Effect of Heat Treatment on Mechanical Properties of D_2 Tool Steel

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Abstract

Cold-work tool steels contain high-carbon, high-chromium or group D steels, AISI $D_2$is recommended for tools requiring very high wear resistance, combined with moderate toughness (shock – resistance), due to some of mechanical properties are not covered and needed to be improved by changing microstructure.

This work was to study the effect of heat treatment on microstructure, hardness, impact and tensile test in D_2 tool steel. Optical microscopy (Oly Maps Microscope) was used to examine the microstructural basis, the mechanical properties were observed from the investigation that both hardness and tensile test values were significantly increased with increasing of tempering temperature by using oil or air quenching media. At the same time the impact value was constant. The mechanical properties has been improved due to the D_2 tool steel was austenitezed at 1050°C for half hour time and tempered for different temperature and quenched.

Key words: Heat treatment of D_2 tool steel. Mechanical properties of D_2 tool steel. Types and Classification of tool steel.

الملخص

الحديد المشكل على البارد يحتوي على نسبة عالية من الكربون والكروميوم وتم تصنيفهم كمجموعة (D)، ويستخدم AISI D_2 للعدد التي تتطلب مقاومة تآكل عالية جدًا بالإضافة إلى مقاومة صدم معتدلة، وبسبب بعض الخصائص الميكانيكية الغير مدروسة وتحتاج إلى تحسين عن طريق تغيير البنية المجهرية. في هذه البحث تمت دراسة تأثير المعالجة الحرارية على البنية المجهرية والصلادة واختبار الشد والصدم لمعدن (D_2).تم استخدام المجهر الإلكتروني (Oly Maps Microscope) لتصوير البنية المجهرية للعينات ولوحظ أن قيمة كل من الصلادة والشد تزداد بزيادة درجة حرارة المعالجة الحرارية حسب أوساط التبريد المختلفة بخلاف قيمة اختبار الصدم ثابتة بالرغم من تغير درجات الحرارة وأوساط التبريد. إذ تبين أن نوع(D_2) عند درجة حرارة الأستنة 1050℃ لمدة 30 دقيقة باختلاف أوساط التبريد سواء زيت أو هواء أدى إلى تحسين الخواص الميكانيكية.

1. Introduction

A variety of carbon and alloy steels that commonly used to make tools were referred to as tool steel. Tool steels differ greatly from steel used in consumer goods and were produced on a much smaller scale. Strict quality control procedures ensure that a particular grade of tool steel will perform a specific task, such as machining or perforating. Cold-work tool steels contain high-carbon, high-chromium, also known as group D steels. These steels are referred to as group D steels and include D_2, D_3, D_4, D_5, and D_7 steels. These steels have a carbon content of 1.5 to 2.35% and a chromium content of 12%. Except for type D_3, all other group D steels contain 1% Mo and are air hardened. Although Type D_3 steel is oil-quenched[1], Type D_2 steel is the most commonly used steel among the group D steels as shown Figure 1 [2].

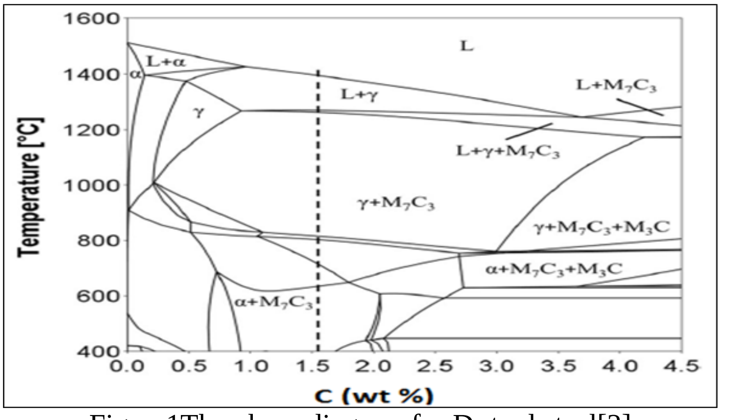


Figure1The phase diagram for D_2 tool steel[2]

Heat-treated tool steel is most commonly used. Many high-carbon tool steels are also more corrosion resistant due to higher element ratios such as vanadium and niobium [3].

