Cutting Mechanics of Soft Materials and the Role of Fracture Toughness

Li Chang, Yiu-Wing Mai, Gordon Williams and Lin Ye
School of Aerospace, Mechanical and Mechatronic Engineering J07
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Abstract

Cutting of soft materials is a common daily life experience (e.g., slicing of meat and cheese) and an essential operation in many industries, healthcare (e.g., surgery) and manufacturing (e.g., paint removal) among others. By measuring the cutting forces of the tool and examining the deformation mechanisms of the workpiece, we can put the cutting process on a strong scientific and technological footing. For it provides an ingenious method to measure the fracture energy, i.e., the specific resistance to cracking, of soft materials like plastics, thin films on substrates and nanocomposites at different cut-depths. The new knowledge gained improves tool design and optimizes cutting conditions to increase the cutting process efficiency with huge economic benefits. For example, cutting with sharp tools will enable the paint industry an effective solution to measure the adhesion energy and scrape paints from metal substrates. It will also provide a unique fracture energy index for food products for correlation with food quality and texture.

Here, we present our recent work on the cutting behaviour of polyolefins with different molecular weights, epoxies with different degree of crosslinks and with polystyrene microspheres. We study the effects of rake angle, cut depth, and tool sharpness as well as chip bending on the fracture energy obtained from the cutting theory. Our results show that fracture has a critical role in the formation of the newly cut surface as the chip is separated from the workpiece by the cutting tool. The surface finish after cutting is dependent on the cutting depth and the ratio between fracture energy and yield strength. These new findings provide useful guidance for understanding the machining behaviour of soft materials like polymers and their nanocomposites.