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Influence of Fracture Parameter on the Shear Lips for 080M40 Carbon Steel in Charpy-v Impact Resistance at Different Temperatures

Abstract - *This article examines the correlation between shape of shear lips and temperature change. Impact toughness properties of Standard Charpy-V samples are evaluated at different temperatures for analysis of the energy of fracture of specimens (080M40 Medium Carbon Steel Z3 & Z7 treatment codes). Shear lips are a characteristic sign of the influence of the meso-level mechanisms on the processes of deformation and failure of the material, which is one of the most important property for extending components service life. Therefore, it is important to know the failure of the materials before choosing these steels for producing different machine parts. The 080M40 Medium Carbon Steel (alike to SAE/AISI 1040) is largely used as a machine component in the heat-treated state (tempered and hardened conditions). It has been used eighteen models of specimens, half of them were Z3 treatment while the other half were treated with (Z7) and then examined. In this study, it had been found impact toughness curves at 26, -12, and -38 °C are not similar. The results showed that lowering the rate of temperatures will decrease relatively impact resistance for the 080M40 Carbon Steel by 42% percentage and causes a decrease in the turning angle of shear lips comparative to the longitudinal axle of the samples. An increase tempering treatment from 300 Co to 680 Co was improved dynamic fracture appearance the metal by 63% because that them lowered distortion of the surface structure specimens had been by blisters on the upper shelf region of shear lip.*

Keywords- *shear lips, dynamic failure, impact toughness, and 080M40 Carbon Steel.*

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1. Introduction

080M40 medium Carbon Steel is widely suited for use in applications where better properties than mild steel are required. It can be induction hardened to produce a good surface hardness with moderate impact and wear resistance. Approbation of the properties of steel material can indicate to loss of reliability and safety of machines. In order to prevent brittle failure under observance conditions, transition temperature established on Charpy-v impact test is fixed for the materials revealing transition behavior. Although, relations for specific shear lips area have to be separately determined. Therefore, impact Charpy-v test is one of the principal material tests employed for material properties description. The employ of Charpy-v specimen with several temperatures indicates to encouragement of correlation procedure of the end result. In some papers, physically grounded evaluation parameters of crack initiation and fracture toughness of materials are developed, which allow linking energy efficiency of failure to the physical mechanisms of deformation at different structural levels for the material [1]. An analysis of the literature review displays the efforts to correlate conclusions for model Charpy-v with special temperatures [2,3]. Small standard specimens are also employed in extra testing technique [4,5,6] to reduce the size of tested metal. From the previous research, Lopez et al. explored the effect of samples dimensions on brittle to ductile transition temperature in impact test Charpy-v has been evaluated [7]. In recent years, the development of research related to the influence of the meso-level mechanisms on the processes of deformation and failure of the material has been recognized. Panin et al. explored the plastic strain at the macro-level is preceded by strain accumulation at the micro-level. The presence of the internal boundaries at the micro-level, meso-level and macro-level affects the load-bearing capacity and fracture toughness of the material [8]. Chausov et al. explored the approaches that allow explaining the nature of the material behaviour under the material exposure to high-energy impulses were

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proposed and physically substantiated [9]. Maruschak et al. make a review about the main physical-mechanical preconditions of the structural–mechanical degradation and mechanisms of the destructive and non-destructive evaluation methods of the material resistance to dynamic loading were found [10], i.e.: the investigation of the material impact toughness, which allows assessing the material condition and its resistance to impact loading in the presence of stress concentrators, is important [11,12,13]. In some papers, the shear lips have been investigated by many researchers, but the information for brittle failure over examine conditions, and transition temperature established on impact tests Charpy-v is for the materials revealing transition action are still limited [1,14].
Some of goods, which were made of 080M 40 Carbon Steel, especially in the automotive industries also, receive impact loads. That makes the importance of the impact resistance of the 080M40 Carbon Steel to be investigated. In previous articles [15,6], the mechanical properties of 080M40 Carbon Steel were influenced by fracture parameters. When the temperature is increase, there is decrease or insignificant decrease to the fracture appearance in the upper shelf region. The results show that correlation procedure for standard Charpy-v results to fracture appearance transition temperatures of specimens. The goal of presented study was to examine influence of Charpy-v sample temperature on brittle-to-ductile transition in the upper shelf region of shear lips, as well as the paper proposed to analyze of energy capacity of failure of specimens in the presence of localized plasticity and in its absence near the tip of the concentrator. Furthermore, the impact resistance for peculiarities of deformation and shape of shear lips for cut out of the 080M40 Carbon Steel has also been studied.