D_2 steel is a high-carbon, high-chromium tool steel that hardens in the air. It is highly wear and abrasion resistant. It is heat treatable, with a hardness range of 55-62 HRC, and is Machinable in the annealed state. When properly hardened, D_2 steel exhibits little distortion[4].

On the other hand, the effect of annealing soling time on evolution of microstructure and mechanical properties of D_2 tool steel was investigated, The increase in soaking time during annealing process causes the morphology of carbides transform irregular shape to nearly round shape and distributed uniformly in a pearlite matrix.The increased amount of carbide dissolution during annealing resulted in enhancement ductility and decrement of strength of D_2 tool steel. The study indicates that desirable properties of D_2 tool steel could be obtained by judicious selection of annealing cycle[5].

D_2 steel is very important steel for tools, some of its properties are not covered yet and need to be studied.

This research deals with the study of the effect of heat treatment on some mechanical properties of D_2tool steel, determining the microstructure, measuring the hardness of the metal, tensile test and impact strength test were carried out. Tests were performed before and after the heat treatment processes to obtain results showing the effect of heat treatment on this mineral as shown Figure 2[6].

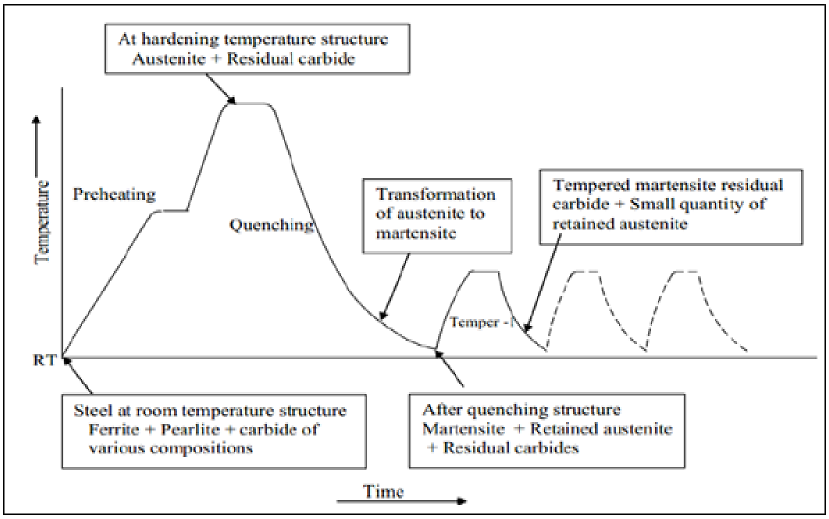


Figure 2 Illustrates the principal points of heat treatment cycle for tool steel in general[3]

Experimental work

1.1 Material

The chemical composition of the type was determined using spark emission spectrometer (model JY132f).

This analysis was carried out in The Research and Development Center in Tajoura, Libya, The chemical analysis result in weight % for D_2tool steel is shown in table 1.

The result indicated that D_2 tool steel was within the limits set of the ASTM-A681 standard[7].

Table 1 Chemical Composition for D_2 Tool Steel

Element	C	Si	Mn	Cr	Mo	Cu	V	Fe
weight%	1.33	0.25	0.32	11.4	0.69	0.14	0.95	Balance

1.2 Samples Preparation

Samples for the following tests were prepared at the center of research and technological as fallowing.

- Impact test.
- Tensile test.
- Microstructure.
- Hardness test.

Charpy V notch impact samples were machined according to ASTM E23 standard[8]. The dimensions of the samples are shown in Figure 3.

