# Tool condition monitoring of an automated robotic drilling process

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This project was carried out at University of Limerick under the supervision of Dr. Eoin Hinchy, Prof. Noel O'Dowd & Prof. Conor McCarthy

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## INTRODUCTION

Drilling is a crucial machining process in aerospace industry. Various challenges are faced in drilling of composites (e.g., delamination, uncut fibres, and tool wear). The outcome of these damage mode will determine the quality and longevity of the hole and structure. Traditionally, drilling tool is replaced after a specific cycle to ensure the hole is well-drilled. A worn tool typically produces excessive cutting force and higher thrust force which is directly proportional to area of delamination and other damages. During the drilling process, real-time torque signals from the servo motor is collected and further processed to detect tool wear. A key advantage of this study is that the drilling process can be automated using real-time sensor feedback from the production line

## Drilling of composite materials

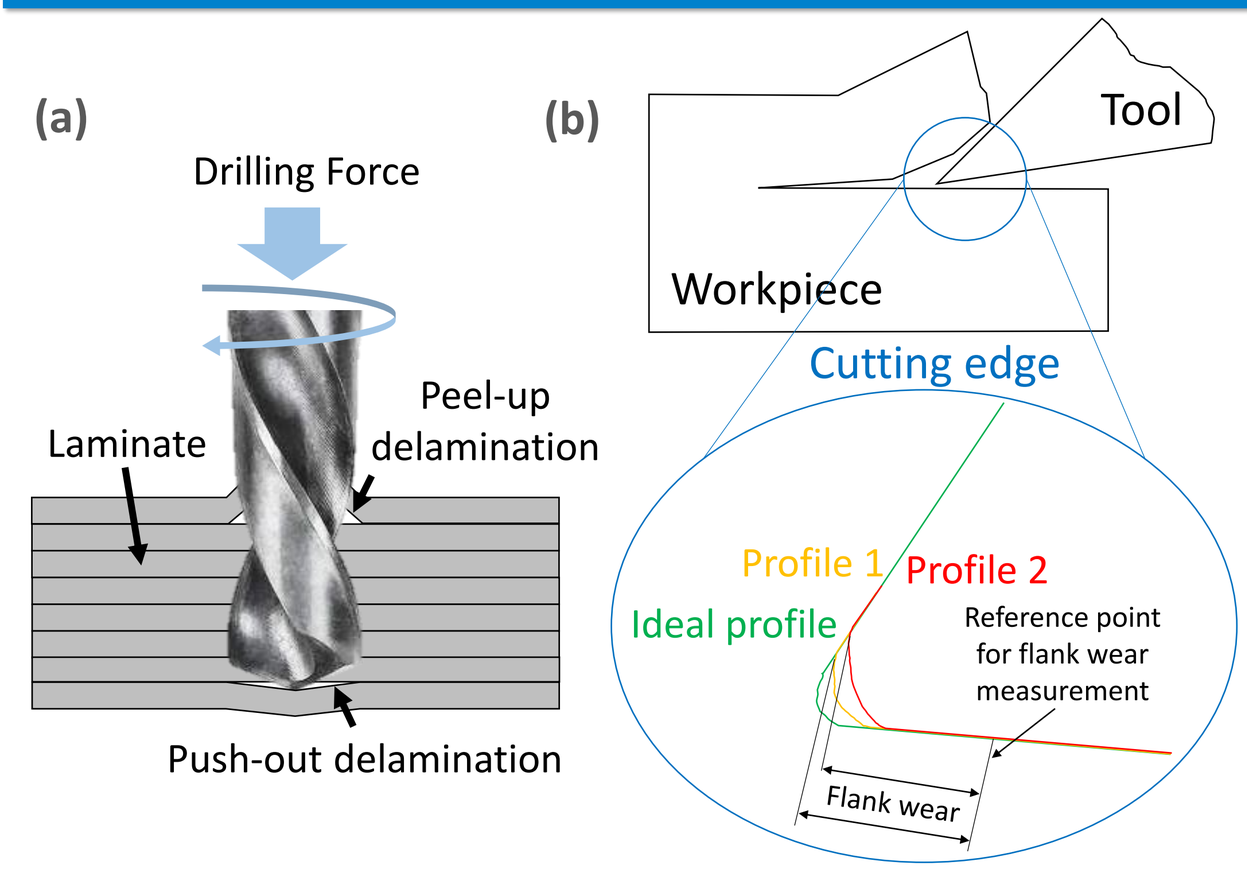



Fig 1: (a) Mechanism of drilling-induced delamination in composite laminate (b) Different worn cutting edges showing flank wear [1]

