Scientific Journal Impact Factor (SJIF) : 3.518
International Journal of Modern Trends in Engineering and Research
ISSN (ONLINE) : 2349 - 9745
ISSN (PRINT) : 2393 - 8161

Study on Fracture Mechanics for Maraging Steel (M250)

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Abstract— Fracture mechanics deals with the investigation of the load carrying capability of a body with or while not a thought of the initial cracks in addition as a study of assorted laws governing of the expansion of cracks.

Fracture mechanics is that the field of mechanics involved with the study of the propagation of cracks in materials it uses strategies of analytical solid mechanics to calculate the propulsion on a crack.

The process involved in the fracture of solids or so complicated and varied to an extent that no single The process concerned within the fracture of solids close to difficult associated varied to an extent that no single formula or criterion may be expected to realistically describe all of the discovered fracture phenomena.

The field of fracture mechanics matured within the last 20 years of the twentieth century. Current analysis tends to lead to progressive advances instead of major grains. This project demonstrates on how the crack initiates, its development , analysing the crack development and how to prevent it from initiating

Keywords— Fracture, stress intensity factor, CTOD, crack growth and cohesive zone

I. INTRODUCTION

Fracture mechanics deals with the investigation of the load carrying capability of a body with or while not a thought of the initial cracks furthermore as a study of a numerous laws governing the expansion of cracks.

The crack could also be unreal like a hole, a notch, a slot, a re-entrant corner, etc. The crack might exist inside a part because of producing defects like scoria inclusion, cracks in an exceedingly assembly or heat affected zones because of uneven cooling and presence of foreign particles. About 50-60 years ago, when accurate analysis for predicting the crack growth was not available, a reasonably high factor of safety was chosen to account for unforeseen factors. A large part of this ambiguity has been cleared with the development of fracture mechanics and understanding the causes and effects of fatigue failure. This currently permits a designer to use a way lower issue of safety, therefore reducing price of such structural parts. at the same time, the burden of those parts is reduced and their responsibleness is increased.The development of failure by harmful crack propagation in structural materials poses issues of style and analysis in several fields of engineering like part trade wherever safety is of preponderating importance. The mere presence of cracks doesn't condemn a part or structure to be unsafe and thus unreliable. whether or not beneath cyclic or sustained loading, it's necessary to grasp however long associate degree initial crack of a precise size would want grow to a vital size at that the part or structure would become unsafe and fails. additionally by knowing however a crack evolves and its rate of propagation, we should always be ready to estimate the residual service lifetime of a part beneath traditional service loading conditions. Standardized fracture specimens are being used for fracture analysis of actual engineering components due to complexity of shape and size, and the results obtained are correlated to the actual geometry through fracture models. The process involved in the fracture of solids are so complicated and varied to an extent that no single formula of criterion can be expected to realistically describe all of the observed fracture phenomena.

Volume 03, Issue 03, [March – 2016] ISSN (Online):2349–9745; ISSN (Print):2393-8161

II. FRACTURE PARAMETERS

Various investigators have tried to characterize the crack victimisation totally different parameters. The parameters square measure stress intensity issue (K), Energy unharness rate (G), J-Integral and CTOD. Among these four parameters, stress intensity issue (K) and Energy unharness rate (G) square measure supported linear Elastic Fracture Mechanics (LEFM), and also the J-integral and CTOD square measure supported Elastic-Plastic Fracture Mechanics (EPFM). The parameter energy unharness rate (G) is energy based mostly and is applied to brittle or less ductile materials. Stress intensity issue (K) is stress based mostly, conjointly developed for brittle or less ductile materials. J-integral (J) has been developed to affect ductile material. Its formulation is kind of general and might be applied to brittle materials conjointly. Crack Tip gap Displacement (CTOD) parameter is additionally developed for ductile materials and, because the name suggests, it's displacement based mostly. The conception of a important crack gap displacement as a fracture criterion is introduced because the study of crack initiation in things wherever important plastic deformation precedes fracture. underneath such Conditions the stresses round the crack tip reach the essential price and thus fracture is controlled by the number of plastic strain. Crack extension takes place by void growth and conglutination with the first crack tip, a mechanism that the crack-tip strain is accountable. A live of the number of crack tip plastic strain is that the separation of the crack faces or crack gap displacement (COD), particularly terribly on the brink of the crack tip. it\'s so expected that crack extension can begin once the crack gap displacement reaches some essential price that is characteristic of the fabric at a given temperature, plate thickness, strain rate and environmental conditions. The criterion takes the shape

