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Experimental Investigation on Characteristic Study of the Carbon Steel C45 in Different Working Conditions Using Toughness Test

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ABSTRACT: *In this paper, the mechanical characteristics of C45 medium carbon steel are investigated under various working conditions. The main characteristic to be studied on this paper is impact toughness of the material with different configurations and the experiment were carried out on charpy impact testing equipment. This study reveals the ability of the material to absorb energy up to failure for various specimen configurations under different heat treated conditions and the corresponding results were compared with the analysis outcome.*

Keywords*: C45 medium carbon steel, failure, heat treated conditions, impact toughness, specimen configuration.*

I. INTRODUCTION

The mechanical characteristics of medium carbon steel C45 under various notch configurations (without notch, V-Notch, Drilled hole notch with different heat treated conditions (Unhardened, hardening, tempering) are studied. Here we are using Palm oil [1] as the quenching medium and its reaction over the specimens are also been studied. The toughness test of the specimen is carried under Charpy Impact testing equipment. The experimental results are compared with the analysis, results where the analysis is made in ANSYS WORKBENCH.

Medium carbon steel has carbon content of 0.45%. Medium carbon steel is the most common form of steel as it provides material properties that are acceptable for many applications. It is neither externally brittle nor ductile due to its amount of carbon content. It has minimum tensile strength and malleable. Steel with normal carbon content has properties similar to iron. As the carbon content increases, the metal becomes harder and stronger but less ductile and more difficult to weld. The process heat treatment is carried out first by heating the metal and then cooling it in specific medium. The purpose of heat treatment is to soften the metal and relive the stress set up in the material. Mechanical properties depend largely upon the various form of heat treatment operations and cooling rate. Hence depending upon the properties and the applications that may be required for any design purpose, a suitable form of heat treatment should be adopted [2].

Reason behind using palm oil as a quenching medium instead of other common medium like water and brine solution is because it has been established that palm oil can also be used as a quenching medium for medium carbon steel since the mechanical strength of some of the samples quenched with palm oil improved when compared with those of the as-received sample. Palm oil cooling improves the ductility of the steel because of its lower cooling rate compared with water. Therefore, palm oil will be a viable quenching medium in such cases for which the improved elongation of the samples is critical [3].

The purpose of impact testing is to measure an object's ability to resist high-rate loading. It is usually thought of in terms of two objects striking each other at high relative speeds. A part or material's ability to resist impact often is one of the determining factors in the service life of a part, or in the suitability of a designated material for a particular application. Impact resistance can be one of the most difficult properties to determine. The ability to determine this property is a great advantage in product liability and safety.

Specimen types include notch configurations such as V-Notch, Drilled-Hole Notch, as well as Un-notched specimens. Then the impact test is to be carried on Charpy impact testing equipment has the reading upto 300 joules.

The main objective of this study is to investigate the effect of notch configurations of the specimen treated under different working conditions.

II. Material Selection And Experimentation

2.1 Material

In this study a set of medium carbon steel C45 specimens have been used, the density is 7.85 gm/cm3, where the chemical composition is (0.42 C, 0.24Si, 0.69 Mn, 0.019P, 0.016Cr, 0.12Ni, 0.16Cu, 0.12Mo, 0.02Ti, 0.002V, 0.004W) .

2.2 Notch Configurations

Three different notches are made in the C45 specimen namely, V-Notch, Drilled-Hole notch and Un-Notched specimens. The notch configurations are taken from ASTM.

2.3 Specimen Dimensions

The dimensions of the specimen used in this project is the standard one which is also taken from ASTM (W= 2B, S = 4W& a/W ≈ 0.5) [4]

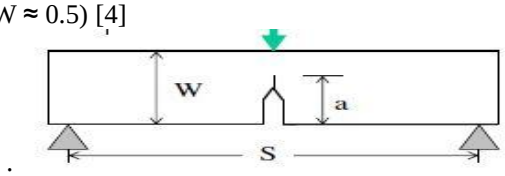

Fig.1. Specimen configuration

2.4 Hardening

The main purpose of hardening is to develop a high hardness level in components for heavy duty service. This treatment consists of heating, soaking and cooling.

- Heating: Specimen is heated slowly in furnace to a temperature up to 850^0 which is above the upper critical temperature [5].
- Soaking: Steel is held at this temperature for 1 hour.
- Cooling: Steel is quenched in oil to attain room temperature.