2. The Practical Part

In this study, it had been explained the fracture behavior of the metal depending on the size consideration in the upper shelf region, just materials exhibiting maximum ductile at room temperature were decided. The fracture appearance transition temperatures (F.A.T.T.) were investigated for 080M40 medium Carbon Steel (C 0.4; Mn 0.67; Si 0.21; P 0.02; S 0.018 %). The tests were achieved by working Charpy-V specimens. Impact tests were accomplished using striking edge radius 2 mm with maximum capacity of a 150 J pendulum for standard samples, located in the Metal Laboratory (NTU), As shown in Figure1. In addition, it had been explained the fracture performance, standard Charpy-v samples at different temperatures were established in the situation of three patch for (26, -12& -38 ^{o} C) and three specimens (constant temperature) at every patch. Furthermore, all of the specimens were investigated in the longitudinal direction. As, a review of the literature shows the effect of specimen orientation on impact test results and The results show that the specimen should be oriented in the rolling direction of the plate (forming direction of any formed part) and the notch should be perpendicular to that surface [17].
Impact toughness was determined on the Charpy-V impact equipment of the BeiJing impact test instrument equipped with the ImpactStar Testing System software. 080M40 Carbon Steel specimens were divided to two notch, the first notch was called code Z7 (0.4% Carbon Steel material, when Oil quenched at 840°C and tempered at 680°C, according to British Standard Specifications 080M40). And other notch code Z3 (0.4% Carbon Steel material, when Oil quenched at 840°C and tempered at 300°C, according to British Standard Specifications 080M40) with dimensions 10 × 10 × 55 mm. The V-shaped notch radius was 0.25 ± 0.025 mm is shown in Figure 1. All specimens were tested according to ASTM E23 standard. After placing the specimens in the impact-testing machine, the test control program was activated by using Impact Star Testing System software for impact test instrument. A starting velocity of the impact testing machine hammer was 5.0 m/s. For every testing condition, as a minimum three repetitions were achieved for every patch. Next, the test, the absorbed energy E and toughness were measured by instrumented record capturing. The investigation was performed at 26, -12 and -38 C°, which corresponds to the most rigid winter conditions in the north of Iraq. Such temperature conditions correspond to the test standards [18,19,20]. F.A.T.T. were established for every one batch by checking of three test specimens. The tests were completed about three test temperatures per batch. Area ductile part and fracture appearance, indicated on the picture below.

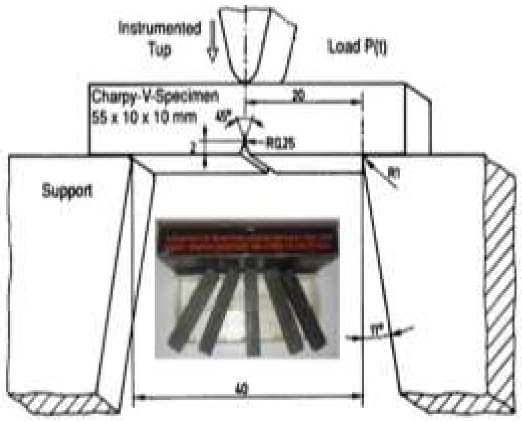

Figure 1: Dimensions used of Charpy specimens with additional instrumentation at the supports.

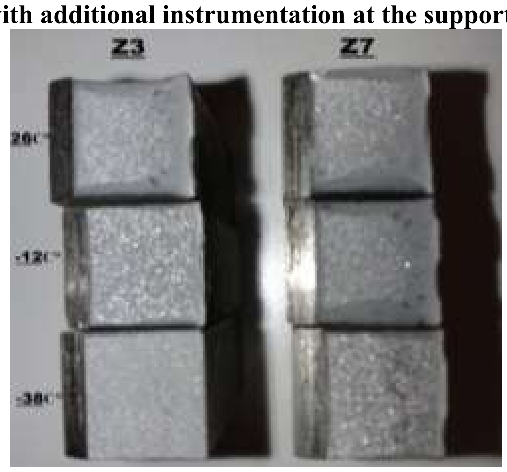

Figure 2: Fracture appearance of tested specimens.

