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Fracture analysis of alluminium MMC reinforcement with FE3O4 using Abaqus CAE

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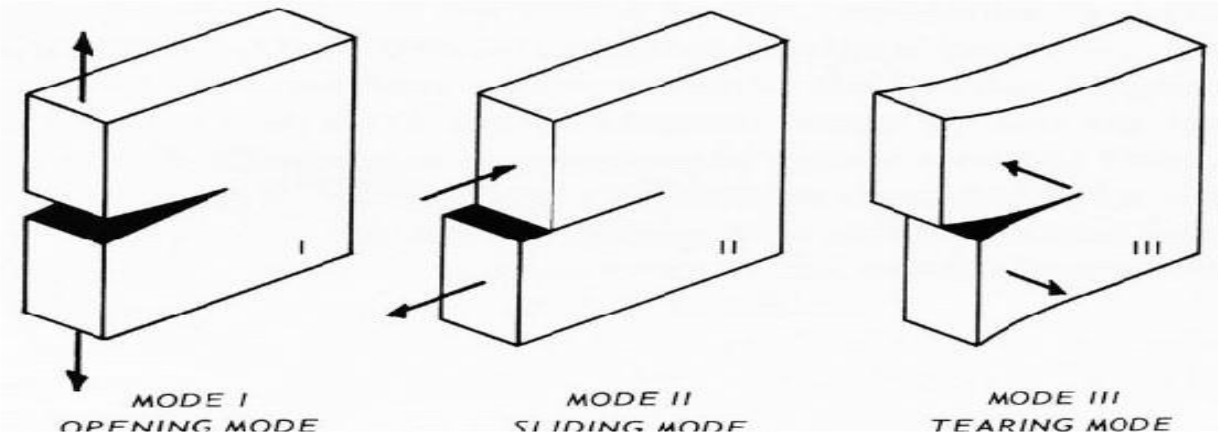
ABSTRACT:

This paper's goal is to use Abaqus software to investigate the fracture behavior of alluminium metal matrix composite (MMC) and compare the results with those of experiments. Al-7075 campact tension (CT) specimens with thicknesses of 5.2 mm are used in crack growth investigations. Fractal parameters including fracture energy, stress intensity factor, fracture toughness, energy release rate, and load displacement relations were evaluated. The stress intensity factor at the crack opening Displacement (COD) level Kic is measured, and the effect of thickness and the stress intensity factor range Δk on Kic is investigated. these metrics are based on different fracture material foundation. When examining how fractures spread across materials, fracture mechanics is crucial. Fracture mechanics is mostly used to comprehend how materials behave.

Keywords : Fracture , Stress Intensity Factor , XFEM crack growth, Abaqus CAE Software

Introduction :

Firstly there are two approaches in the fracture mechanics : linear Elastic fracture mechanics(LEFM) and the elastic- plastic fracture mechanics(EPFM) .The one studied in the present work is the LEFM . The LEFM only considers a small plastic zone around the crack tip and the remaining zone with an elastic linear behavior .The zone where the crack tip is located is a zone with a high concentration of tension .There are 3 loading models shown in fig 1 . which originate a crack and respectively propagation.



The stress, strain and displacement fields near the crack tip are cumulatively represented by a parameter called as Stress Intensity Factor (SIF). When the Stress intensity factor crosses the threshold value called Fracture Toughness (Critical Stress Intensity Factor) which is a material property, the crack starts to propagate. The stress field around the crack tip is asymptotic i.e. theoretically the stress is infinite at the crack tip. Stress intensity factor can be used to evaluate the structural integrity of the component under the given loading and boundary conditions. The critical stress intensity factor for metals can be obtained from the test mentioned in ASTM E399 standard. Another parameter Energy Release Rate (ERR) is used to estimate the energy required for the crack faces to separate and crack growth to occur.

ABAQUS software provides both Conventional Finite Element Method (CFEM) and Extended Finite Element Method (XFEM) for the evaluation of Stress Intensity Factor and Energy Release Rate for different modes.

2 Experimental procedure

Fracture Toughness

For each wt.% of the reinforcement results obtained using computerized fracture testing machine and the maximum load were recorded and tabulated to determine fracture toughness and stress intensity factor.

Increase in the fracture toughness attributed to the uniform distribution, formation of fine particles during, strong interfacial mechanism developed between matrix and the reinforcement, interaction of FE3O4 particles with a crack tip forms residual thermal stress which block the initiation of internal cracks in the composites due to these reasons COD decreases with increase in wt.% of FE3O4 reinforcement . Further, it is evident from the previous works that load bearing capacity of the composites decreases due to the clustering of FE3O4particles in the surrounding matrix and addition of hard FE3O4 leads to the formation of brittle phase.

The fractured specimens after the test, it is noticed that crack propagation in all the specimens appears to be perpendicular to the direction of the load this is realistic for all conventional materials. Hence the Al 7075and different wt. % of FE3O4 composites developed by stir casting process are seems to be free from casting defects. It is also noticed that energy observed by the FE3O4 composites during the plastic region is maximum compared to that of unreinforced alloy. Further, it is evident that beyond 6 wt. % of the reinforcement energy absorption capacity decrease. Hence, optimization of reinforcement wt. % is essential to develop FE3O4composite for present day engineering design and development activities.

