

FRACTURE TESTING OF IMMISCIBLE POLYMER BLENDS:- ACTIVITIES
OF VAMAS TECHNICAL WORKING PARTY

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This paper outlines the activities of the Versailles Project on Advanced Materials and Standards (VAMAS) Technical Working Party on Polymer Blends (TWP-PB), with particular emphasis on the characterisation of the fracture properties of engineering grades of immiscible polymer blends. Determination of fracture mechanical parameters in such materials is complicated by inhomogeneity and anisotropy in the samples.

BACKGROUND

VAMAS is an international scheme to stimulate the introduction of advanced materials into high technology products and engineering structures, with the overall aim of encouraging international trade in such materials. The organisation seeks international agreement on codes of practice and performance standards and encourages multilateral research aimed at furnishing the enabling scientific and metrological base necessary to achieve agreement on standards. VAMAS operates under a Memorandum of Understanding signed by senior representatives of government in the participating countries : Canada, France, FRG, Italy, Japan, UK, USA and the CEC (VAMAS Bulletins (1)).

There are currently fourteen active Technical Working Parties covering a wide range of advanced materials and technologies; this article relates to TWP4 - Polymer Blends.

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TECHNICAL WORKING PARTY ON POLYMER BLENDS

Immiscible polymer blends.

Blends and alloys of engineering polymers are rapidly gaining acceptance as structural materials, replacing parts traditionally made in metal. This new emphasis on polymer blends is increasingly evident in the automotive industry. Immiscible polymer blends can offer a particularly promising balance of properties - they can be made resistant to fracture without serious detrimental effects on the stiffness of the material or its thermal stability.

At one extreme, immiscible polymer blends are prepared by mechanical melt mixing of two homopolymers which are mutually incompatible, without any attempt to stabilise the morphology. Such a blend may exhibit a fairly coarse morphology, with the dispersed phase forming domains on the scale of 10 μm or larger (Fig.1). These domains become more or less oriented during processing of the material, depending on the processing conditions (temperature, shear, shear rate, pressure).

On the other end of the scale, it is possible to achieve extremely fine (sub-micron) dispersions of one polymer in another, or co-continuous structures on a small scale. Such well compatibilised blends will exhibit homopolymer-like behaviour and can be characterised by already standardised measurement techniques. However, an increasing number of commercial blends are formulated with only partial compatibilisation between its component homopolymers; under specified processing conditions the dispersed phase can then be deformed into a desired morphology, such as fibrils, lamellae or platelets.

For such a complex material to be used reliably, it is necessary to be able to predict the performance of the material for a given structure and for a given processing route. The following relationships therefore need to be established :

- processing conditions and morphology stability;
- morphology and properties.

The activity of the VAMAS TWP-PB is directed to address both these relationships by considering the melt rheology, the thermomechanical characteristics and the mechanical properties of immiscible blends in

relation to their morphology. The first necessary step has been to identify the minimum set of test methods which can be used to provide a meaningful characterisation of a blend. The author of the present article is responsible for the co-ordination of the mechanical properties characterisation part of the activity; the article therefore concentrates on this aspect.

Characterisation of mechanical properties.

Polymer blends exhibit **viscoelastic behaviour** which needs to be taken into account when determining parameters such as the elastic modulus or the yield stress of the material. If the values of these parameters are to be used in the treatment of fracture data, then they need to be determined under loading conditions (strain, strain rate) relevant to the fracture test. In practical terms, the brittle-ductile transition temperature of a polymeric material depends on the conditions of test (Fig.2).

The above considerations apply equally to homopolymers, miscible blends and immiscible blends. The polymer blends of most interest commercially in addition exhibit highly **non - linear stress-strain** characteristics at ambient temperature and above. Modulus values are therefore highly strain dependent and yield stresses cannot be determined unambiguously by any 'deviation from linearity' or 'off-set' procedures.

The greatest problem, in terms of test procedures, arises from the **inhomogeneity and anisotropy** of morphology, inherent in the nature of immiscible polymer blends. In this respect, the blends should be considered as particulate composites, closer in their nature to short-fibre reinforced thermoplastics than to homopolymers or miscible polymer blends. No standards are currently available to take into account the morphology - property relationships in these types of materials.

Morphology - property relationships.

Rubber - toughened thermoplastics such as high impact polystyrene or toughened nylons are the only class of immiscible polymer blends in which fracture properties have been studied extensively and in relation to the material morphology (Bucknall (2)). In

comparison, the thermoplastic - thermoplastic blends are much newer materials, with an incomplete and inconsistent data base.