$$\delta = \delta_c \qquad (1.1)$$

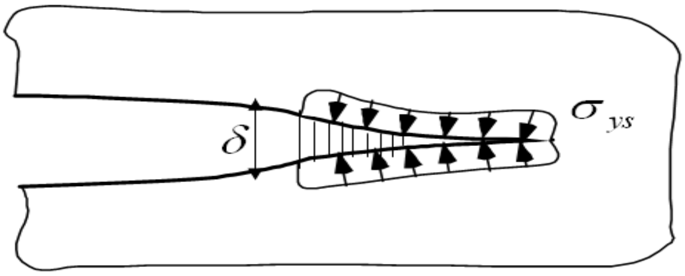


Fig. Representation of CTOD

Where δ is the crack opening displacement and δ_c is its critical value. It is assumed that δ_c is a material constant independent of specimen configuration and crack length.

III. METHODOLOGY

3.1 COHESIVE ZONE MODELING TECHNIQUE

The cohesive model has been formulated such that it can be used for practical application. Cohesive zone model is widely utilized in engineering to predict various behaviors such as the crack propagation in the interface of the two materials, fatigue crack propagation and the delimitation in the composite materials. Cohesive zone model can be represented in Finite Element Analysis with the help of some software packages. ANSYS is the software which is used in this paper work to model the cohesive zone in the CT specimen. Interface elements representing the damage are implemented between the continuum elements representing the elastic plastic properties of the material. Several investigations deal with the effect of the shape of the traction–separation function on the resulting fracture behavior. Where the normal separation traction can be found out by using the formula given as follows.

$$T = T_{0}.\left[2\left(\frac{\delta-\delta_2}{\delta_0-\delta_2}\right)^3 - 3\left(\frac{\delta-\delta_2}{\delta_0-\delta_2}\right)^2 + 1\right] \qquad (3.1)$$

Due to the simple geometry, the hybrid technique using a finite element analysis is not needed: the applied force at fracture is divided by the instantaneous cross section as in a thin flat tensile specimen a uniform stress state can be assumed. The flow stress of the material can also be used as this traction separation stress (σ_{max}) as shown in figure.3.1.

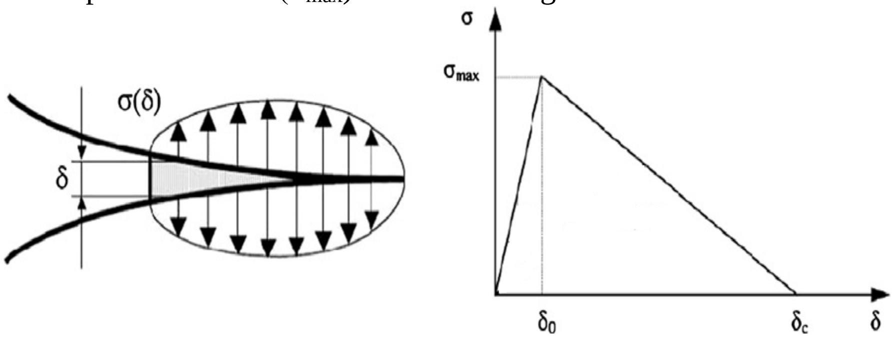
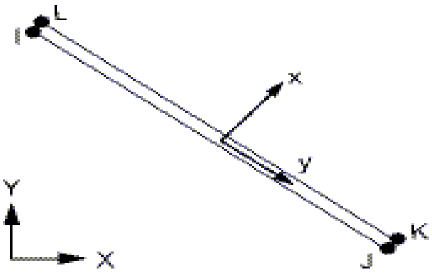


Figure.3.1.Representation normal traction separation stress

The interface elements employed in this study (Fig. 1) are the distributed non-linear truss elements existing between surfaces forming the crack surfaces. They are assumed to have zero mass and zero volume. Fig represents a model of two linearly connected elements. The top element represents an elastic–plastic continuum, which represents the plastic zone near the crack tip. The non-linear truss element represents a potential failure surface. The relation between the bonding stress and COD is when the opening displacement is small; the bonding between the two surfaces is maintained. As the bonding stress increases until it reaches a flow stress value, the opening displacement further increases, the bonding strength is rapidly lost and the surfaces are completely separated.

Cohesive zone can be modeled in ANSYS by using interface elements. Inter 203 is the suitable interface element for continuum element Plane 82 which is used to mesh the areas around the cohesive zone. Initially, geometry with given dimension has to be modeled. One interface element and a continuum element have to be selected where interface element is used to define cohesive zone and continuum element is used to describe the elements around the cohesive zone. A Local coordinate system is created at the crack tip. Crack tip is modeled with singular element by using concentrated key point. Cohesive zone properties are defined by calculating the flow stress of the material. Cohesive zone is meshed ahead of crack tip throughout the ligament area.



