were used of medium carbon steel according to apply measurements accredited laboratory for the purpose of testing them prior to the forging process to determine the value of the loads vs yield and ultimate strength as well as strain rate by using a device (Universal Testing Machine) Capacity (5 tons) .

2 : 3 : 2 Hardness Test :

Rockwell hardness tester SHR-150E has been used to measure the hardness of Three specimens of the engineering material before the forging process.

2 : 4 Heat treatment procedures:

2 : 4 : 1 Hardening process : Twenty seven specimens were heated to (850^{o}C) in the furnace, in order to change the microstructure into austenite phase, for a period of two hours [17] to make sure that hardening process was completed, then , dropped the specimens in a container of oil for rapid cooling to room temperature .

2 : 4 : 2 Tempering Process : The maximum hardness of a steel grade, which is obtained by hardening, gives the material a low toughness. Tempering reduces the hardness of the material and increases the toughness. Through tempering ,can adapt materials properties (hardness/toughness ratio) to a specified application . Low temperature (160-650°C): used for case hardening components and cold working tool steels. For the current research , the (200, 400 and 600) ^{o}C temperature have chosen experimentally and held for 120 minutes as tempering time.

2 : 4 : 3 Forging hammers operate : Germany pneumatic forging hammer (air hammer), working style of (40 kg), Weight of stroke (200 mm) , engine power (4KW), was used to the purposes of current paper under (20 , 30 , 40) kg loads .

2 : 4 : 4 Experimental Tests : the heat treated specimens were taken for the hardness and tensile test to evaluate the ultimate tensile strength, yield strength, strain rate and hardness properties.

3 : Results and Discussion :

According to testing procedures and heat treatment operations, the mechanical properties of medium carbon steel (AISI 1045) by hammering forging, were explained in the following items:

3 : 1 The relationship between the tempering temperature and ultimate strength :

Fig. (3) in which ultimate tensile strength is plotted vs tempering temperature shows that ultimate tensile strength of tempered specimen decreases with an increase in tempering temperature , at different values of applied load .

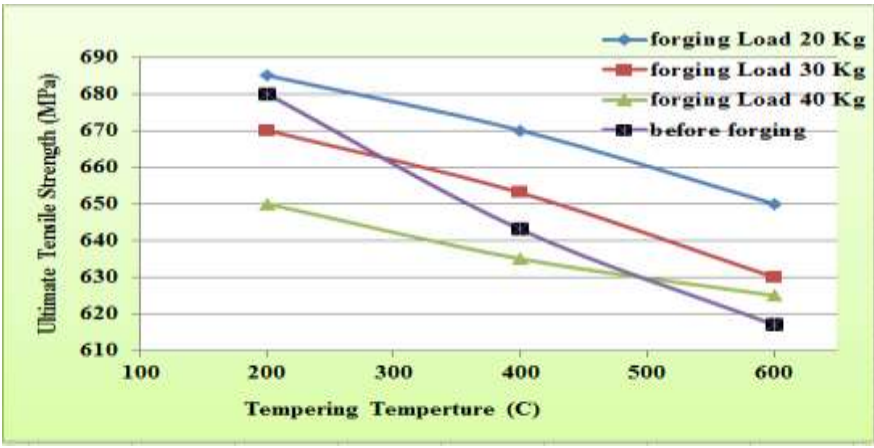

Figure (3) Tempering temperature Vs Ultimate tensile strength

3 : 2 The relationship between the tempering temperature and Yield strength :

Fig. (4) in which yield strength is plotted vs tempering temperature shows that yield strength of tempered specimen decreases with an increase in tempering temperature , at different values of applied load .

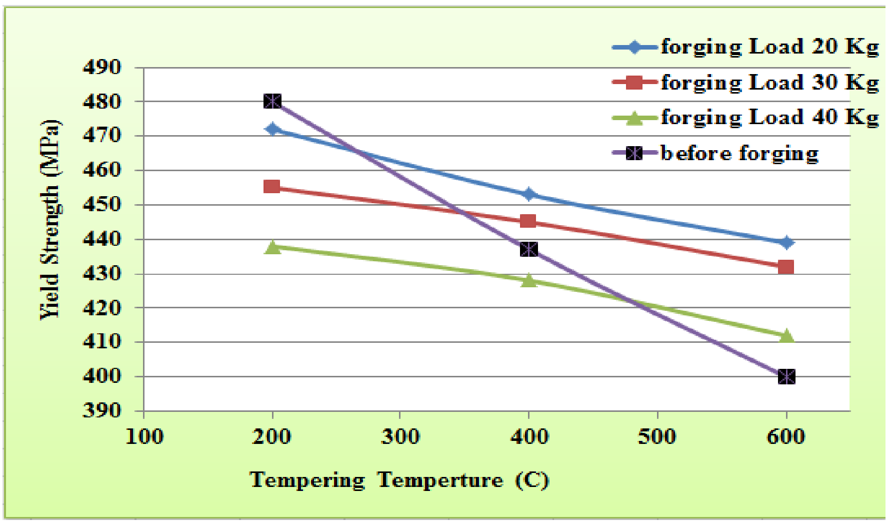

Figure (4) Tempering temperature Vs Yield Strength

3 : 3 The relationship between the tempering temperature and Strain Rate (%):

Fig. (5) in which strain rate is plotted vs tempering temperature shows that strain rate of tempered specimen increases with an increasing of tempering temperature , at different values of applied load .