Fracture properties database. Although most blend producers quote a "fracture resistance" for their material, this is in practice of very limited use to a designer or a material selector. The only truly reliable assessment of a material's suitability for a proposed application remains making the appropriate part and testing it. In addition to the obvious cost implications, this approach still has limitations when applied to blends in which morphology may be critically dependent upon exact processing conditions : even a slight change in part design may alter the strength and the position of the 'weak spots' in the structure. There appears, therefore, to be a need for detailed morphology - fracture evaluation of at least some representative blend types.

Approach used by the VAMAS TWP-PB. The above stated problem relating to the fracture properties characterisation of polymer - polymer blends having a particulate and unstable morphology is being tackled on two fronts:

a) by the evaluation of the limits of applicability of current fracture mechanics methods to these types of materials; in collaboration with the EGF Task Group on Polymers and Composites;

b) by a further investigation and modification of more empirical methods, such as the use of the Charpy test to determine brittle - ductile transition temperature for a given geometry specimen.

A particularly serious problem is the need for thick (> 6 mm) specimens for the fracture mechanics tests. Not only are such thick sections extremely difficult to produce from the blends under consideration, the morphologies obtained in them may also be quite unrepresentative of those obtained in thicknesses of material actually used in structures.

A compromise between the a) and b) approaches may be a suitable solution to the problem - development of a method based on the essential work of fracture is being pursued (VuKhanh (3)).

OVERVIEW

This contribution seeks to draw attention to and illustrate some of the problems encountered when attempting to apply the normally accepted fracture tests to immiscible polymer blends. The complex and coarse morphology of the materials is the cause of **large scatter** in fracture values, such as would be quite unacceptable for metals or homopolymers.

To what extent can this scatter be rationalised by taking into account the relationship between the crack trajectory and the directionality of the morphology?

In a material in which large scale debonding between the phases can occur prior to final fracture, what validity requirements should be met to ensure a 'plane strain' condition?

Is fracture mechanics a practical, or indeed relevant, approach to the characterization of this type of material? If not, then what approach should be taken?

REFERENCES

- (1) VAMAS 6-monthly bulletins, available from the VAMAS Secretary, National Physical Laboratory, Teddington, Middlesex, England.
- (2) Bucknall, C.B., Macromol. Chem., Macromol.Symp., Vol. 16, 1988, pp. 209-224.
- (3) Vu Khanh, T., Polymer, Vol. 29, Nov. 1988, p.1979.

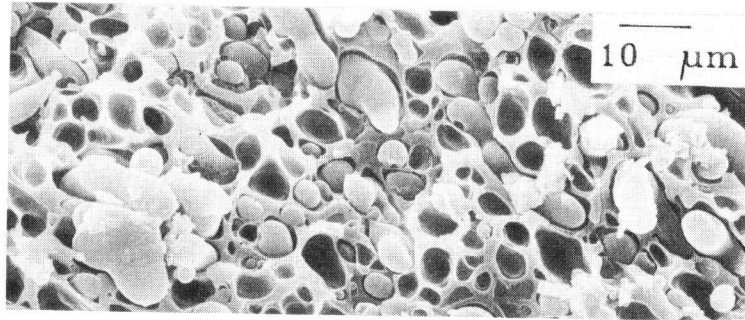


Figure 1 SEM of a cryo-fracture surface of non - compatibilised blend of polycarbonate (75 wt.%) and LLD polyethylene (25 wt.%), fractured transverse to sheet extrusion direction.

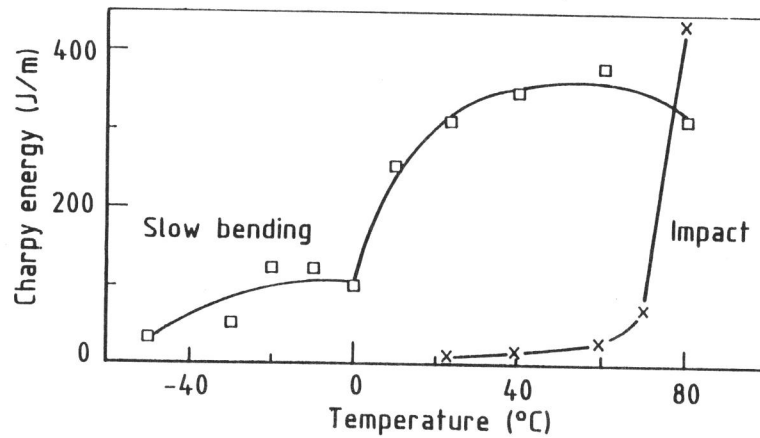


Figure 2 Brittle - ductile transition in a commercial polyamide 6 / polypropylene blend at crosshead speeds of 10 mm/min (slow) and 3 m/s (impact). Samples 6x12x60 mm, razor notched to depth of 6 mm. Span 48 mm.