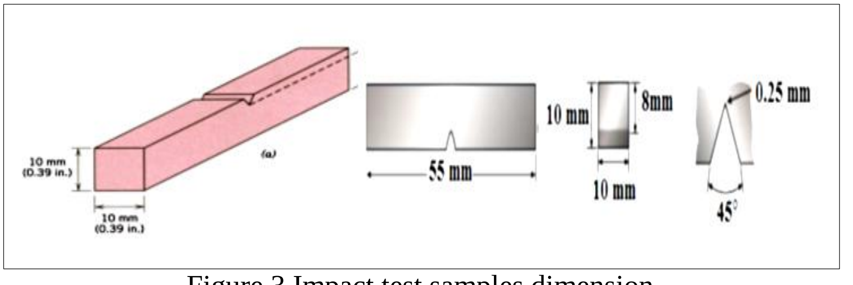


Figure 3 Impact test samples dimension

For tensile testing samples were prepared with dimensions of $20mm \times 210mm$ at The Higher Technical Center for Training and Production, as shown in Figure 4.

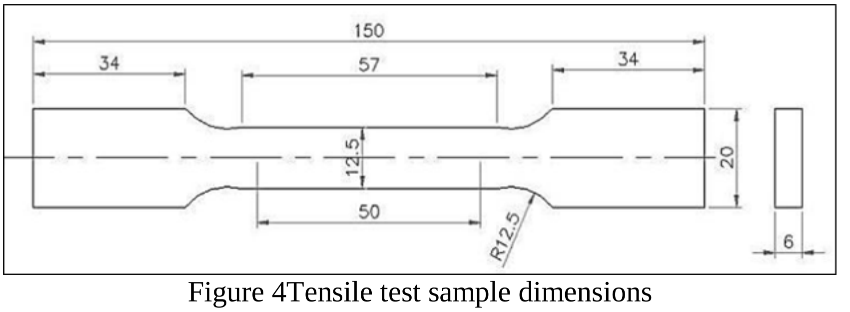


Figure 4Tensile test sample dimensions

For the hardness testing, samples were prepared with dimensions of 20mm × 20mm , as shown in Figure 5 A,B and C.

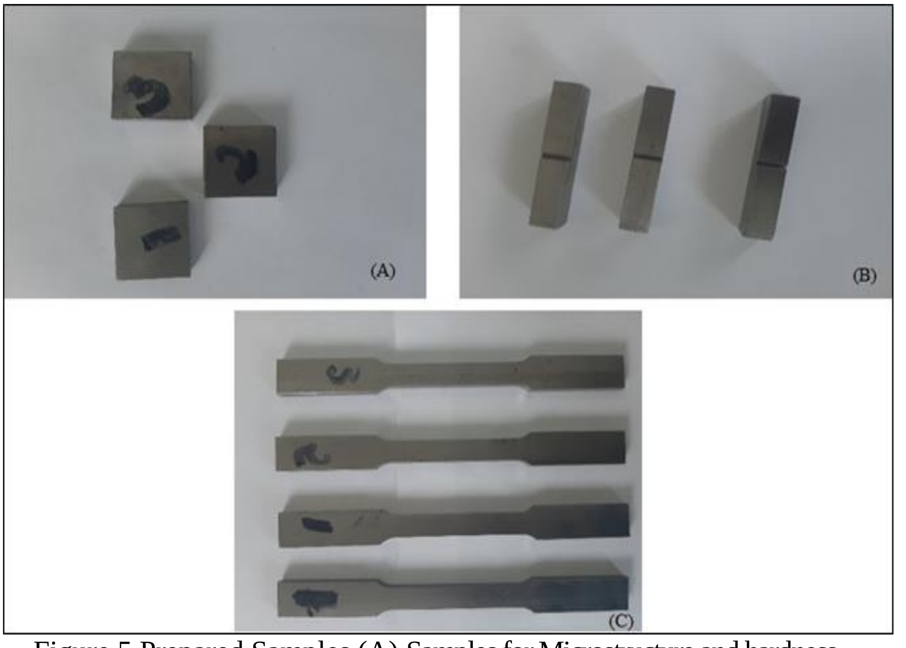


Figure 5 Prepared Samples (A) Samples for Microstructure and hardness test,(B) Sample for impact test and (C) Samples for Tensile test

Sample preparation of metallography examination, metallographic samples were ground by the abrasion of the specimen surface against water lubricated abrasive wheels (silicon carbide papers changing from "120 to 1200 girt emery paper").