To provide the required test temperature, the specimens were cooled by liquid nitrogen for 10 min prior to placing them in the impact-testing machine. All the experimental data, including fracture energy and its components, were calculated automatically using the control program of the impact testing machine, which is based on the ASTM standard. The dynamic fracture toughness of specimens (ξ) was calculated automatically from the following formula:

$$\xi = \frac{2Ar}{Wi(h-v)} \quad (1)$$

where (Ar) is the making for crack initiation; h, (v) is the height and the notch depth; and (Wi) is width of the sample. As a review of the literature [21]. The chemical composition of the 080M40 Carbon Steel material is presented in the table 1 below.

Table 1: Experimental chemical composition of 080M40 Carbon Steel material, (%wt.).

Elements	C	Si	Mn	P	S
%wt.	0.40	0.21	0.67	0.02	0.018

3. Results and Discussion

The dynamic deformation of Charpy-v samples had a graded nature failure. As each material has different absorbed energy. The process of plastic deformation of specimens tested at 26, -12, and -36 °C. This kind of structure is described by high ductility and strength in case of high hardness, which increases performance characteristics of components service life. Moreover, at 26 °C, the mobility of dislocations is higher [26]. At -38 °C, the crack tip is oppressed with relaxation processes, and samples get broken very quickly. In addition, the redistribution of energy expenditures on the crack propagation and initiation takes place.

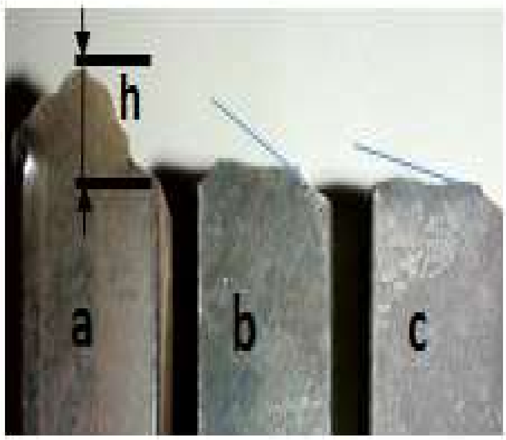

Figure 3: Images of shear lips of Charpy-v samples tested at 26°C (a), -12°C (b) and -36°C (c).

It is found that at both -38 and 26 °C, an improve in the energy efficiency of fracture is accompanied by an improve in the height of shear lips. The largest height of shear lips was 28.38% at 26°C and 4.73% at -38°C (Figure 3). Therefore, it should be noted that the height of shear lips improves with an improve in the energy efficiency of fracture at both temperatures, which achieved to the involvement of the metal plasticity at the meso-level. This, in its turn, causes an increase in the general energy efficiency of the specimen fracture. A change in the shape of the specimen fracture takes place simultaneously with a change in the height of shear lips [23]. Although shear lips are typical in the specimens of both types, they are a little higher and narrower in the specimens tested at -38 °C, and their slope angle relative to the specimen axis is smaller than in the specimens tested at 26 °C, which determines their smaller area. At the meso-level, translational shears of grain conglomerates take place in metal, which are sensible for relaxation processes [23,24]. At the same time as a result, structuring of the specimen fracture surface takes place at the meso-level in the appearance of conglomerates of the regularly deformed grains. Area, morphology and kinetics of deformation be dependent on the resistance of the metal microstructure to the shear lips forming [22]. The crack initiation took place in the brittle manner in several areas, and the fracture area has a graded shape. Figures 2 & 3 describes the fracture faces of samples experimented at different temperatures. Results indicate that side area ductile part is like for all Model Charpy-v samples at the matching temperature. The crack propagates with the formation of 'shear lips' and specimen failure (Figure 2). All these processes form relevant section on the specimen fracture area (Figure 4). It is found, by an early developed computer-aided automatic method, by using Raster Design 2017 and Adobe Illustrator.CC. 2017.V21.0.0 software programs, when we tested the specimens (Z7) at 26 °C, the zone of propagation and the area of shear lips is 47.49% (Figure 4 a), For comparison, in specimens (Z3) tested at -38 °C, it is noted almost, this area was 17.5% (Figure 4 f).