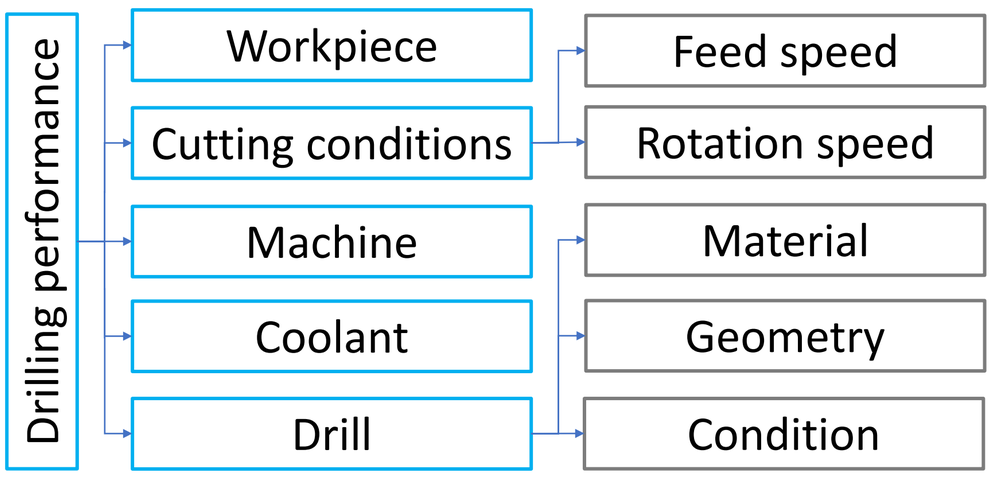
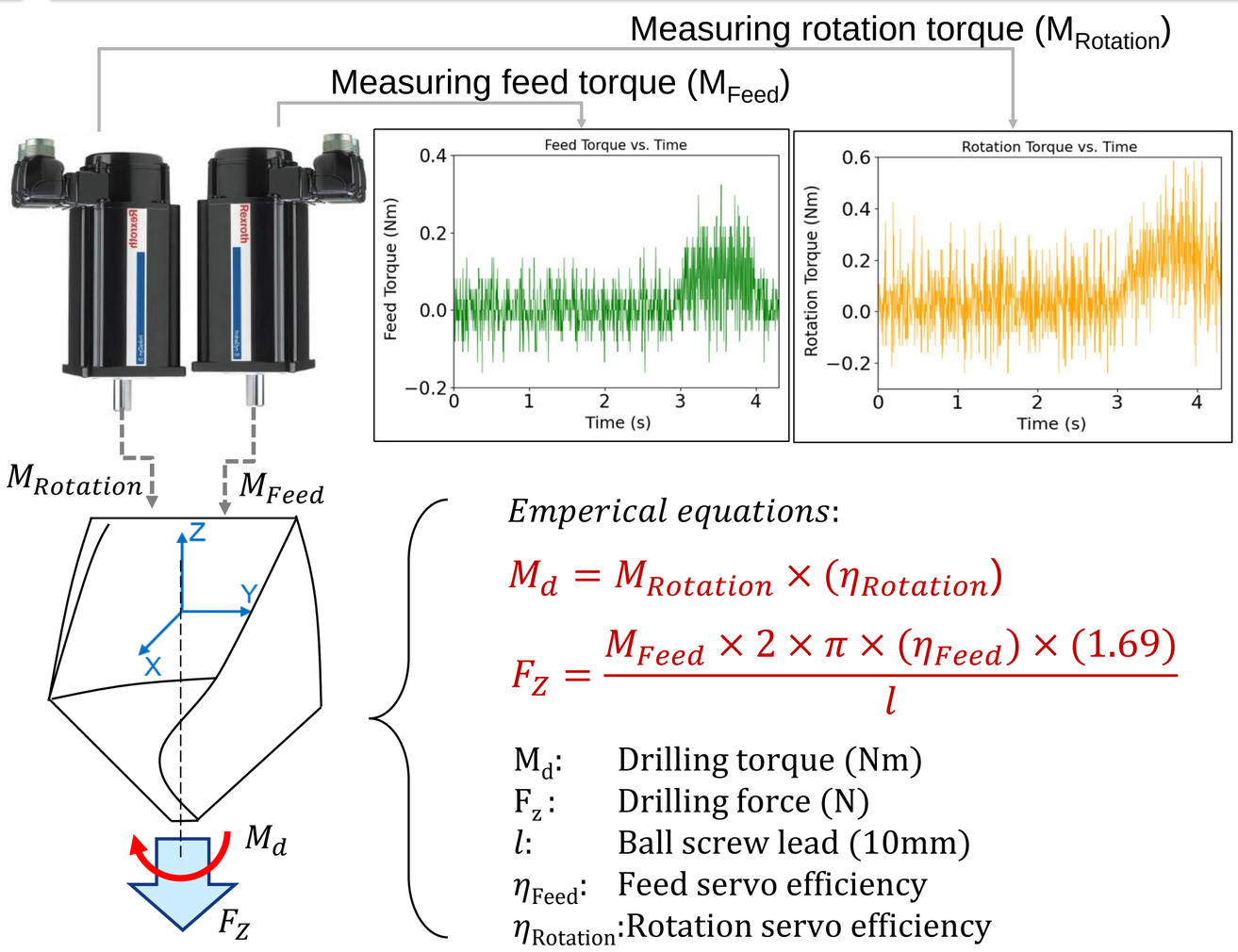