After grinding, the polishing process was done by the use of the rotary disk with diamond paste. Polishing should yield a scratch free specimen surface. Then, the etching operation was done with the 2% metal solution (2%nitric acid solution in 98% ethyl alcohol). Microstructural examination was carried out using OLY MPAS Microscope as shown in Figure 6.All practical tests were completed at the Industrial Research Centre.

Figure 6 OLY MAPS Microscope

1.3 Heat treatment

The heat treatment schedule is shown in Table 2 for D_2 tool steel material.

Table 2The heat treatment process[9]

Number Of Sample	1	2	3
Austenitizing temperature (C^0)	1050	1050	1050
Time (min)	30	30	30
Tempering temperature(C^0)	550	200	200
Time(min)	30	30	30
Media quenching	Oil	oil	air

2. Experimental tests

2.1 Hardness test

A Vickers hardness testing machine was used to measure the hardness using 15Kg before and after heat treatment. The final hardness value are the average three readings.

2.2 Charpy V- Notch Impact testing

The impact test was taken before and after heat treatment. Using impact test machine (MFL D-680).

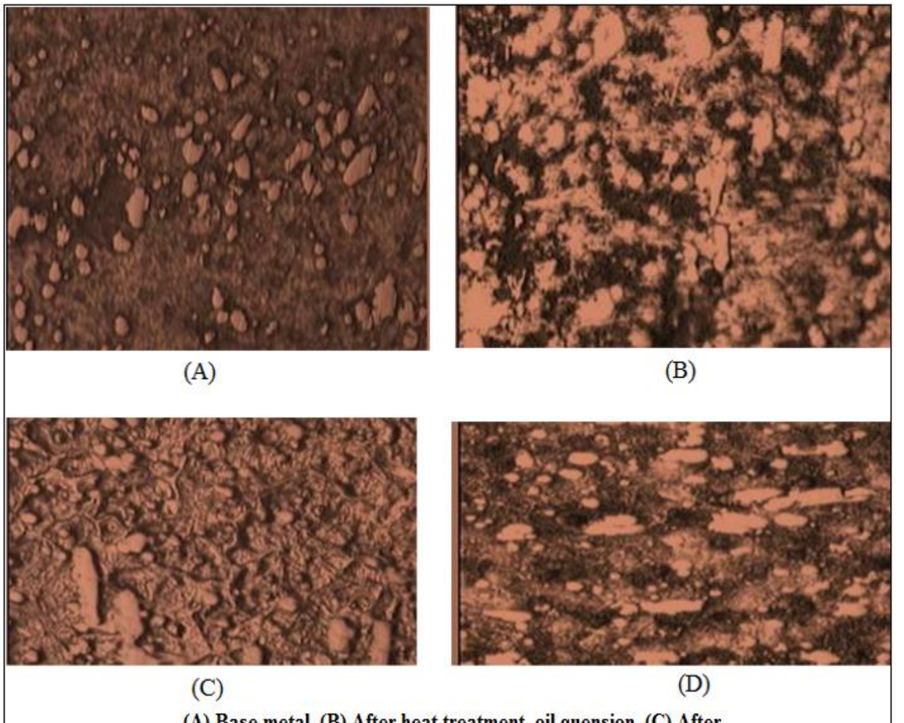
2.3 The tensile test

This test was performed by tensile machine (UH-1000KNI) that gives the values recorded before and after the heat treatment process.

3. Result and Discussion

3.1 Metallographic Examination

Figure 7 shows optical micrographs for all specimens (after and before heat treatment). The micrographs of the base metal shows the presence of primary and secondary carbides with different sizes in the sample with ferritic matrix.While microstructure for specimens after heat treatment shows dissolve carbon and chromium, resulting in formation primary and secondary chromium carbides.



(A) Base metal, (B) After heat treatment, oil quension, (C) After heat treatment, air quenching and (D) After heat treatment, oil

Figure 7 A, B, C and Dof microstructure before and after heat treatment

3.2 Hardness test

The final hardness value are the average three readings.
Referring to the obtained measured hardness, results as shown in table 3 and Figure 8.