2.5 Tempering

Hardening treatment develops maximum hardness, excellent wear resistance and high strength in steel. At the same time, it adversely affects properties such as ductility and toughness. Hence in hardened condition, steels are generally brittle. The ductility and toughness of steel can be enhanced and these internal stresses are relieved by another heat treatment process called tempering.

Tempering was performed at 600°C for one hour then the specimen is brought to the room temperature by means of air cooling [5].

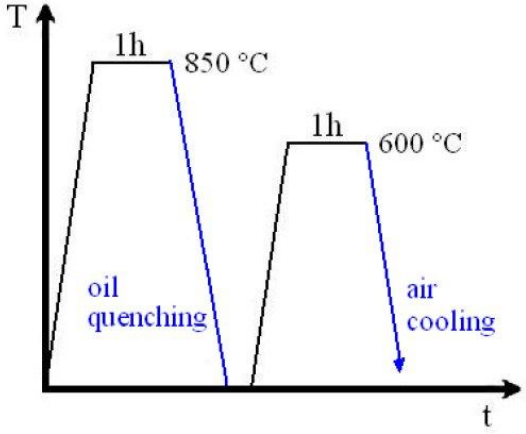

Fig.2. Time temperature Diagram for heat treatment of C45

2.6 Charpy impact test

Impact tests are designed to measure the resistance to failure of a material to a suddenly applied force. The test measures the impact energy, or the energy absorbed prior to fracture. Charpy bar test pieces (12x6x50 mm^3) were machined. Three specimens of each set were tested to ensure the repeatability from which the average is calculated.

III. Results And Discussions

3.1 Experiment

The following table shows the impact energy values and corresponding impact strength for each type of specimen

Table.1. 1 Experimental Data

S.No	Heat treatment	Specimen Configuration	Energy absorbed (J)	C/S Area (mm^2)	Impact strength (J/mm^2)
1	Unhardened	V-Notch	29	60	0.483
2		Drilled Hole Notch	26	42	0.619
3	Hardened	V-Notch	38	60	0.633
4		Drilled Hole Notch	31	42	0.738
5	Tempered	V-Notch	42	60	0.700
6		Drilled Hole Notch	36	42	0.857

Impact Strength (J/mm^2) = (energy absorbed) / (specimen cross sectional area)