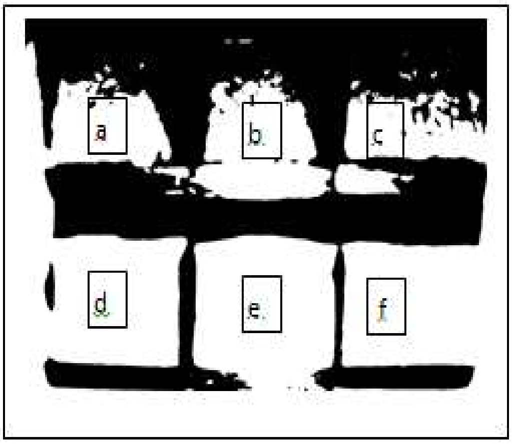

Figure 4: Shear lips depended on the Area below the notch specimens (Black color is shear area).

Shear lips are a characteristic sign of the influence of the meso-level mechanisms on the processes of deformation and failure of the material [23]. During the investigation of fracture areas of Charpy samples, a change in the appearance of shear lips (height h) is found (Figure 3a), which are formed on their side surfaces. The development of shear lips in the metal at 26 °C, the shape of shear lips becomes more 'rounded' and their height increases significantly (Fig. 3a). At -38 °C, shear lips have a weakly developed shape (Figure 3c). Moreover, it was complemented by the formation of the metal delamination at the zones of shear and constant crack growth within the sections of sapling near crack edges. An increase in temperature produces a rise in the turning angle of shear lips in relation to the longitudinal axle of the sample. Figure 5 present the correlation between temperatures and shear lips area for ordinary Charpy-v. These dependencies can be estimated by exponential expressions indicated in the figure below.

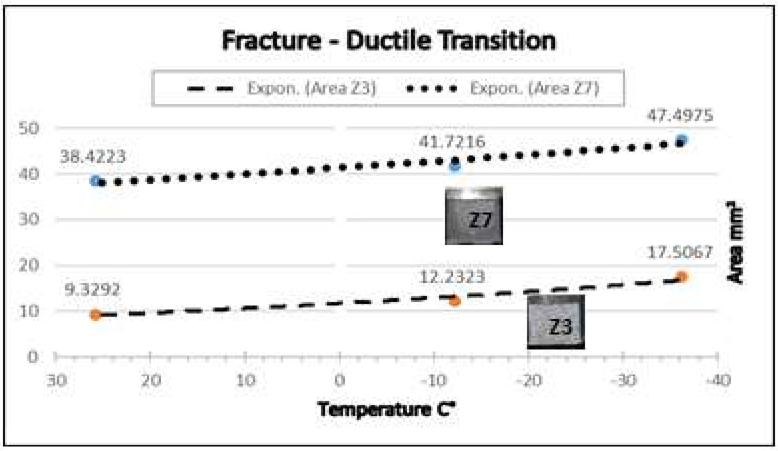

Figure 5: Correlations between shear lips area and temperature for model Charpy-v sample.

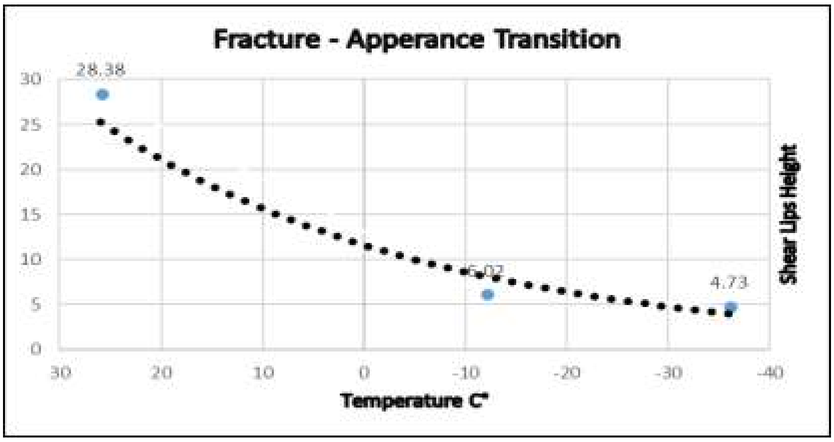

Figure 6: Correlations between shear lips height and temperature for model Charpy-v sample.

