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Review article

Effect of fibre content and notch radius in the fracture behaviour of short glass fibre reinforced polyamide 6: An approach from the Theory of Critical Distances

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A B S T R A C T

This paper presents an analysis of the notch effect on the fracture behaviour of short glass fibre reinforced polyamide 6 (SGFR-PA6) with different amounts of fibre content. The research is based on the results obtained in an experimental programme composed of 125 fracture specimens, combining five different fibre contents and five different notch radii. Concerning the apparent fracture toughness, a clear notch effect has been observed, with an increase in the fracture resistance when the notch radius increases. Moreover, the apparent fracture toughness has been reasonably predicted through the Theory of Critical Distances. The results have also shown a direct relation between the apparent fracture toughness and the fibre content. The research is completed with the Scanning Electron Microscopy analysis of the evolution of the fracture micromechanisms when both the notch radius and the fibre contents increase.

Contents

1. Introduction

Notched components present an apparent fracture toughness (i.e., the fracture resistance in notched conditions) which is greater than the fracture toughness observed in cracked components (e.g., [1–13]). Hence, when performing fracture assessments, it may be over-conservative to consider that notches behave as cracks and it is therefore necessary to consider the actual behaviour of notches.

There are two main failure criteria in notch theory: the global criterion and the local criteria [1,2]. The global criterion is analogous to the fracture analysis in cracked components, and establishes that fracture takes place when the notch stress intensity factor (K_ρ), which defines the stress and strain fields in the vicinity of the notch tip, reaches a critical value (K_ρ^C). This approach is of unquestionable significance, but its application is highly limited because of the lack of analytical solutions for K_ρ, or/and standardised procedures for the experimental definition of K_ρ^C.

As regards local criteria, these are based on the stress-strain field at the notch tip and are easier to apply than global criteria. The most important are the Point Method (PM) and the Line

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Nomenclature

a	notch length
e	maximum strain
E	Elastic modulus
K_ρ	notch stress intensity factor
K_ρ^C	critical notch stress intensity factor
K_I	stress intensity factor
K_{IN}	apparent fracture toughness
L	material critical distance
ρ	notch radius
σ_U	ultimate tensile strength
σ_0	material strength parameter (the inherent strength)
$\sigma_{0.2}$	0.2% proof strength
LM	Line Method
PM	Point Method
SEM	Scanning Electron Microscopy
SGFR-PA6	Short glass fibre reinforced polyamide 6
TDC	Theory of Critical Distances

Method (LM), both being variations of the Theory of Critical Distances (TCD), explained in Section 2, by which estimations of the apparent fracture toughness exhibited by notched components may be easily derived. The resulting expression of the LM is particularly simple, and provides similar predictions to those generated by the PM [14]. Thus, for the sake of simplicity, the analysis here will be focused on the LM estimations.

The notch effect phenomenon has been widely analysed in numerous works with thousands of experimental data (e.g., [1,14–17]), whereas the application of the TCD to analyse the notch effect in particular materials has been widely validated (e.g., ceramics [7], alumina and sod-lime glass [8], PMMA [9], Al7075-T651 [10], steels S275JR and S355J2 [11], steels S460M and S690Q [12], granite and limestone [13]).

Short fibre reinforced thermoplastics (SFRTs) constitute an important class of technical plastics which are replacing metal parts in engineering components due to their easy fabrication and good mechanical properties [18]. The monomer of PA 6 is one of the most common commercial grades for moulded parts, leading to high strength, high stiffness, good toughness, translucency, good fatigue life and good abrasion resistance [19]. Reinforcing PAs with short glass fibres leads to a significant increase in strength, stiffness, heat distortion temperature and abrasion resistance, although

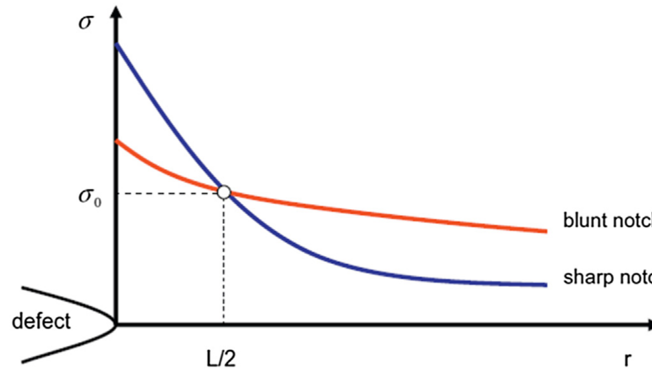

Fig. 2. Obtaining L and σ_0 parameters.

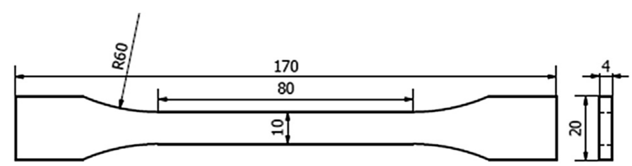

Fig. 3. Tensile specimens dimensions (mm).

properties can be anisotropic (including mould shrinkage, which implies potential distortion). In the case of PA 6 – unlike many polymers – this is achieved without loss of impact strength, but strain at fracture is reduced substantially [20]. In recent years, as a consequence of these favourable properties, SGFR-PA6 has found an increasing number of applications in the automotive [21] and railway industries [22]. Such applications imply the existence of notches or stress risers that may jeopardise the structural integrity of the corresponding component. Fig. 1 shows a short glass fibre reinforced polyamide flanged plate [23,24] used in Spanish high speed railway lines.

Thus, the aim of this paper is to analyse the notch effect in SGFR-PA6 with different amounts of fibre content, and to validate the use of the TCD in the analysis of this effect in this particular material. Moreover, it is intended to relate the macroscopic (fracture) behaviour of the material with the fracture micromechanisms occurring at the notch tip.

With all of this, Section 2 gathers some theoretical background on the TDC, Section 3 describes the experimental programme used to analyse the notch effect and to validate the LM application in

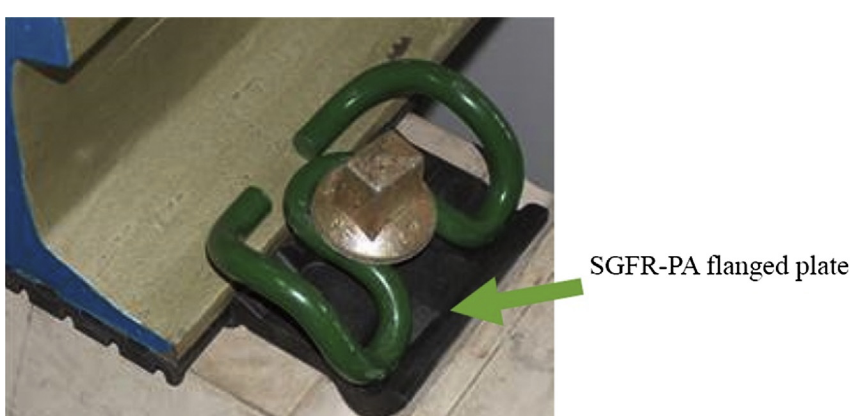

Fig. 1. Railway fastening system [24].