Modeling of crack diffusion in composite materials

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Abstract. Our aim is to investigate the crack diffusion created at single region of composite materials by using the fiber bundle model. So, we have applied an external single crack in one fiber of the composite material, and we then continue to increase this load at a very slow rate until the considered fiber breaks and its load is redistributed to its neighboring intact ones. This breaking and redistribution dynamics repeat itself and this process ensures an advancing interfacial fracture and the area of the damaged region increases with time until a final crack of material. Our calculations are done in the context of the local load-sharing rule. The results show that the damaged region area increases with time by following the Lifshitz-Slyozof law with an exponent growth $x=2$. This permits us to deduce the behavior of the crack diffusion with the applied load. The corresponding results of the life time materials exhibit an exponential decreasing with the applied load and a linear decreasing with temperature.

1. Introduction

Focusing on the use of naturally different substances in the onset frucster has ever been the issue of several surveys in the engineering community for its mere technological developments. In fact, the somatogenetic handling, sometimes meant as an indispensable separation, is apparently causing a vast waste of time for extreme macroscopic blockage of the solid, while depending on the amplitude of the applied stress [1–3]. That is why scientists are actually devoting a great deal of time to tackle many theories and experiments for the clarification of the unpredictable fractures, e.g., the velocity of propagation, the roughness, and the onset of precursors.

In the contrast, the fiber bundle model describes a collection of elastic fibers under load. The fibers fail successively and for each failure, the load distribution among the surviving fibers changes. Even though very simple, this model captures the essentials of failure processes in a large number of materials and settings. This model has been studied extensively since it can be analyzed to an extent that is not possible for more complex materials [4–6]. The statistical distribution of the magnitude of avalanche phenomenon in fiber bundles is well studied [7–9], and the failure dynamics under constant load has been investigated through recursion relations which in appears a phase transitions and associated critical behavior in this model [10]. However, there are two extreme rules which consider a bunch of fibers hanging from a rigid ceiling and a platform is connected to the ends of these fibers and a load hangs from that plat form. Once the fibers begin to fail, we can distinguish two transfer load type: Global load sharing (GLS) in which the load of a broken fiber is equally shared with all intact fibers in the whole system. We assume a long-range interaction among the fibers and we treat analytically the problem by using the mean-field approximation [3]. The other type consists in a local...
load sharing (LLS), in which the terminal load of the failed fiber is distributed equally to all the nearest neighboring intact fibers.

Hence, one creates the initial applied load localized at an arbitrarily chosen central site in the framework of the local load-sharing fiber bundle model. So, initially, no load is applied on any fiber except for the one at the central site. As the applied load increases beyond the failure threshold of this central fiber, it breaks and the load carried by it is redistributed among its nearest neighbors and so on.

In this paper, we study the crack diffusion in composite materials subject to a local load-sharing fiber bundle model in two dimensions under an external load applied at a single point. By the use of the local load-sharing rule, the redistributed load remains localized along the boundary of the broken patch.

2. THE MODEL

The fiber pack product identifies accumulation flexible materials below load. Under some conditions when the length of the fibers of the composite material exceeds its breaking critical value, the material cracks [11]. So, for every single disappointment, the strain circulation one of the remaining materials changes. Ergo, that creates a feedback method that could make the sum total disappointment of the system. Although quite simple, that product reflects the necessities of disappointment procedures in a significant number of components and settings. We provide here evaluation the fiber pack product with various fill redistribution elements from the function of see of data and mathematical science as opposed to components technology, with an emphasis on ideas such as for example criticality, universality and fluctuations.

