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Characterization of Failure Surfaces of Epoxy Adhesive Under Various Fatigue Loading Conditions

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In this manuscript an attempt has been made to characterize the failure surface of an important aerospace epoxy adhesive material FM73. FM73 adhesive used was obtained from Cytec Engineering Materials. It is OST (one side tacky) film adhesive (dark green) and has a polyester mat as carrier. Epoxy resin thermosetting adhesives, such as FM73, give good durability when bonding metals and are suitable for bonding structural composite systems as well.

To characterize the epoxy adhesive failure surface, Double Cantilever Beam (DCB) specimens were used for fatigue tests. These tests were performed to study the FM73 epoxy adhesive behavior under mixed mode crack growth. DCB samples were prepared. Mild steel adherends were prepared with dimensions 200 mm x 15 mm x 10 mm and of 200 mm x 15 mm x 7 mm. Repeatable DCBs were prepared in terms of adhesive thickness, initial pre-crack length and same environmental conditions i.e. temperature. The thickness of the mild steel adherends were kept same while they were bonded with the adhesive mentioned, FM73. The joints were tested under a range of both fatigue loading conditions from mode I (opening mode) to mixed-mode (where contribution of opening as well as shearing mode present) were selected to test the bonded joints through the help of variable-mode loading fixture designed[1,2].

A visual and scanning electron microscopy (SEM) investigation showed fracture propagated in a cohesive fashion within FM73 adhesive for almost every test conducted. For SME analysis of the fracture surfaces, samples were gold coated with a 8 nm thick layer. A Hitachi S3200N scanning electron microscope (SEM) was fully used to examine the fractured specimens. A 20kV electron beam was used for scanning to minimize any charging effects. Fig. 1 shows test specimen and corresponding SEM images after pure mode I analysis. A unique feature of the epoxy failure was observed as marked with arrow in Fig. 1(b & e). It is evident that adhesive failed when applied tensile (mode I) force exceeded the bearable strength and the phenomenon is cohesive rather than interfacial. Similar facture modes/features have been reported in literature for epoxy resins [3, 4]. It is suggested from SEM analysis of Figure 1 that initially fracture is dominated by cohesive regime that is later transformed into interfacial. This is attributed due to absence of circular regions in the Figure 1(c & d) that at middle and end positions of test specimen.

Figure 2 shows the mixed mode (mode II dominant) test specimen and related SEM images. The arrow shows the direction of crack propagation. It is suggested that crack growth rate decreases as the crack length increases for fatigue experiments carried out under displacement control. Moreover, it is evident that adhesive fracture is clearly different in both failure modes. There is no evidence of circular regions (cohesion failure) in Figure 2(b to f). This suggests that fracture is dominated by a combination of cohesion and interfacial of the epoxy resin and is limited by the presence of polyester. The applied stress tends to distribute around fibers. Therefore, this failure is suggested to be not pure cohesive rather than a mixture of both cohesive and interfacial.

Finally, it is suggested that the “fibre- like” features on fracture surface correspond to the polyester in the adhesive. Crack may tend to grow in and around this carrier rather than remaining within the bulk of the adhesive layer. It is presented with evidence that the cohesion failure is dominating under mode I and both cohesion and interfacial failures are critical under mode II.

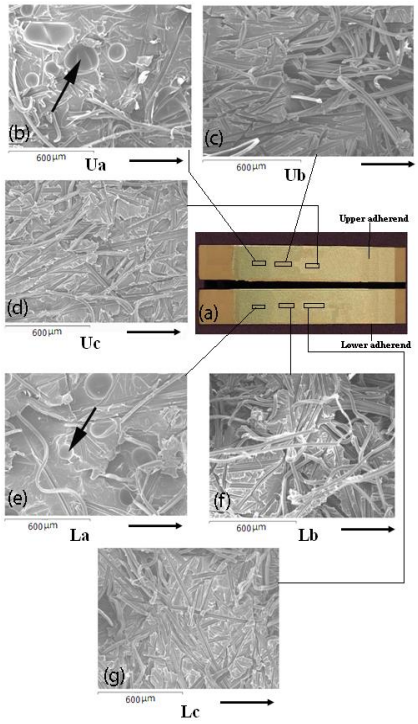

Figure 1. SEM images of Mode I fatigue surfaces

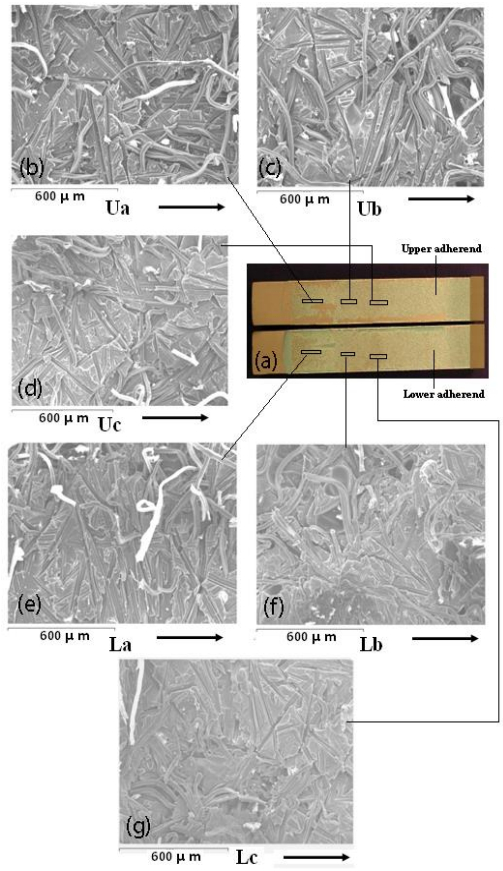

Figure 2. SME images of Mixed-Mode fatigue specimens

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