Inter 203 Element

There is no much difference in making cohesive zone using contact elements from interface elements. While using contact elements, type of contact in the ligament length ahead of crack tip should be decided. The contact elements should be selected based on the type of contacts. Then the nodes should be merged by defining proper contact and target nodes.

3.2. MATERIAL NON LINEARITY

The stress-strain behavior of elastic-plastic deformation is not simple as it is well known to be nonlinear. With the availability of inexpensive computers nonlinear stress-strain behavior can be accounted for but the more serious problem is of non-uniqueness of the elastic-plastic behavior. That is, loading behavior of elastic-plastic materials differ from unloading behavior. For a given value of strain there are two values of stress and therefore one has to keep track whether the specimen is being loaded or unloaded. An analog can be drawn with dealings with a person who is simple and straight forward like a linear elastic material. Nonlinear elastic material corresponds to a man who is honest but rude. But elastic-plastic material is like dealing with a man who is not only rude but speaks truth sometimes and lies other times.

For many metals, the stress-strain relations get further complicated due to bauschinger's effect which shows that yield stress in unloading is different from that in loading. We would not elaborate such problems here. But we realize that solving problems of an elastic-plastic material is quite difficult even for regular components with no voids or cuts. The magnitude of complexity increases further when the problem is involved in the vicinity of a crack tip.

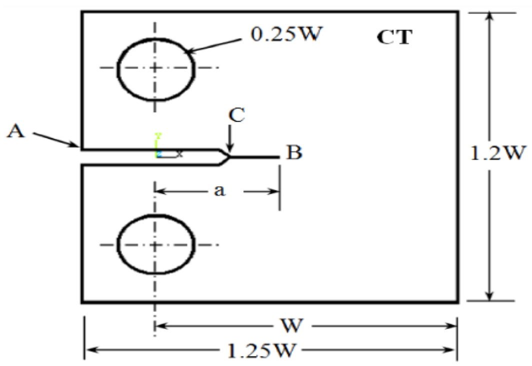
Elastic-plastic behavior makes the analysis of fracture mechanics complex because of the existence of two zones, elastic-plastic near the crack tip and elastic surrounding it. The interface between the zones is also not known as priori and we have to determine it while carrying out the rigorous analysis.

Because of these complex problems of elastic-plastic analysis, it has, so far, not been possible to tackle the problem face to face directly and defeat the enemy flatly. In fact, we look for solutions in clever ways which are improved over those of LEFM but are not too difficult for designers in field applications. CTOD is one such method which, in spite of some observations, is most acceptable to designers and researchers elastic-plastic fracture mechanics (EPFM). In this chapter we would consider CTOD for the material Maraging steel (M250) in CT specimen.

IV. ANALYSIS AND FINDINGS

4.1PREPROCESSING WORK IN ANSYS

Full specimen is modeled in this paper work, since it is required to model the entire specimen for creating the cohesive zone ahead of crack tip.



Compact Tension Specimens.

In this study Compact Tension specimen is considered. Input parameters CT specimen is given below.

a =7.1069 mm; W = 14.96 mm σ = 125.24MPa; B = 7.54 mm a is crack length, W is width of the specimen, B is thickness of the specimen, σ is applied pressure

4.1.1 MATERIAL PROPERTIES

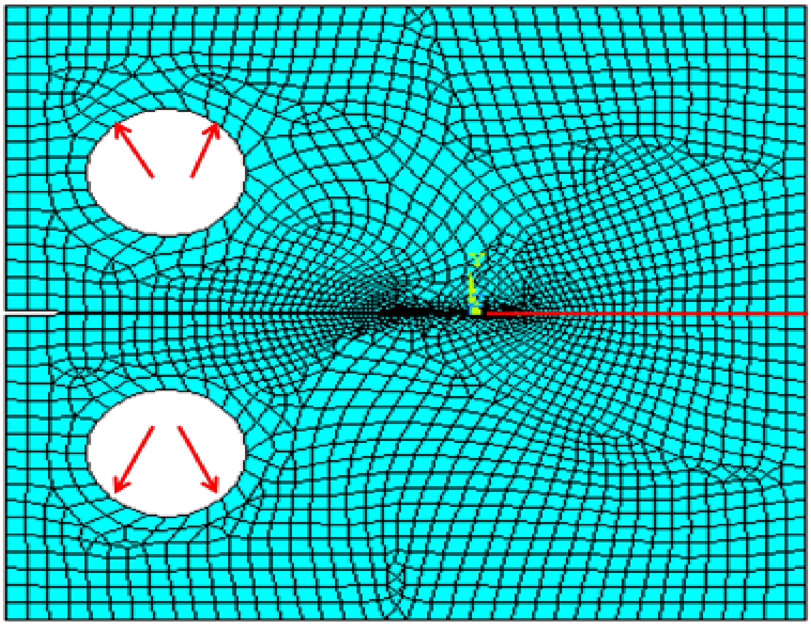
The material properties of Maraging steel (M250) which are used in this paper work taken from [1] are given below