We contemplate a deal of size \( M \) consisting of a big quantity of materials held at equally ends. We examine equal-load-sharing versions in which the fill formerly moved by an unsuccessful fiber is distributed similarly by closest friend unchanged materials [12–15]. The pack middle is at the mercy of an area regular additional tension similar to the fibers direction. The strain moved by that fiber is redistributed similarly among their closest remaining neighbor(s). In that way, the materials which are just confronted with the strain, state, following an avalanche, has a somewhat minimal fill than the people that are accumulating fill gives from the sooner problems and surviving. Within our function we think that the original regional load \( f_0 \) is likely to be corresponding to the unchanged materials which stimulate an original elongation \( \delta l_0 \) distributed by the Hooke's legislation:

\[
\delta l_0 = \frac{f_0}{k}
\]

(1)

where \( k \) denotes the stiffness, which is assumed to be the same for all the fibers. The local elongation of fibers \( i \) have time-dependent fluctuations due to the presence of thermal noise load and to load transfer following breaking events given by:

\[
\xi_i = \gamma l_0 \sqrt{K_B T}
\]

(2)

Where \( l_0 \) is the initial length of fibers and \( K_B \) is the Boltzmann constant and is coefficient of proportionality. The presence of the thermal noise will affect the lifetime for a constant applied stress controlled by the temperature \( T \) of the system [2,9]. So, the actual stress arising \( \delta l \) of fiber \( i \) is written as:

\[
\delta l_i = \delta l_0 + \xi_i
\]

(3)

3. THE RESULTS

Originally, we used a lot on a single fiber devoted to the material. We then keep on to boost force at a really gradual charge before the focused fiber pauses; force moved by its redistributed similarly among their four neighbors. Because we keep on to boost force just on the materials which are presently
holding a nonzero fill, that breaking and redistribution character replicate itself. This method guarantees a developing interfacial fracture and the location of the ruined location raises. That subject has been commonly learned around years, equally theoretically and experimentally [16-17] in the Plexiglas try out two dishes were taken and condition was presented by sandblasting and then were joined together creating a clear stop by having a simple plane. Therefore, when we continue to increase the external load, the material cracks totally at time $t_f$. So, the corresponding results of the calculation of the lifetime are plotted in fig 1. We remark clearly that the lifetime decreases exponentially with the applied load. The same result has been found in the two cases when we applied the external load on all intact fibers of the materials (LLS rule [2] and GLS rule [3]).

![Fig 1: the lifetime versus applied load for system of size $L=500$](image)

To be able to investigate the crack diffusion created in the midst of the material, we have determinate the full-time evolution of the region $A$ of the damaged region versus both applied load $f$ and temperature $T$. The corresponding answers are plotted in fig 2. The obtained results reveal that the damaged region increases with applied load and they are more consisting with the Lifshitz-Sloyosof law:

$$A = B(T)t^x$$

(4)

where $x$ is crack diffusion exponent and $B$ is a constant which depends only on the system temperature and related to the diffusion coefficient of the created crack by:

$$D \propto B(T)^{1/x}$$

(5)

So the calculated value of the diffusion exponent of the created crack is $x \approx 2$. 

Fig 2: the time evolution of the era of the damaged region for two different values of the applied load

Utilising the formula (5), we have determined the diffusion coefficient of the created crack versus applied load. The corresponding results are plotted in fig 3. Therefore, we are finding that the diffusion coefficient increases linearly with the applied load.

Fig 3: the diffusion coefficient versus applied load for system of seize $L=500$

4. CONCLUSION

To sum up, we have investigated the crack diffusion created at single point of the composite materials by using the fiber bundle model in the local load sharing rule. So, we have considered a fiber bundle
on which we have applied an external load at a single point, and we then continue to increase this load
at a very slow rate until the centered fiber breaks and its load is redistributed to its neighboring intact
fibers. This breaking and redistribution dynamics repeat itself and this process ensures an advancing
interfacial fracture and the area of the damaged region increases with time until a final crack of
material. The equivalent effects display that place reveals a Lifshitz-Sloyosof law with an exponent
growth \( x=2 \). The discovered law enables us to deduce the conduct of the crack diffusion coefficient.
We are finding that the developed split in the midst of the material rises linearly with used fill.

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