Table 3Hardness value measurement for samples base metal and after heat treatment

Sample number	Hardness measurement Hv	Quenching media	Tempering Temperature ℃
Base metal	231	-	-
1	579	Oil	200
2	454	Air	200
3	510	Oil	550

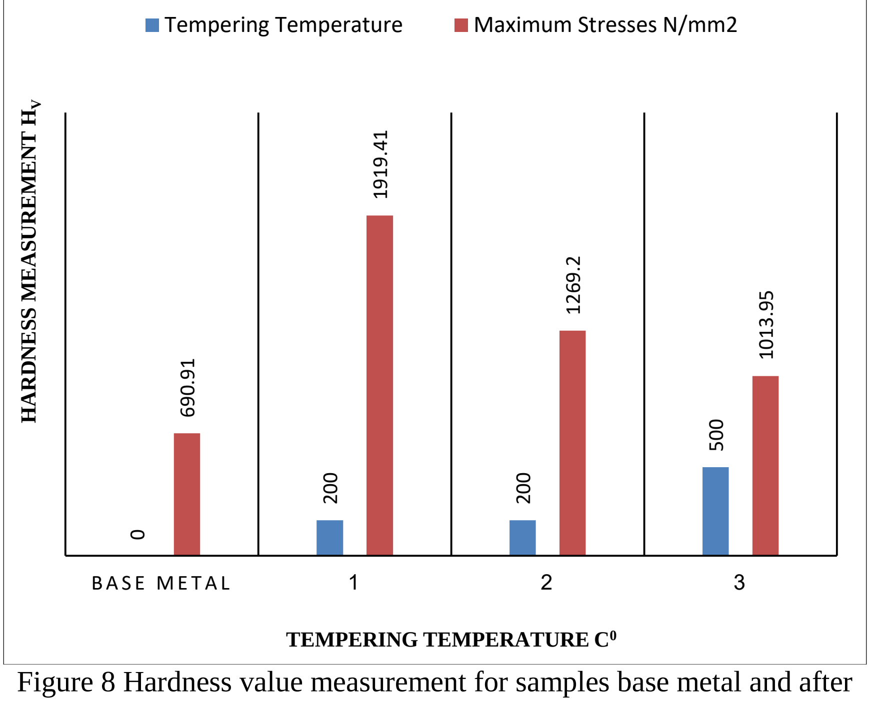


Figure 8 Hardness value measurement for samples base metal and after heat treatment

3.3 Impact testing

Referring to the obtained measured impact energy, results as shown in table 4.

Table 4 Measured Impact Energy

Sample	Impact energy (J)
Base metal	6
1	7
2	7
3	7

The change in tempering temperature and type of media doesn't affect in the impact test.

3.4 Tensile test

Typical stress strain curve is obtained for tensile testing samplesof D_2 tool steel is shown in Figure9, Figure 10, Figure 11 and Figure 12.And the relationship between tempering temperature and tensile test value as shown in Figure 13 and table 6.