3.2 Variation of impact strengths

The following graphs shows the impact strength variation of impact strengths

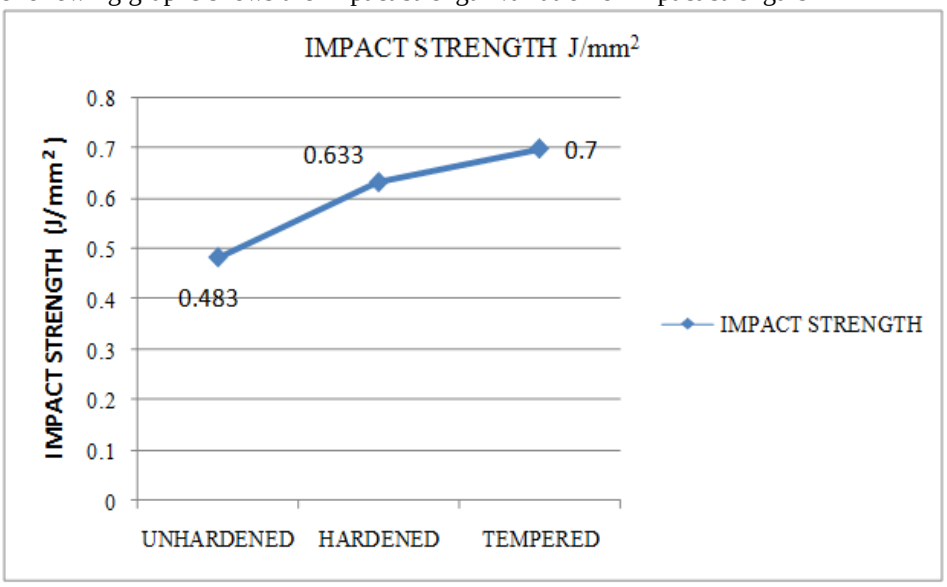

Fig 3. Impact Strength for V-notch

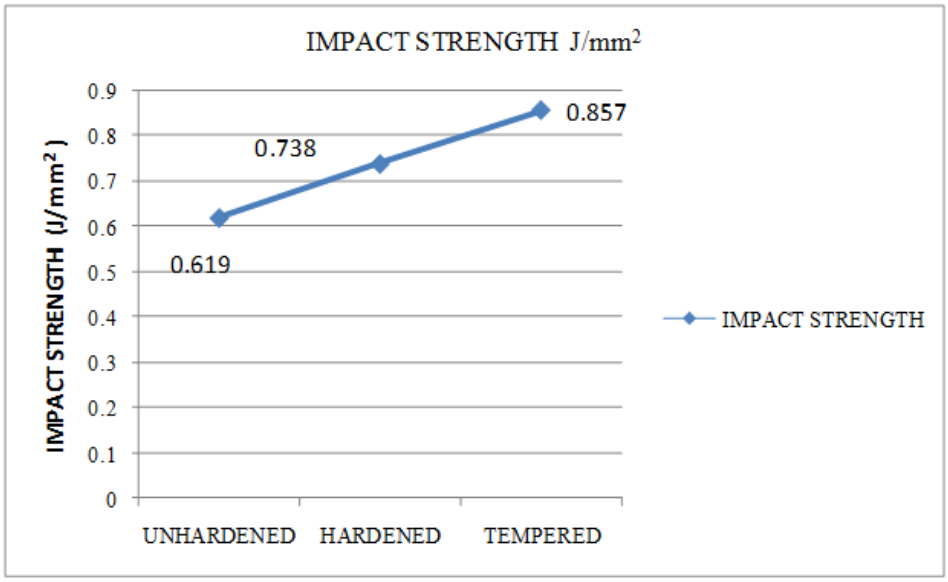

Fig 4. Impact Strength for Drilled hole notch

From the experimental results, it is clearly explained that the hardened specimen too achieve good toughness characteristics by quenching it in palm oil. Generally hardened specimens are lack in toughness but here it compensates its character nearer to the tempered one.

3.3 Analysis Results

Analysis was done for the C45 designing the notch in ANSYS WORKBENCH. As the mechanical properties like yield strength and ultimate strength are mostly the same for hardened and tempered specimen So, the two different conditions are considered as one and the results were taken.