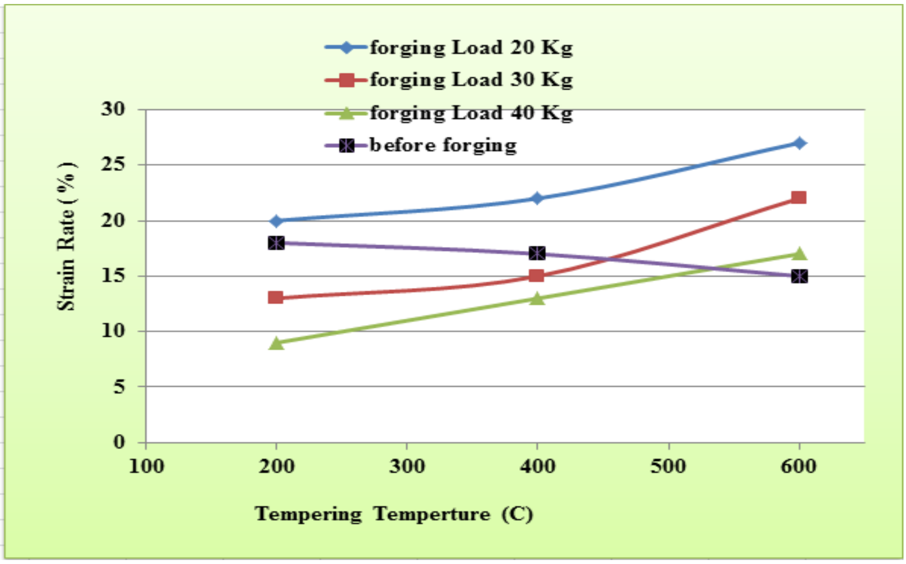

Figure (5) Tempering temperature Vs Strain Rate (%)

3: 4 The relationship between the tempering temperature and Hardness:

Fig. (6) In which hardness is plotted vs tempering temperature shows that hardness of tempered specimen increases with an increasing of tempering temperature , at different values of applied load , while it decreases before forging .

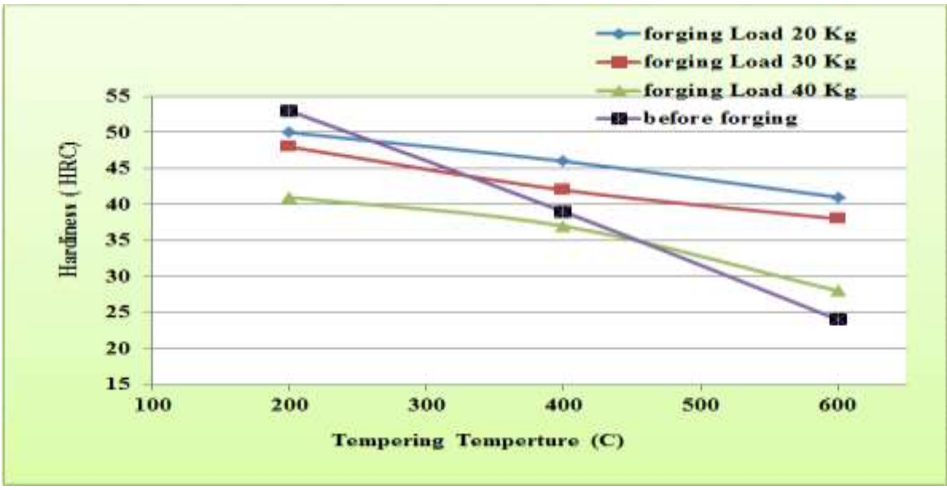

Figure (6) Tempering temperature Vs Hardness

When the tempering heat treatment occurs at (200°C) which is used to remove the internal stresses produced as a result of the process of deformation due to distortion of the microstructure , the martensite begins to excretion atoms of excess carbon during this process, the crystallization approximately near by cubic shape .

At the tempering temperature of 200-400°C, the separation of the carbon atoms from the martensite continues to form cementite (Fe_3C), which is a very fine particle called (secondary trostite), which is martensite in addition to very small particles of cementite (Fe_3C), and its hardness is less than the martensite but its toughness is greater.

The tempering temperature at (450-650°C) will produce an aggregation small granules of cementite, consisting particles larger in size and smaller in amount .This structure is called sorbite or tempered sorbite, whose hardness and tensile strength is less than secondary trostite, with increasing of toughness and ductility of the material

The strength of the steel is reduced to impact, when it is tempered at a temperature of (250-400°C). This phenomenon is referred to the “Brittleness of tempering “, which produced from the degrade the remaining austenite or deposition of carbide, which should be avoided the tempering process at this temperature[9].

4: Conclusions:

1- The tempering and cold hammering forging increases the ability of medium carbon steel (AISI 1045) to resist the internal stresses produced by hardening processes .
2- Ultimate tensile strength and yield strength of tempered MCS 1045 decreases with an increase in tempering temperature .
3- strain rate of tempered MCS 1045 increases with an increasing of tempering temperature.
4- Hardness of tempered MCS 1045 decreases with an increasing of tempering temperature

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الخلاصة:

البحث الحالي يناقش تأثير درجة حرارة المراجعة كواحدة من المعاملات الحرارية للصلب المتوسط الكاربون (فولاذ 45) المشكل بطريقة الحدادة بالقوالب المفتوحة (المطارق) ، اختيرت ثلاث درجات حرارية للمراجعة (200 ، 400 و 600) درجة حرارية ، مع اختيار ثلاثة احمال لمطرقة ميكانيكية (20 ، 30 و 40) كغم ، تم تحضير عينات الشد ومراجعتها وطرقها ومن ثم تمت عمليات حساب اقصى اجهاد شد وحمل الخضوع وكمية الانفعال ومقدار الصلادة ، توصل البحث الى ان عملية التشكيل بالحدادة تكسب المادة الهندسية متانة اكبر واجهاد شد اقصى بأستخدام عملية المراجعة وخاصة في درجات الحرارة المنخفضة .