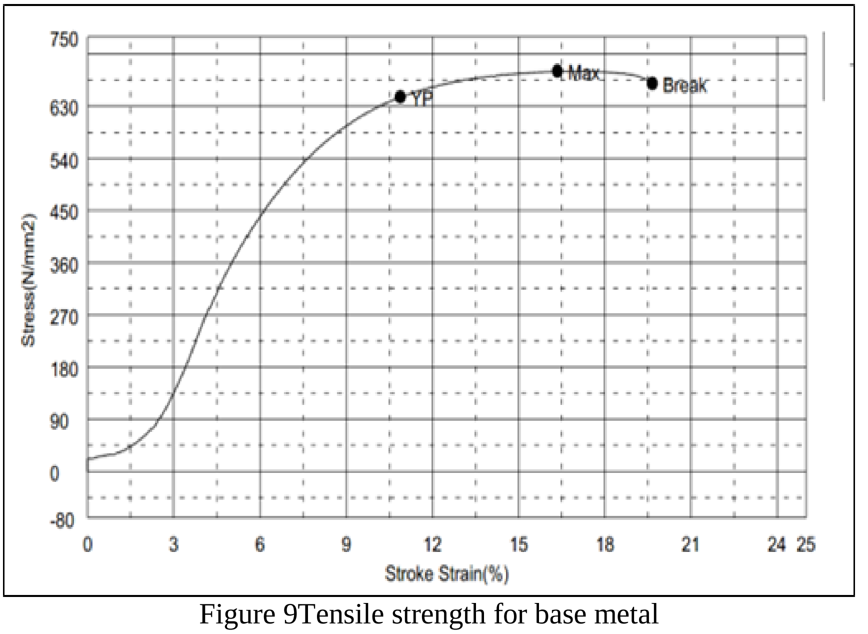


Figure 9Tensile strength for base metal

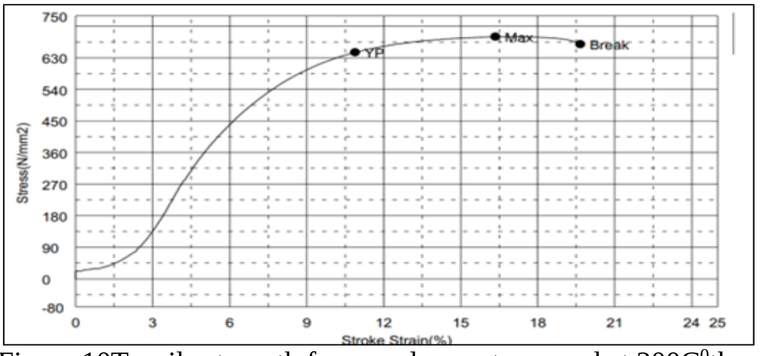


Figure 10Tensile strength for sample was tempered at 200C^{0}than quenching in oil

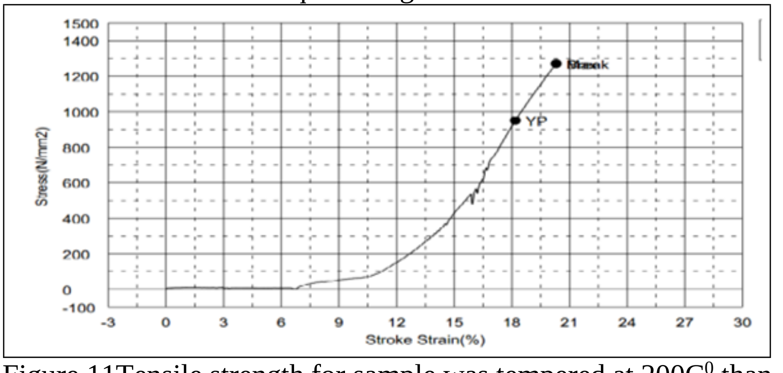


Figure 11Tensile strength for sample was tempered at 200C^0 than quenching in air

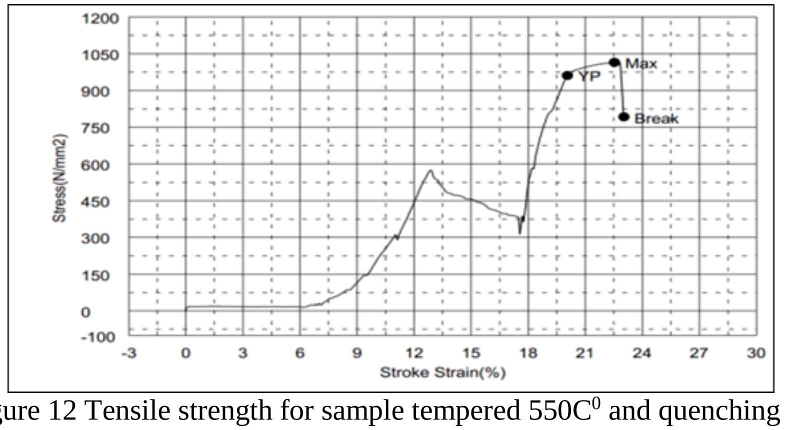


Figure 12 Tensile strength for sample tempered 550C^0 and quenching oil

Table 5 Tensile propertiesof D_2 tool steel under different tempering temperatures