Plastic deformation at the meso-level is connected with the rotational dynamics of the conglomerates of grains, and the energy dissipation occurs as a result of friction on their boundaries. One of the revelations of this is the formation of shear lips. In this paper, we propose an approach, which helps to understand the relationship between the energy micro parameters of fracture and deformation parameters, as well as the fracto-graphy data and developed computer-aided-automatic methods. On the basis of such an integrated approach and a quantitative analysis of specimen fracture zones, physical and mechanical interpretation of the mechanisms of specimen failure is possible, taking into account the developed and localized plasticity in the vicinity of the concentrator tip [25], which can be used in fracto-diagnostics and developed computer-aided-automatic methods when analyzing the causes of fracture of real structures [21]. From figure 6, the influence of shear lips height to the impact resistance was observed by the pattern of the slope or the gradient of the graph. In on ductile to-brittle transition, the greater gradient of the lines means the greater the effect. It also shown in Figure 7 that the line of transition temperature was comparatively steeper than impact toughness specimens. It means that the transition temperature is obviously affecting the upper shelf region of shear lips [13,14,26]. F.A.T.T. and impact toughness specimens at matching transition temperature for every batch of samples were computed. Results are gives in Figure 8 shown dependency of F.A.T.T. on impact toughness for model Charpy-v. It was found, that impact toughness specimens at for model Charpy-v is linearly relational to sample temperature. In order to describe the F.A.T.T. in this metal take place, once impact toughness specimens are about 21.42 % of specimens' temperature. Figure 8 approves, that showed correlation procedure give up like results to correlation from Smallman [27]. Sokolov [28] approves influence of specimen height, notch depth and notch root radius on temperature transition growth. The benefit of suggested correlation formula, comparing to constant correlation diagram is a possibility to discovery the correlation between model Charpy-v samples and F.A.T.T., and further precise answers for Z7 & Z3 treatment codes.

4. Conclusions

Unusual feature of fracture nucleation of specimens from the 080M40 Carbon Steel used in the machines, vehicles, and structures are investigated below impact forcing. The effect of the medium carbon steel structure on the processes of its deformation and failure under dynamic loading was analyses. Impact toughness of every one of specimens examined is analyses as the full amount of energy expenditures on the propagation, and nucleation of cracks in the metal was investigated. As a conclusion, the influences of transition temperature to the Charpy-v impact resistant have been investigated. Altogether, several types of tests were achieved with as a minimum three repeats and for that reason exceeding 9 Charpy-v impact tests instrumented were achieved. A decrease in the test temperature from 26 down to -38 °C causes a three out of eight decrease in the impact toughness. The correlation formula supposes that the area of ductile part positioned on the edges of F.A.T.T. is relational to shear lips. A procedure to the quantifiable description of fracture impact procedure that contains the computation of shear lips extent like a quantifiable fracture factor was developed. A relationship between the energy efficiency of crack propagation and the height of shear lips is established. A latest approach in correlation from model Charpy-v test results with approximate F.A.T.T. temperature was proposed Correlation for model Charpy-v specimens suggests the influence on transition temperature.

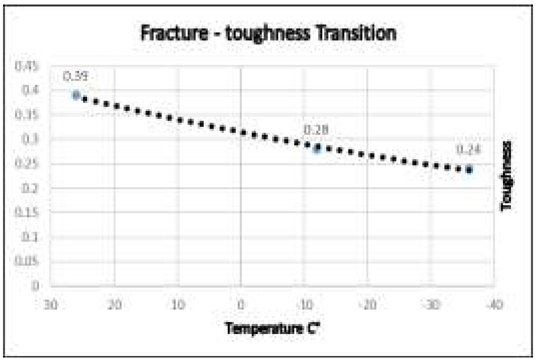

Figure 7: Correlations between impact toughness and temperature for model Charpy-v sample.

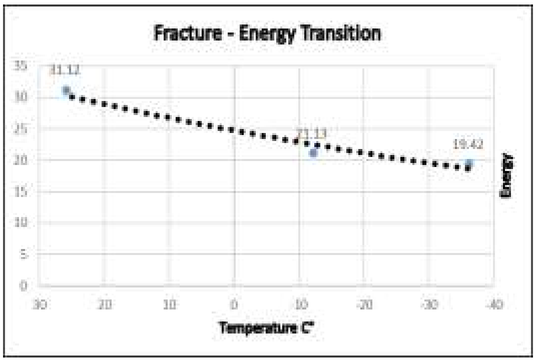

Figure 8: Correlations between energy and FATT for standard Charpy-v Specimens.

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