Polymeric materials toughness measurement by statistical fractography

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Abstract
Parts made of polymers play an ever increasing role in many different industries (i.e. aerospace, medical, automobile, etc…) which are attracted by their very interesting material properties. Therefore, there is a need to understand why and how these parts fail to prevent incidents, reduce cost, and move toward a more sustainable approach to the dimensioning of structures made of this type of material. Here, we seek to apply the statistical fractography method to polymers to achieve this goal.

1. Introduction

The recently born field of statistical fractography emerges from the desire to go beyond the simple qualitative interpretation of fracture surfaces resulting from the failure of a material, and infer from it both its mechanical properties and the root-causes of its failure [1][3][4]. This quantitative approach of the field is based on a deep understanding of the non-linear damage mechanisms at play at the crack tip during propagation, and that is expressed through a model used to bridge the measured fracture surface's roughness and the fracture properties of the material, such as its toughness K_c. This new approach has been showed to predict the crack propagation direction, the local toughness values, as well as the critical stress at the onset of failure in a wide range of materials, including alloys, rocks, and ceramics. These information, measured post-mortem on the fracture surfaces of materials, turn out to be particularly precious to determine the reasons behind a catastrophic failure. However, this method is still poorly predictive for polymeric materials. The reason ? A lack of understanding of the role played by the different dissipative mechanisms at play during crack growth (i.e. visco-elastic flow) during failure and their influence on material toughness K_c

2. Results

Here, we conduct fast fracture experiments on PMMA (Poly(methyl methacrylate)) using high speed cameras, and deploy digital image correlation (DIC) methods to measure a displacement field at the free surface of the specimen. The extracted displacement around the crack tip is then turned into boundary conditions for a finite element simulation numerically reproducing the experiment. This approach allows us to accurately measure the material toughness K_c as the crack propagates, as well as some cohesive zone parameter, as presented in [2]. In parallel, we do a post-mortem analysis of the same specimen to extract meaningful lengths related to damage processes that we can finally relate to the material toughness through micro-mechanics model of crack propagation.

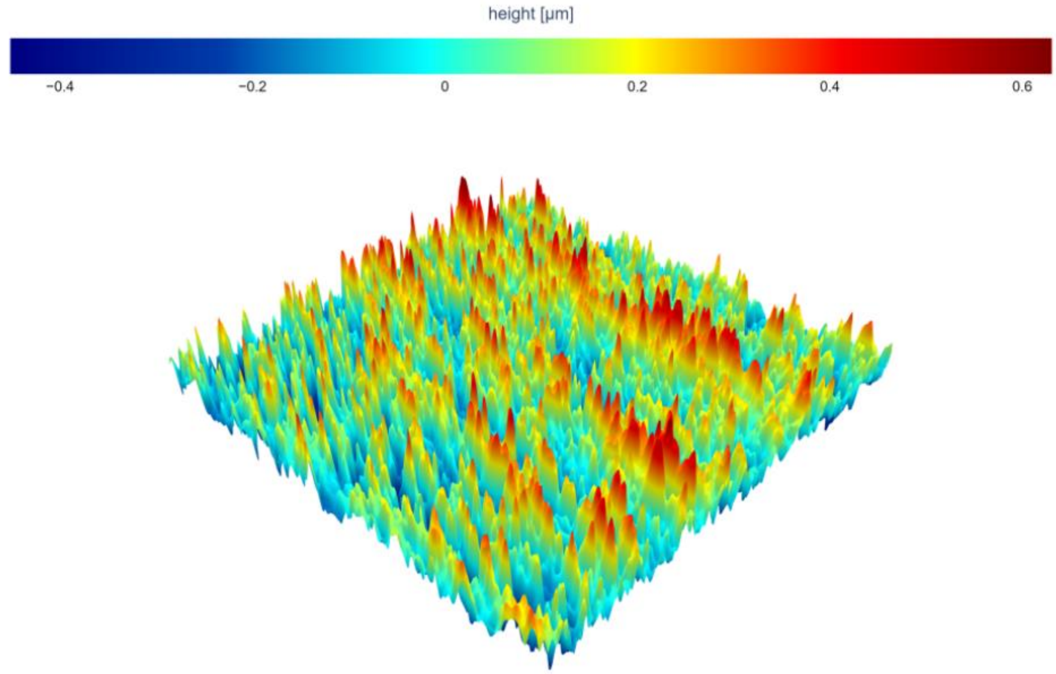

Figure 1: Fracture surface height map of PMMA obtained by interferometric profilometry

3. Conclusions

We show that our fractographic approach provides reasonable estimate of the fracture toughness, paving the way for the application of statistical fractography to the failure analysis of polymeric parts.

4. References

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