Sample	Maximum Stresses N/mm^2	Break Strain%
Base metal	690.91	19.65
1	1919.41	12.61
2	1269.20	20.32
3	1013.95	23.02

Table 6The relationship between tempering temperature and tensile test value

Sample	Tempering Temperature C^0	Maximum Stresses N/mm^2
Base metal	-	690.91
1	200	1919.41
2	200	1269.20
3	500	1013.95

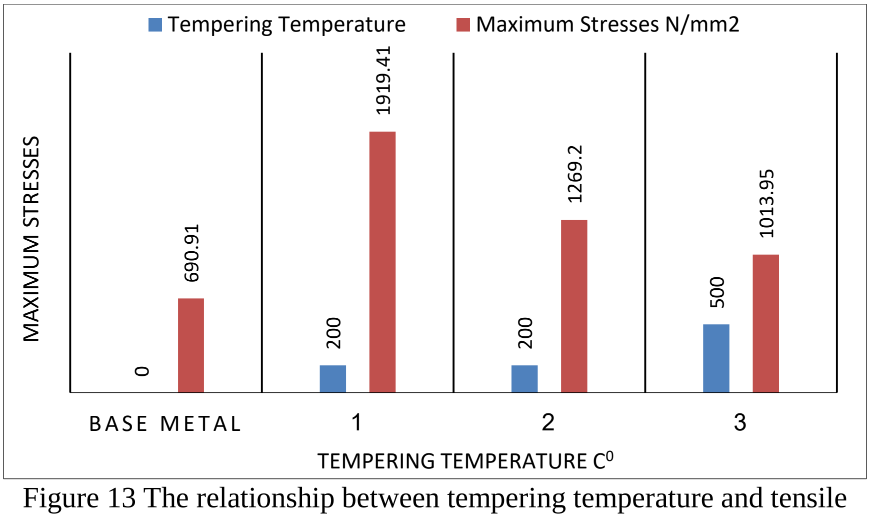


Figure 13 The relationship between tempering temperature and tensile test value

The maximum stress for base metal was 690 N/mm^2, while for sample 2 was quenching in oil media was 1919.41 N/mm^2 exposed to tempering temperature 200C^0 compared to sample 3 was quenching in air media recorded 1269.20 N/mm^2 but for sample 4 different in tempering temperature up to 500 C^0 and quenching in oil record the less value 1013.95 N/mm^2.
Figure 7-A shows the microstructure obtained for base metal for D_2 Tool Steel high carbon high chromium. It consists of primary and secondary carbides with different sizes ferrite (α). For mechanical test, Hardness, Impact and Tensile test. The measurement of all them 231 H_V, 6J and 690.94 J respectively.
Figure 7-B, in this sample tempered at 200 C^0 and quenching in oil. The microstructure consists of chromium carbide and retained austenite. Increased carbide content improves the hardness 579$H_V$and tensile strength 1919 J.While Figure 7-D in this sample tempered at 500C^0 and quenching in oil. The microstructure consists of chromium carbide and retained austenite but less than in the sample on Figure 7-B, because this sample tempered at a higher temperature than it. Resulting decrease the hardness and tensile strength.
Finally, the sample D_2 tool steel on Figure 7-C, tempered at 200C^o and quenching in air. The microstructure consists of chromium carbide and high retained austenite. Resulting decreased the hardness with increased tensile strength.

4. Conclusion

The effect heat treatment on mechanical properties of D_2 tool steel, the base metal for D_2 shows presence of primary and secondary carbides with different sizes in the sample with ferritic matrix.While microstructure for specimens after heat treatment shows formation primary and secondary chromium carbides.other hand; The value of hardness measurement increase with increse tempering tempreture and oil quenching while decrese with air quenching.
Further more, The impact energy increse with heattreatment compared with base metal.While the tensile strength of D_2 tool steel

has significantly increased with increasing ofTempering temperature**.** Finally,effect of heat treatment on mechanical properties of D_2 were improved.

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