Journal of Applied Mechanical Engineering
ISSN: 2168-9873

Chang and Wang, J Appl Mech Eng 2012, 2:1
DOI: 10.4172/2168-9873.1000e110

Editorial Open Access

Cutting Tests: A New Method to Determine the Fracture Toughness of Polymeric Materials

L. Chang* and H.J. Wang

*Centre for Advanced Materials Technology, School of Aerospace, Mechanical and Mechatronic Engineering, The University of Sydney, Sydney NSW 2006, Australia

In modern materials science, how to accurately determine the fracture behaviour of engineering materials has been a longstanding problem [1-4]. Nowadays, the most widely used approach is linear elastic fracture mechanics (LEFM) analysis, which defines the fracture toughness in terms of the stress-intensity factor, *K*, or the strain-energy release rate, G [5]. Accordingly, standard measurement methods have been developed for polymers [6-8], which were initially applied to metals [9]. In practice, however, it remains a challenging task to determine the fracture toughness of tough polymers by using the existing standard methods, especially when there is an accompanying low yield stress. Such a combination leads to both crack growth and crack blunting which are difficult to separate. In addition it is impractical to apply the methods for polymeric thin films/paints or micro fabricated materials, owing to the stringent requirements for the shape and/or size of specimens.

With this in mind therefore, the community has made a great effort to explore alternative ways to characterise the fracture toughness of polymers. In particular, theories of measuring toughness of materials by use of orthogonal cutting theory have been put forward. It is said that cutting of a very thin strip of material may be considered as a crack propagation process, and it is possible to measure the cutting force during cutting hence calculate the energy dissipation. However, for many years the fracture energy was not considered as part of energy dissipation in metal cutting process as the energy was said to be too small to exert an influence. It was not until Atkins' studies [10, 11], which firmly established the fracture terms are important in any cutting analysis. Atkins and Vincent [12] subsequently advanced the theory of critical fracture energy, G_c, is equivalent to the cutting energy extrapolated to zero cutting depth. Based on Atkins and Vincent's theory, Ericson and Lindberg [13, 14] characterised the fracture toughness of two kinds of polymers, PMMA and epoxy, by using an instrumented ultra microtome. Their testing results were claimed in the same order of magnitude as those measured using the conventional standard testing methods. Later on Williams [15], Patel et al. [16] and Williams et al. [17], systematically deduced a linear relation between cutting force and cutting depth to extrapolate G_c based on the orthogonal cutting mechanism and Merchant's force minimisation. The results showed that cutting tests were capable for characterise the toughness of the polymers with low yield stress but moderately high toughness, which were not easily satisfied by the requirement of the conventional standard testing methods.

Recently, authors carried out cutting tests to determine the fracture of various polymeric materials including polymer nano composites [18, 19]. The work was conducted on the basis of the recently developed fracture mechanics for the cutting process by Williams [15], Patel et al. [16], and Williams et al. [17]. The fracture toughness, G_c of pure polymers such as polyamide, polypropylene and epoxy was measured using an orthogonal cutting method on a CNC surface grinder. In particular, the fracture toughness epoxy based nano composites with 10 wt% nano-rubber and 10 wt% nano-silica particles, was also studied. During the test, the cutting forces were measured by a multi-axis dynamometer, and depths of cut are precisely controlled from 10 μm to 150 μm. High speed cutting tools with three rake angles of 10º, 20º, and 30º were used for the cutting. The G_c values of pure polymers and epoxy nanocomposites with 10 wt% nano-silica particles are in good agreement with those obtained from the standard compact tension test. However, the cutting method produced higher values in yield strength than the conventional tensile test.

In summary, the results have shown that the cutting tests are capable for conveniently measuring the fracture toughness of polymers as a new standard method. However, it is also noted the results can be also affected by the cut depth and the sharpness of cutting tools, depending on the properties of polymers. It is worthwhile performing more research in this area to provide much insight into the role of the fracture energy in the cutting process.

References

1. Griffith AA (1921) The phenomena of rupture and flow in solids. Phil Trans R Soc Lond A 221: 163-198.
2. Irwin G (1957) Analysis of stresses and strains near the end of a crack traversing a plate, J Appl Mech 24: 361–4
3. Barenblatt GI (1962) The mathematical theory of equilibrium cracks in brittle fracture. Adv Appl Mech 7: 55-129.
4. Rice JR (1968) A path independent integral and the approximate analysis of strain concentration by notches and cracks. J Appl Mech 35: 379–386.
5. Williams JG, Ellis Horwood (1984) Fracture Mechanics of Polymers.
6. ASTM D6068-10 Standard Test Method for Determining J-R Curves of Plastic Materials.
7. ISO13586:2000, Plastics-determination of fracture toughness (GIC and KIC) linear elastic fracture mechanics (LEFM) approach.
8. Hale GE, Ramsteiner F (2001) J-fracture toughness of polymers at slow speed. In: Moore R, Pavan A, Williams JG, (2001) editors fracture mechanics testing methods for polymers, adhesives and composites Elsevier Science, London.
9. ASTM E1820-08, Standard test method for measurement of fracture toughness for metals.
10. Atkins AG (2003) Modelling metal cutting using modern ductile fracture mechanics: quantitative explanations for some longstanding problems. Int J Mech Sci 45: 373-396.
11. Atkins AG (2005) Toughness and cutting: a new way of simultaneously determining ductile fracture toughness and strength. Eng Fract Mech 72: 849-860.
12. Atkins AG, Vincent JFV (1984) An instrumented microtome for improved

***Corresponding author:** L. Chang, Centre for Advanced Materials Technology, School of Aerospace, Mechanical and Mechatronic Engineering, The University of Sydney, Sydney NSW 2006, Australia, E-mail: li.chang@sydney.edu.au

Received October 23, 2012; **Accepted** October 25, 2012; **Published** October 27, 2012

Citation: Chang L, Wang HJ (2012) Cutting Tests: A New Method to Determine the Fracture Toughness of Polymeric Materials. J Appl Mech Eng 2:e110. doi:10.4172/2168-9873.1000e110

histological sections and the measurement of fracture toughness. J Mater Sci Lett 3: 310-312.

13. Ericson ML, Lindberg H (1997) Design and potential of instrumented ultra microtomy. Polymer 38: 4485-4489.
14. Ericson ML, Linderg H (1996) A method of measuring energy dissipation during crack propagation in polymers with an instrumented ultramicrotome. J Mater Sci 31: 655–662.
15. Williams JG (1998) Friction and plasticity effects in wedge splitting and cutting fracture tests. J Mater Sci 33: 5351-5357.
16. Patel Y, Blackman BRK, Williams JG (2009) Determining fracture toughness from cutting tests on polymers. Eng Fract Mech 76: 2711-2730.
17. Williams JG, Patel Y, Blackman BRK (2010) A fracture mechanics analysis of cutting and machining. Eng Fract Mech 77: 293–308.
18. Wang HJ, Chang L, Ye L, Study of the Fracture Toughness of Nanoparticles Modified Epoxy by Cutting Tests, ACUN6–Composites and Nanocomposites in Civil, Offshore and Mining Infrastructure, Melbourne.
19. Wang HJ, Chang L, Ye L (2012) Measuring the Fracture Toughness of Polymer Nanocomposites from Cutting Tests, 8th Asian-Australasian Conference on Composite Materials (ACCM-8), Kuala Lumpur, Malaysia.