Fig 2: The primary factors which determine the drilling performance of composites

## Physics-based drilling force model




*Emperical equations*:

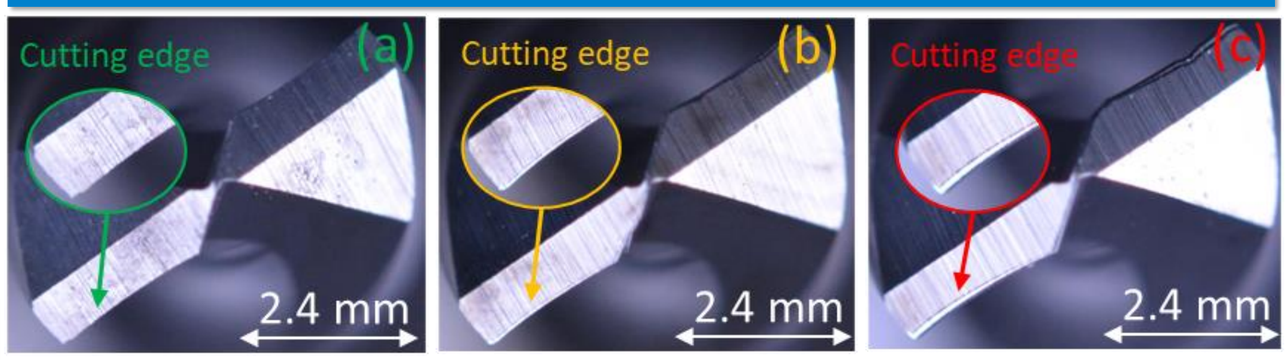
$$M_d = M_{Rotation} \times (\eta_{Rotation})$$

$$F_Z = \frac{M_{Feed} \times 2 \times \pi \times (\eta_{Feed}) \times (1.69)}{l}$$

$M_d$: Drilling torque (Nm)
$F_z$: Drilling force (N)
$l$: Ball screw lead (10mm)
$\eta_{Feed}$: Feed servo efficiency
$\eta_{Rotation}$: Rotation servo efficiency

Fig 4: Physics-based drilling torque and thrust force calculation based on data extracted from servo motors.