Table 4.1 Material Properties for Maraging steel (M250)

Properties	Maraging steel (M250)
Young's modulus(E)	184123.29N/mm2
Poisons ratio (ϑ)	0.3
Yield Stress(σ_{ys})	1652.98N/mm2
Ultimate Strength(σ_{ult})	1712.8 N/mm2

4.1.2 MESHING AND BOUNDARY CONDITIONS

The model is meshed with two elements which are PLANE 82 and INTER 203. The PLANE 82 element is used to mesh the areas around the cohesive zone where INTER 203 is used to mesh the interface elements ahead of crack tip. The total model is discritized into 8549 nodes and 2858 elements. The meshed model is fixed for all degrees of freedom at right end. The applied load which is taken from [1], is converted into projected area pressure of the hole which is modeled with the specimen. And the pressure is applied at the top feature of the hole.



4.2. RESULTS AND DISCUSSION

Dugdale strip yield model is the theoretical model which is used in this analysis; Where Crack Tip Opening Displacement can be used to predict the crack growth. According to that, Critical CTOD is the point at which the instability of crack growth will start. The critical CTOD of the material is calculated through theoretical formulas by converting the experimentally measured CMOD values to CTOD [2]. And the formulas used are

$$(\mathrm{CTOD})_c = (\mathrm{CTOD})_p + (\mathrm{CTOD})_e \qquad (4.1)$$

$$(\mathrm{CTOD})_p = \frac{(\mathrm{CMOD})_c + (r \times b)}{a + (r \times b)} \qquad (4.2)$$

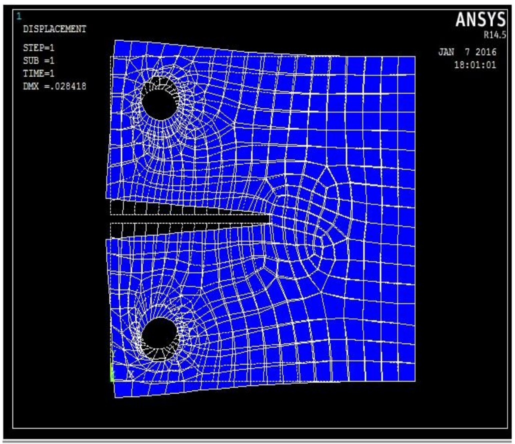
$$(\mathrm{CTOD})_e = \frac{K^2{}_{IC}(1-\vartheta^2)}{2\sigma_{ys}E} \qquad (4.3)$$

r is the geometrical rotation factor generally it is taken 0.44 to 0.47 for compact tension specimen. b is the thickness of the material. Critical stress intensity factor is calculated by using the critical crack length and pressure applied at that crack length. And the method to calculate this CTOD using ANSYS software is invoked and the results obtained from the ANSYS is validated with the calculated theoretical results

Table.4.3 Comparison of critical CTOD result

Parameter	Numerical (mm)	Theoretical (mm)	% of error
$(\mathrm{CTOD})_c$	0.11	0.1	6

The result of CTOD which is obtained numerically from finite element software ANSYS is given below.



1V. CONCLUDING REMARKS

- A simple and accurate numerical procedure for finding out the CTOD from Finite Element software ANSYS using cohesive zone is discussed.
- The results of static crack growth are validated with the theoretical values calculated from the experimental results with less than 6% of error.
- The nature of alternating stress intensity for different crack length and different strength ratio of notched CT specimen is analyzed.
- The error between theoretical and ANSYS values of crack extension is found to be less than 2% at different values of applied pressure.
- The material constants M, k and n are obtained from numerically generated load vs. V_{ff} curve and validated with the experimental results.
- The resistance curve of the material has been generated theoretically and critical crack extension and corresponding critical load are evaluated from the resistance curve.
- The curve plotted between CTOD and da for both the theoretical and ANSYS values follows the same path.
- It is found that the crack initiation and propagation for Maraging Steel (M250) at various applied pressures grossly depend on Stress Intensity Factor, Energy Release Rate and Crack Tip Opening Displacement.

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