# MODELING OF GLASS MATRIX COMPOSITES BY THE COUPLED CRITERION AND THE MATCHED ASYMPTOTICS APPROACH. THE ROLE OF A SINGLE PLATELET.

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**Abstract**
The fracture toughness of glass can be increased by introducing a second constituent with high modulus, strength and/or ductility. Among others, a very attractive solution for industrial proposes is the borosilicate glass/$Al_2O_3$ platelet composite. Hence, in this work different toughening mechanisms in this composite are analysed from the point of view of the Coupled Criterion, together with the Matched Asymptotics approach.

## 1. Introduction

One of the main drawbacks of glass is its very low fracture toughness, which is faced by the addition of a second constituent. An example is the borosilicate glass/$Al_2O_3$ platelet composite, in which alumina platelets are embedded in a glass matrix. According to literature, different toughening mechanisms were experimentally observed, some of them related to a change in the crack path. Therefore, the aim of this work is to study the effect of such toughening mechanisms, considering the role of a single platelet. In Fig. 1 a scheme of the problem is shown. It can be observed that the dimensions of the platelet are much smaller than the ones of the specimen. For this reason, a special emphasis is put in the analysis of the size effect. In experiments the length of the platelet is $d = 5 - 25\mu m$. However, a huge range $d = 2 - 300\mu m$ is considered in this study. For each value of $d$ the so-called apparent fracture toughness of the composite, $K_{IC}^{app}$, is obtained through the application of the Coupled Criterion (CC). Moreover, Matched Asymptotic Expansions with respect to $d$ are -used to reduce the excessive mesh refinement due to the smallness of the platelet, in comparison with the dimensions of the specimen. In addition they allow a single calculation whatever the platelet size.

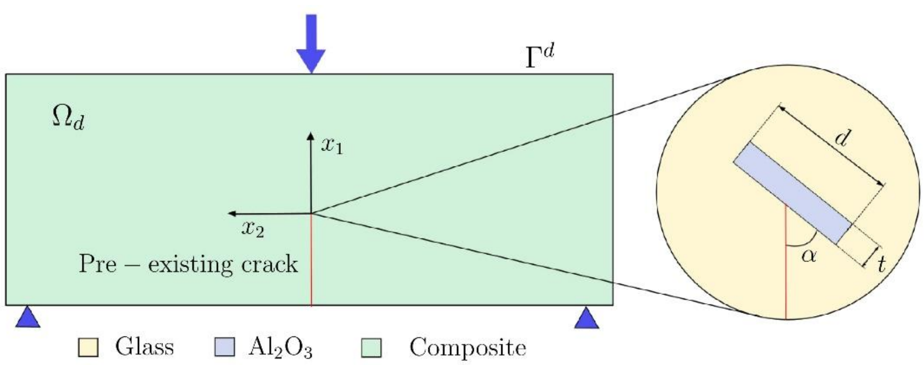


Fig.1 – Schematic view of the symmetric 3-points bending test. An alumina platelet with a certain inclination $\alpha$ is embedded in the glass matrix. The pre-existing crack impinges the platelet.

## 2. Results

In this study different orientations of the platelet $\alpha = 0^o, 90^o, 45^o$ are considered:

a. Orientation $\alpha = 0^o$: the platelet is parallel to the pre-existing crack, and therefore there is just one possible crack path, the one through the interface glass-alumina. For very short platelets it is observed that there is no enhancement in $K_{IC}^{app}$ with respect to the fracture toughness of glass $K_{IC}^{g}$. In that case the presence of a single platelet is not enough to enhance the apparent fracture toughness. It means that other toughening mechanisms should be invoked for improving $K_{IC}^{app}$ , such as a significant increase in the mechanical properties. Moreover, the newly created crack length depends on the platelet size. If the platelet is very short initiation ends in the glass region, whereas if it is long enough it remains along the interface glass-alumina.

b. Orientation $\alpha = 90^{o}$: the platelet is perpendicular to the pre-existing crack. In that case, different crack paths are studied, looking for the predominant mechanism, i.e., the crack path related to the lowest value of $K_{IC}^{app}$. Hence, in Fig. 2 an example of this comparison is shown.

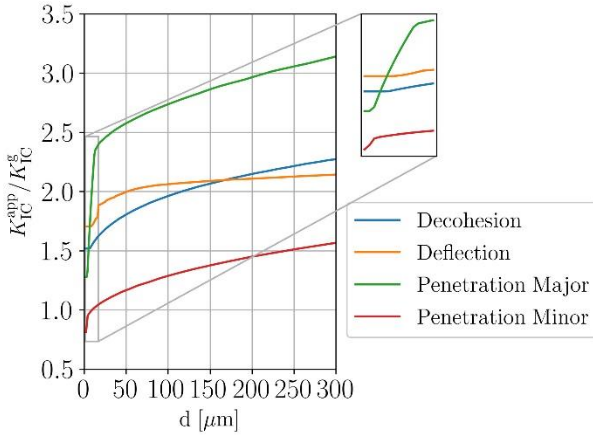


Fig.2 – Evolution of $K_{IC}^{app}$ /$K_{IC}^{g}$ with respect to the length of the platelet $d$, for a single deflection, a decohesion and a penetration, when α = 90◦.

Notice that no experimental data were provided for the fracture properties of alumina, being these parameters even more difficult to obtain, since they sometimes differ from the values measured in a bulk material. For this reason, a range for the tensile strength $\sigma_c^a$ and the fracture toughness $K_{Ic}^{a}$ is considered in this analysis. Consequently, there are two cases for penetration, so-called major penetration and minor penetration. They are related to the lowest (minor) and the highest (major) values in the alumina fracture properties. When the properties of alumina are not big enough the crack penetrates into the platelet, otherwise for long platelets either a decohesion either a deflection can occur. It was also observed that the alumina fracture toughness $K_{IC}^{a}$ plays a more important role in the evolution of $K_{IC}^{app}$ than the alumina tensile strength $\sigma_c^a$.

c. Orientation $\alpha = 45^{o}$: as in the previous case a comparison among several possible crack paths is made. For very long platelets the crack increment remains either along the interface glass-alumina or inside the alumina platelet. For very short cracks the crack growth is unstable and it ends in the glass region.

## 3. Conclusions

One of the main conclusions obtained in this study is the size effect observed in the problem. For very short platelets the failure is produced due a lack of available energy in the platelet, i.e. the energy condition is governing the failure. Moreover, if the size of the platelet is small enough the crack propagation is unstable, joining the glass region beyond the platelet, whereas for long platelets the crack has a stable growth, and the crack increment remains inside the platelet, or along the interface glass/alumina. Furthermore, a study of the influence of alumina fracture properties has been made, from which it can be concluded that $K_{IC}^{a}$ has a greater effect than $\sigma_c^a$.

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