## Signal comparison of different tool condition



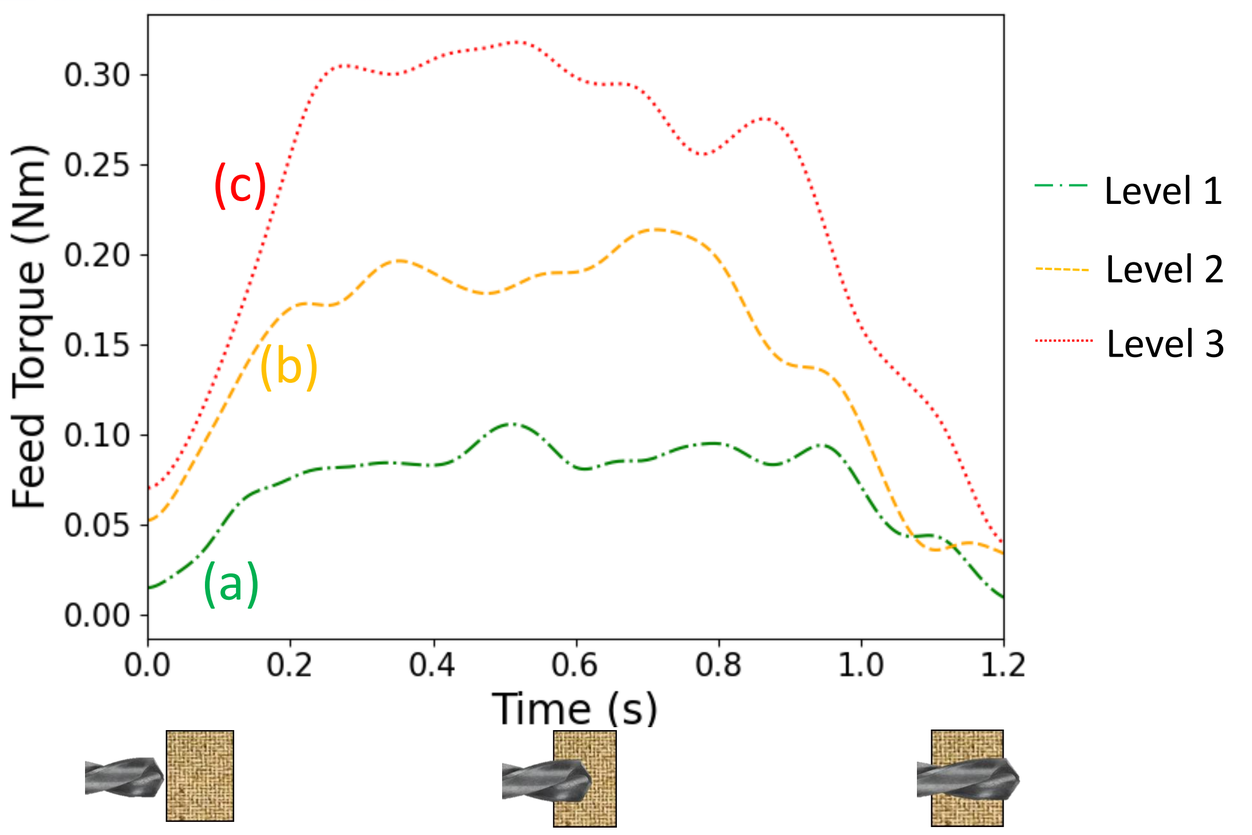




Fig 5: Plot illustrates different feed torque collected using different level of worn tool

## Experimental setup

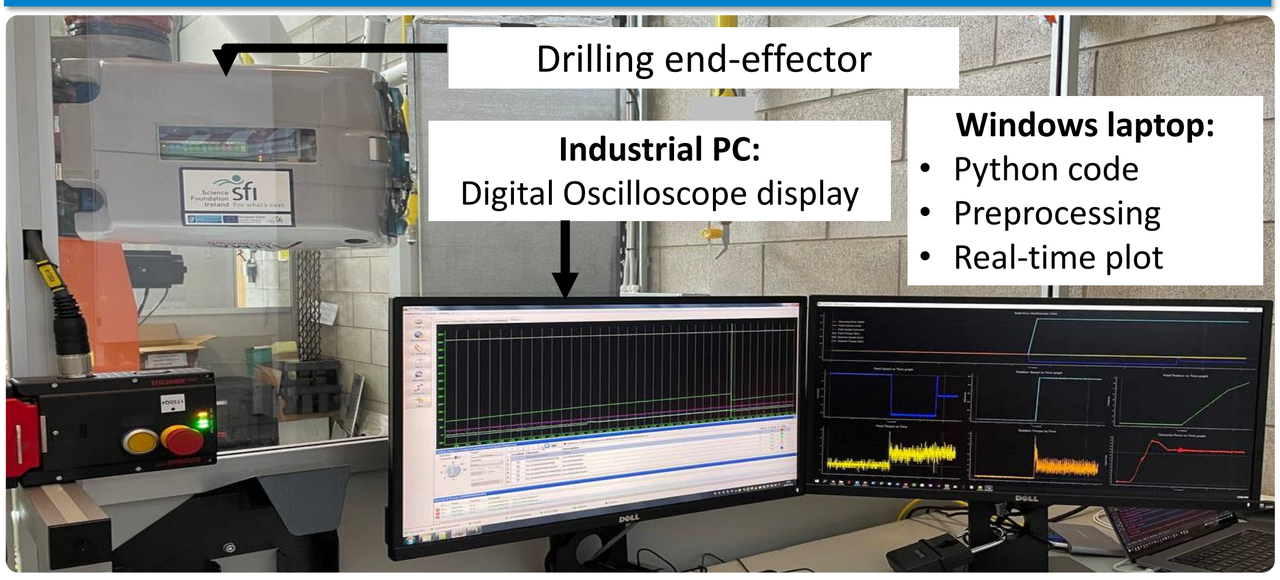



Fig 3: Real-time data collection and visualization of robotic drilling process

## References

[1] D. S. Raj and L. Karunamoorthy, 'A new and comprehensive characterisation of tool wear in CFRP drilling using micro-geometry and topography studies on the cutting edge', *Journal of Manufacturing Processes*, vol. 32, pp. 839–856, Apr. 2018, doi: 10.1016/j.jmapro.2018.04.014.

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