

## Article

# Hybrid Finite Element–Smoothed Particle Hydrodynamics Modelling for Optimizing Cutting Parameters in CFRP Composites

Alessandro Abena <sup>1</sup>, Sabbah Ataya <sup>2</sup>, Hany Hassanin <sup>3,\*</sup>, Mahmoud Ahmed El-Sayed <sup>4</sup>, Mahmoud Ahmadein <sup>5</sup>, Naser A. Alsaleh <sup>2</sup>, Mohamed M. Z. Ahmed <sup>6</sup> and Khamis Essa <sup>1</sup>

- <sup>1</sup> School of Engineering, University of Birmingham, Birmingham B152TT, UK; k.e.a.essa@bham.ac.uk (K.E.); a.abena@bham.ac.uk (A.A.)
  - <sup>2</sup> Department of Mechanical Engineering, Imam Mohammad Ibn Saud Islamic University (IMSIU), Riyadh 11432, Saudi Arabia; smataya@imsiu.edu.sa (S.A.); naalsaleh@imsiu.edu.sa (N.A.A.)
  - <sup>3</sup> School of Engineering, Technology, and Design, Canterbury Christ Church University, Canterbury CT11QU, UK
  - <sup>4</sup> Department of Industrial and Management Engineering, Arab Academy for Science, Technology and Maritime Transport, Alexandria 21599, Egypt; dr.mahmoudehsayed12@gmail.com
  - <sup>5</sup> Department of Production Engineering and Mechanical Design, Tanta University, Tanta 31512, Egypt; m.ahmadein@f-eng.tanta.edu.eg
  - <sup>6</sup> Mechanical Engineering Department, College of Engineering at Al Kharij, Prince Sultan Bin Abdulaziz University, Al Kharij 16273, Saudi Arabia; moh.ahmed@psau.edu.sa
- \* Correspondence: engh@nisisalamsa@yahoo.com

**Abstract:** Carbon-fibre-reinforced plastic (CFRP) is increasingly being used in various applications including aerospace, automotive, wind energy, sports, and robotics, which makes the precision modelling of its machining operations a critical research area. However, the classic finite element modelling (FEM) approach has limitations in capturing the complexity of machining, particularly with regard to the interaction between the fibre–matrix interface and the cutting edge. To overcome this limitation, a hybrid approach that integrates smoothed particle hydrodynamics (SPH) with FEM was developed and tested in this study. The hybrid FEM-SPH approach was compared with the classic FEM approach and validated with experimental measurements that took into account the cutting tool’s round edge. The results showed that the hybrid FEM-SPH approach outperformed the classic FEM approach in predicting the thrust force and bounce back of CFRP machining due to the integrated cohesive model and the element conversion after failure in the developed approach. The accurate representation of the fibre–matrix interface in the FEM-SPH approach resulted in predicting precise chip formation in terms of direction and morphology. Nonetheless, the computing time of the FEM-SPH approach is higher than the classic FEM. The developed hybrid FEM-SPH model is promising for improving the accuracy of simulation in machining processes, combining the benefits of both techniques.

**Keywords:** finite element modelling; smoothed particle hydrodynamics; orthogonal cutting; chip formation



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## 1. Introduction

Fibre-reinforced polymers (FRP) are currently experiencing a growing demand across various industries, including automotive, aerospace, construction, and marine. The reason for this is the remarkable characteristics of these materials, which include particular strength and stiffness, damage resistance, resistance to fatigue, corrosion, and acoustic and thermal insulation properties, all of which surpass those of metals and ceramics [1]. Since the 1980s, composites have been widely used in several applications and currently constitute about 50% of the entire structure of modern aircrafts [2,3]. Due to this demand, aerospace manufacturers invested in developing FRP materials and the complemented machining

# Physicochemical Hydrodynamics

**VM Jensen**

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petite robe noire eau de parfum absolue was launched in 2023 top notes are cherry almond and bergamot middle notes are smoke rose tea and iris base notes are leather patchouli and tonka bean

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web mar 5 2014 the little black dress edit guerlain s la petite robe noire collection review if you were to ask me what i think is the most joyful and exuberant feminine fragrance on the market today i would answer with guerlain s la petite robe noire

[la petite robe noire rose cherry guerlain for women](#) - Apr 04 2022

web jan 2 2023 summer fall day night perfume rating 4 21 out of 5 with 62 votes la petite robe noire rose cherry by guerlain is a floral fruity fragrance for women this is a new fragrance la petite robe noire rose cherry was launched in 2023 the nose behind this fragrance is delphine jelk

**la petite robe noire légère guerlain for women fragantica com** - Nov 11 2022

web jan 9 2018 la petite robe noire légère was launched in 2018 the nose behind this fragrance is thierry wasser top notes are sour cherry almond rose water lime and lemon middle notes are black tea rose raspberry licorice peony and peach base notes are tonka bean vanilla violet patchouli and white musk

[la petite robe noire eau de parfum intense guerlain](#) - Mar 15 2023

web la petite robe noire eau de parfum intense an irresistible gourmand floral sillage la petite robe noire s iconic rose is beautifully enhanced by fruity notes of blueberry and raspberry a dash of bergamot along with white musk and a woody sandalwood patchouli accord create a fragrance with an exquisite and unforgettable sillage

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web robe noire est le nom que donnaient aux xvi e et xvii e siècles les amérindiens de nouvelle france hurons algonquins iroquois aux missionnaires jésuites il fait allusion au vêtement ecclésiastique une longue soutane noire que ces missionnaires portaient traditionnellement

**la petite robe noire guerlain for women fragantica com** - Apr 16 2023

web la petite robe noire by guerlain is a amber vanilla fragrance for women la petite robe noire was launched in 2009 the nose behind this fragrance is delphine jelk top notes are almond anise and lemon middle notes are macarons licorice and rose base notes are vanilla patchouli tea and musk