# Finite element modelling validation of fibre orientation inversion in CFRP using high-frequency eddy-current testing

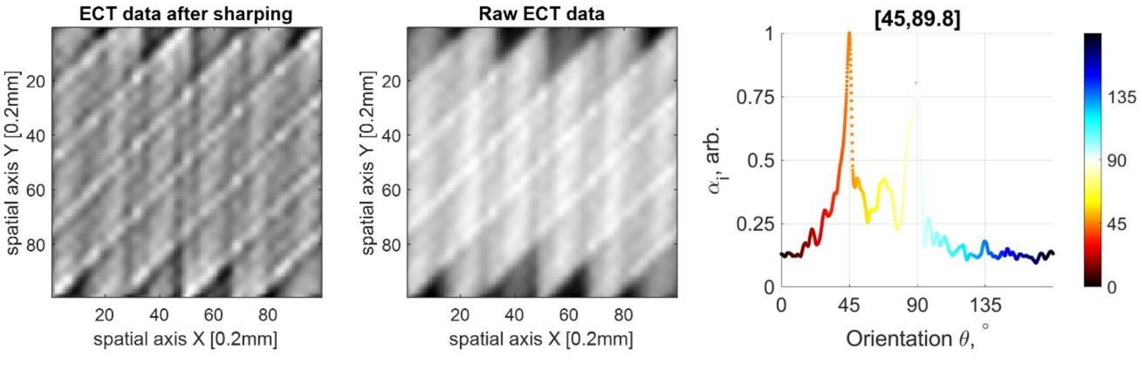
Qiuji Yi[1,2], Robert Huges[1], Paul Wilcox [1], Geir Olafsson[2], Janice Barton[2] and Ole Thomsen[2,3]

[1] Department of Mechanical Engineering, Ultrasonics and Non-destructive Testing (UNDT), University of Bristol, UK, BS8 1TR

[2]Department of Aerospace Engineering, Bristol Composites Institute (ACCIS), University of Bristol, UK, BS8 1TR

[3]National Composites Centre, UK, BS16 7FS

**Abstract :** Carbon fibre reinforced plastic (CFRP) has been increasingly employed for the manufacture of components in various industries including aerospace and high-value automotive engineering. Non-destructive testing (NDT) techniques are crucial to improve quality control and thus to extend their serving life. Eddy current testing (ECT) techniques can be well adapted to detect those fibre-related defects by measuring the variation of electric resistance. Previous work has demonstrated its ability to characterise fibre orientation, as well as detect misorientation (off-axis) and fibre waviness. Furthermore, high-frequency ECT (10-20 MHz) has the potential to increase the resolution to 200 $\mu m$ with better accuracy compared with traditional ECT (lower than 2MHz). Despite the progress of detecting waviness and characterisation the fibre orientations in previous work using experimental ECT, the physics behind it is not fully explored in terms of the interaction of electrical response between coil and fibres at different depths, which hinders the accurate inversion of defects or layer depths based on the fibre orientations. In this work, the electromagnetic modelling of the spatial variation observed in ECT scanning was simulated by employing a 2D conductivity wave function as a function of orientation $\theta$ and volume fraction $v$. Thus, a multi-layer and spatial variant tensor is calculated for modelling the electromagnetic properties of the composite. A virtual ECT scan is simulated over the material using the model to retrieve the electrical properties of the coil, building up a 2D map of resistivity. The 2D data is processed with 2D gaussian sharping to remove the low-frequency pattern, which is later fed into two inversion techniques: Radon transform and Gabor-based principal component analysis. The former can achieve fibre characterisation, while the latter can reconstruct the individual layers based on the orientations. The primary results are presented in Fig.1. The results demonstrate the validity of this modelling approach.




(a) (b) (c)

Figure 1 Primary results:(a) 2D sharping gaussian filtering on FEM data, (b) FEM data exported from COMSOL,(c) radon transform for orientation inversion(peaks are at 45 and 89.8 [degs])