Figure: Fractured test specimens

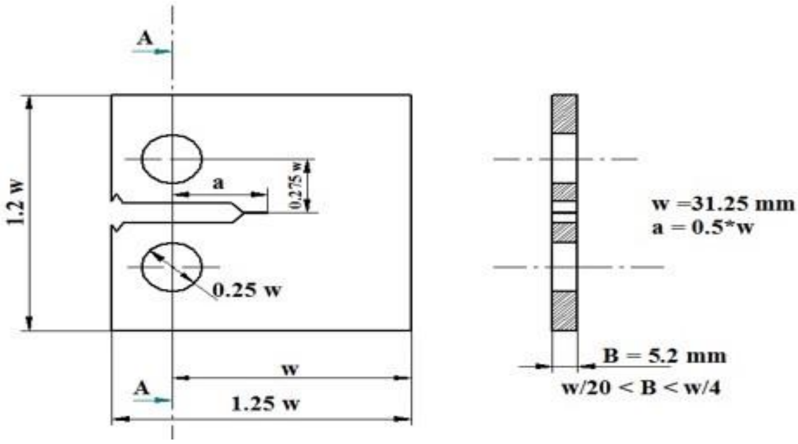


Fig : ASTM E399 Fracture Test Specimen

Stress Intensity Factor (KIC)

Stress intensity factor is one of the important parameters in the fracture mechanics to predict the state of stress near the crack tip when flaws exist and propagate in any structure. In the present research work stress intensity factor of Al 7075and different wt. % of Fe3O4 were estimated theoretically using maximum load obtained from the fracture tests as per ASTM E399 and Equation

$$K_{IC} = \frac{Pmax}{BW}\sqrt{\pi a}$$

Where, P_{max} = Maximum peak load in N

B = Thickness of the specimen W= Width of the specimen

a = length of notch

The stress intensity factors for Al 7075 and 3, 6 wt. % of FE3O4. It is noticed that with increase in the addition of the reinforcement stress intensity factor decreases. Hence, stresses developed in the composites due to the application of the load decreases drastically.

Reduction in the stress intensity factor may be due to uniform distribution of FE3O4 particles, increase in rigidity, interaction of FE3O4 particles with a crack tip starts dominating the toughening process and cause a continuous increase in the fracture toughness of the composite with reduction in KIC.

It is also observed that reinforced FE3O4 particles creates strong interfaces and forms crack bridging that dominant toughening mechanism and resist the micro cracking and its propagation which is most likely responsible for the reduction in the stress intensity factor.

Further, presence of FE3O4 particles resist the crack to propagate in a non-planar fashion thus reducing the energy dissipation at the crack tip which minimizes the crack growth and stress intensity factor. Hence, Al7075 alloy can be considered as a suitable matrix for developing FE3O4 reinforced aluminium based metal matrix composites

SIMULATION RESULTS :

We have done by taking 3 different reinforcement values they are 3%, 6% and we have taken different material properties and load condition for different values we found two different stress values and deformation values figure are shown in the below

For 3%reinforcement by taking material properties and load condition by applying these condition we have found stress value ,deformation value and crack growth value figure are shown below

