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INVESTIGATION OF MIXED MODE I AND II FRACTURE MECHANICAL BEHAVIOUR OF SLS PRINTED IASCB SPECIMENS BY DIGITAL IMAGE CORRELATION

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ABSTRACT

This work focuses on the fracture mechanics properties of polyamide (PA) for selective laser sintering (SLS) and investigates the capability of additive manufacturing process to build 3D artificial cracks, otherwise impossible to create by classic methods.

IASCB semi-circular specimen with tilted crack subjected to asymmetric three-point bend loading were tested in order to cover a wide range of stress intensity factors (KI, KII and mixed modes) and T-stress. Moreover, Digital Image correlation (DIC) technique was used by full strain field analysis with the purpose of evaluating the fracture behaviour.

Keywords: Additive manufacturing, Fracture mechanics, Stress intensity factor, Mixed mode, IASCB specimen, Elasto-plastic crack, Digital image correlation.

INTRODUCTION

Additive manufacturing is a recent and promising technology which in the last decades has become widespread in many different fields. However, the mechanical behavior of the used materials has not been completely investigated, especially for what concerns fracture behavior. Brugo et al. (2016) have shown on CT specimens that it is possible to insert intentionally cracks in any desired direction during the AM process and that the building direction influences the fracture toughness.

IASCB specimens (Saghafi, 2010) were manufactured by SLS with an EOS Formiga P100 using polyamide PA 2200 powder. This specimen is a semi-circular disk of radius R that contains a radial edge crack tilted with respect to the load direction. Cracks were initiated in two different ways: they were manufactured during the sintering process or manually initiated after the manufacturing (only for mode I). A total of 15 SLS specimens were manufactured with different crack angles with respect to a vertical axis (0°, 10° and 50°) and tested with different support spans in order to obtain different crack opening mode combinations. The stress intensity factors were obtained by the classic mechanical test and by the DIC measurement of the displacement and strain field developed at the crack tip. This approach was already used in literature (McNeill, 1987) on various types of specimens and proved to be feasible for linear elastic fracture problems.

RESULTS AND CONCLUSIONS

The experimental fracture tests conducted on IASCB specimens are summarized in the graph of Fig. 1, where red and blue circles represent SLS and manually induced crack, respectively.

The KIs of the manually induced crack specimens result to be about 10% lower than the SLS ones, because the crack tip is sharper than the printed one due to the limit of the printing resolution (0.1mm). The experimental data points of the SLS printed cracks were compared with the theoretical criterion MTS (Maximum Tangential Stress) and GMTS (Generalized Maximum Tangential Stress). Cleary the GMTS curve fits better because of the fact it also takes into account the effect of T-stress.

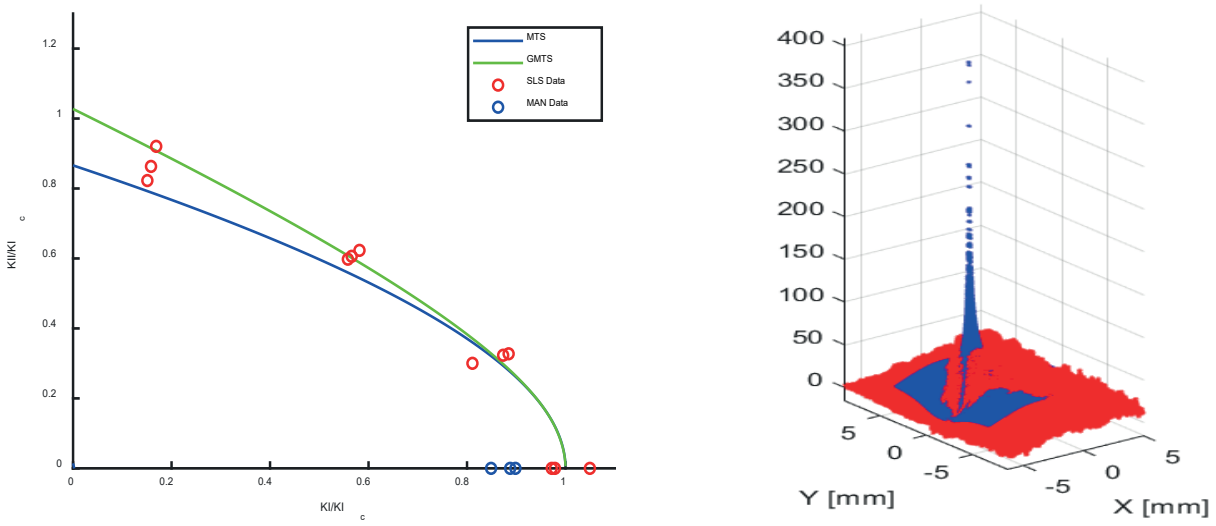

Fig 1 - Mode I and II fracture mechanical results, compared with MTS ang GMTS model (left). Experimental stress field developed at the crack tip compared with Irwin theoretical model for stress (right).

As can be seen in Fig. 1 (right), due to the elasto-plastic behavior of the material, the Irwin theoretical model does not fit well the DIC data. In order to overcome this issue an approach based on the J Integral can be utilized and will be the next development of the research.

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