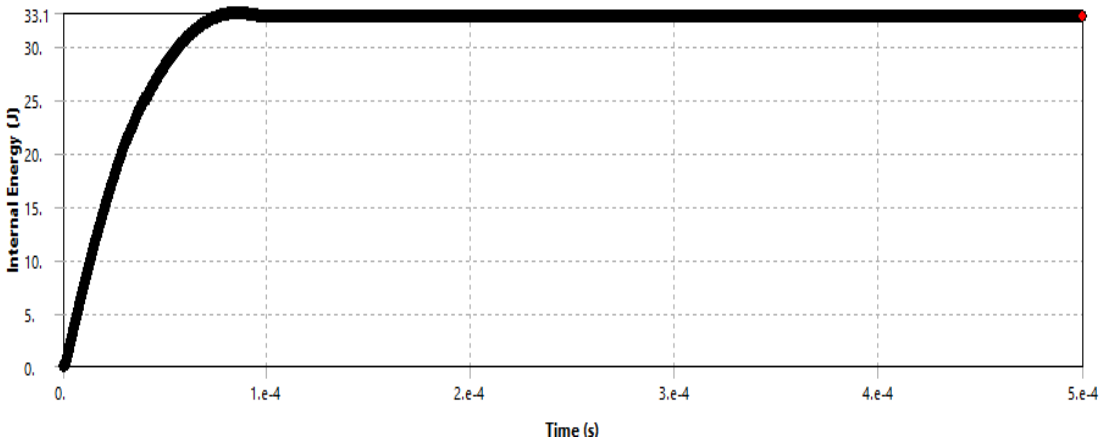

Fig 5. Energy stored for v notch specimen without heat treatment

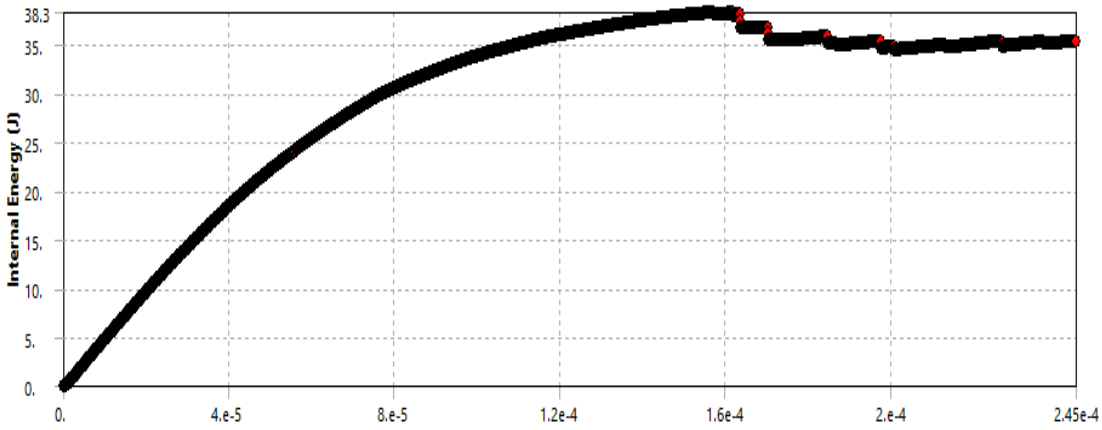

Fig 6. Energy stored for drilled hole notch specimen without heat treatment

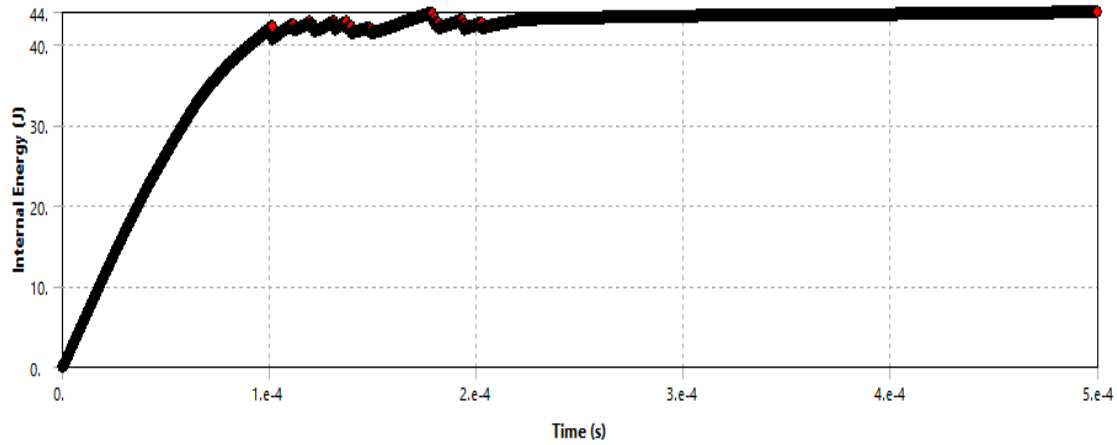

Fig 7. Energy stored for v-notch specimen with heat treatment

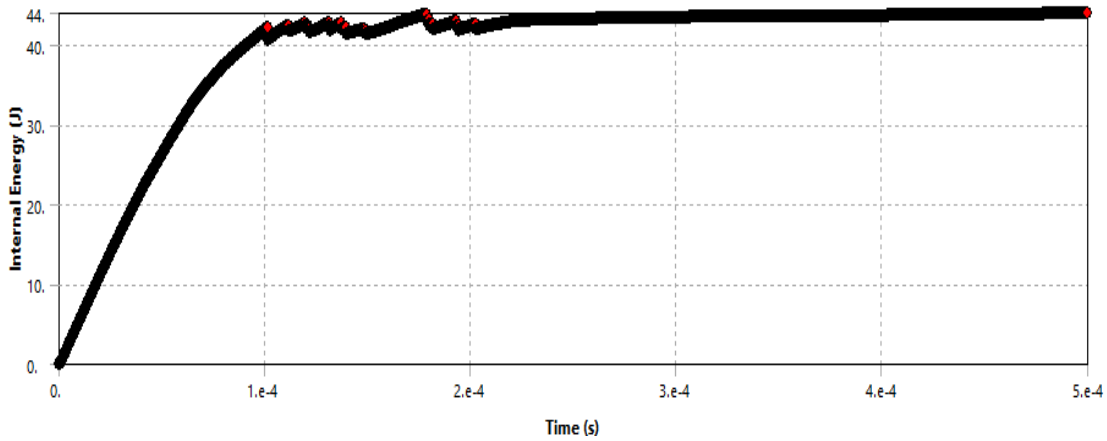

Fig 8. Energy stored for Drilled hole notch specimen without heat treatment

3.4 Result and Comparison

The impact strength / Energy absorbed by the specimen was obtained through experimentation and analysis, values obtained from the both cases are compared and shown in below figure 9 and figure 10.

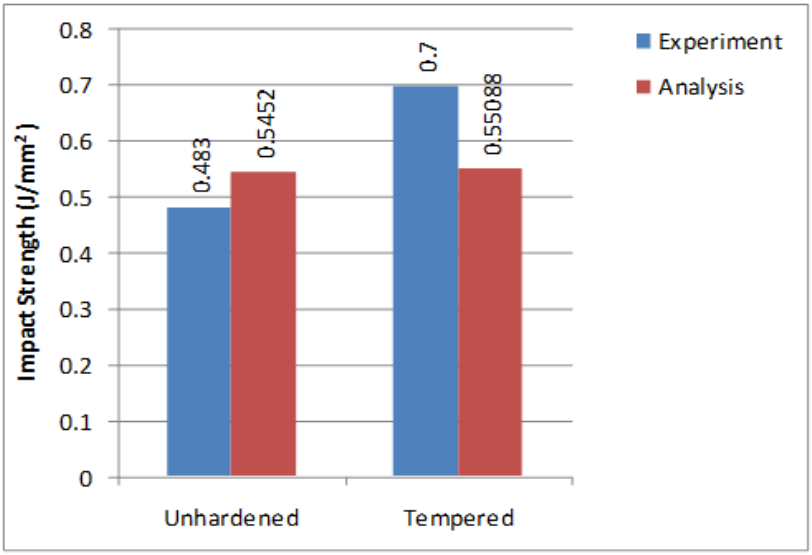

Fig 9. Analysis and experiment comparison for v-notch specimen

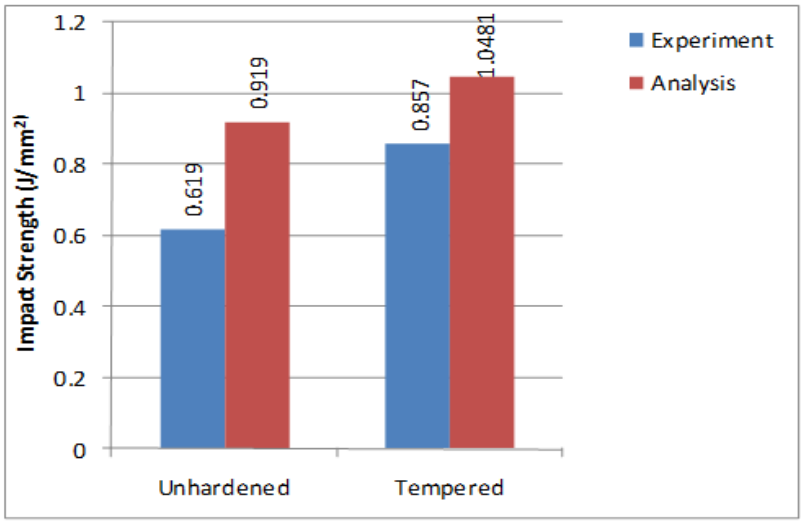

Fig 10. Analysis and experiment comparison for drilled hole notch specimen

The above analysis results show the variations between the unhardened and heat treated specimen in energy absorption. The internal energy absorbed by the heat treated specimen is higher than the un-hardened one which describes that the heat treated specimens are good in toughness characteristics.

IV. Conclusion

- From the experimental values the impact strength was found to be in the order, Tempered > hardened > unhardened.
- From Analysis results also shows that the heat treated specimens achieves greater energy absorbed than unhardened specimens.
- The same result is experienced for both notched (V- notch & drilled hole) and un-notched specimens.
- By varying the notch configuration it is found that drilled hole notch had more impact strength than v - notch specimen.

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