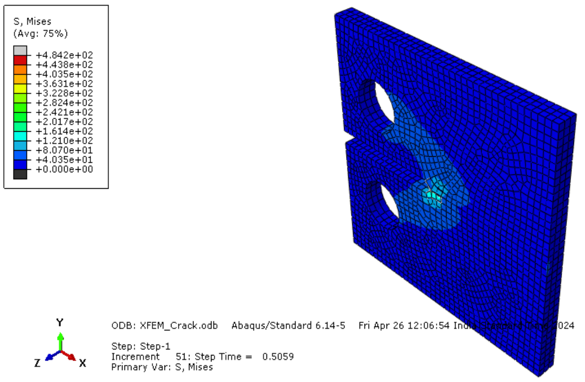


Fig : 3% reinforcement stress

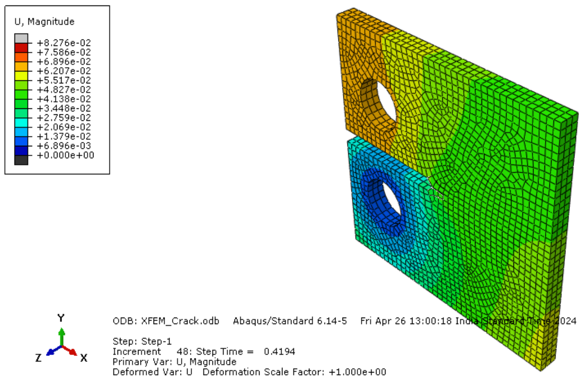


fig : 3% reinforcement deformation

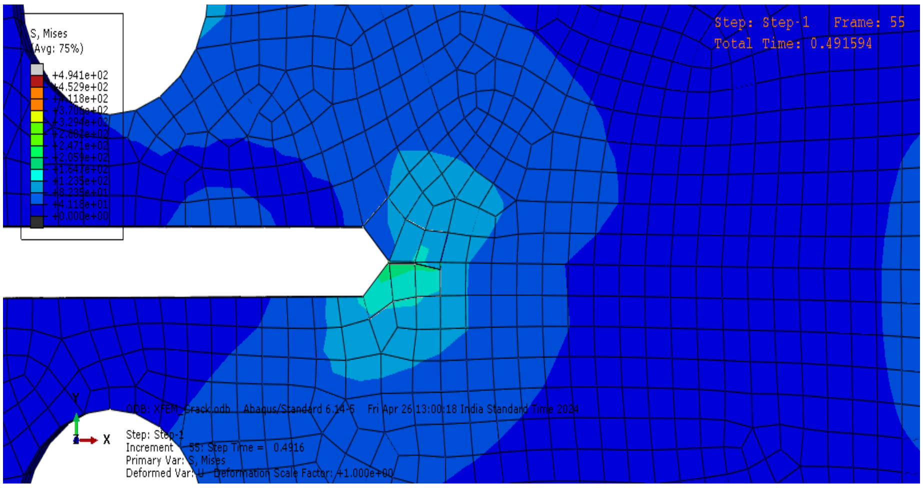


Fig : 3% reinforcement crack growth

For 6 % reinforcement by taking material properties and load condition by applying these condition we have found stress value ,deformation value and crack growth value figure are shown below

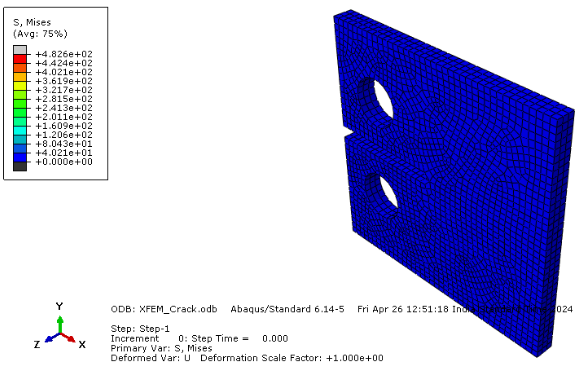


Fig : 6% reinforcement stress

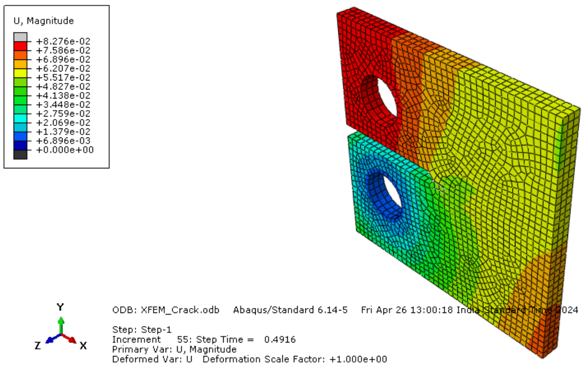


fig : 6% reinforcement deformation

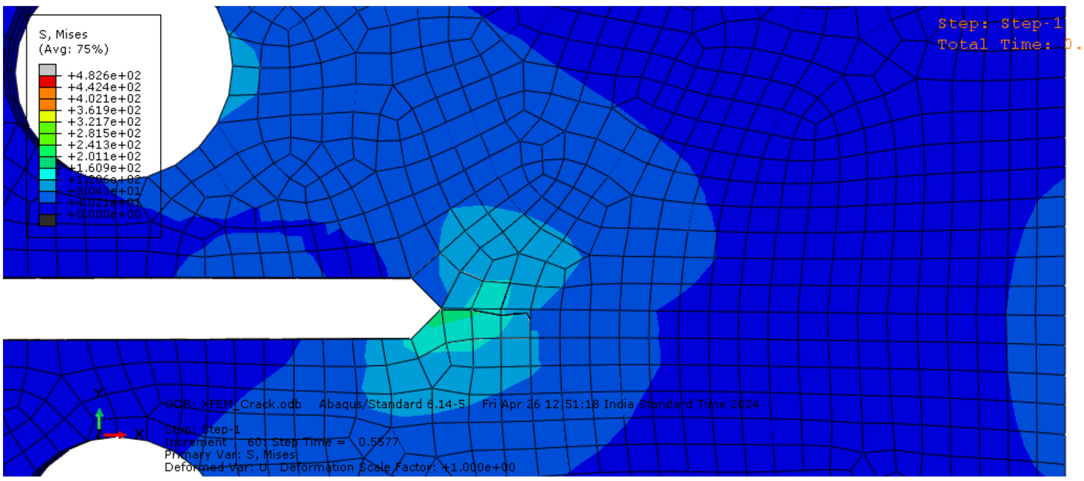


Fig : 6% reinforcement crack growth

CONCLUSION

Fracture analysis of aluminium and metal matrix in Abaqus software provides valuable insights into the behavior and failure mechanisms of these materials.Accurate material properties, proper meshing, and appropriate modeling techniques are essential for reliable fracture analysis.Abaqus offers a wide range of tools and capabilities to simulate crack initiation, propagation, and fracture toughness analysis, allowing for accurate prediction of failure behavior.

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