

01.06 CD - Multiscale modelling

MORPHOLOGY ANALYSIS AND SHAPE OPTIMAL OF CFRTP-SMC BASED ON MONTE-CARLO SIMULATION

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Introduction

Monte Carlo Simulation Model

Result Analysis and Comparison

Summary and Future Plan

Introduction

Carbon fiber reinforced plastics (CFRP) have high specific strength and stiffness, which is used in a wide range of applications such as aircraft, automobile and sports gear.



BMW i3^[2]



Lamborghini^[3]



From the viewpoint of application to mass-produced vehicles, there are high expectations for carbon fiber reinforced thermoplastic(CFRTP).



[1] https://www.boeing.com/commercial/aeromagazine/articles/qtr_4_06/article_04_2.html
[2] http://www.bmw-i.jp/BMW-i3/
[3] https://www.lamborghini.com/jp-en



Comparison

This research focused on CFRTP-SMC (Carbon fiber reinforced thermoplastics sheet molding compound). This material has many advantages such as higher fiber volume fraction than injection molded materials, more suitable in complex Design than continuous laminates material and in-plane isotropic.

Type of composite system	Injection molded	CPT (carbon fiber paper reinforced thermoplastics)	CFRTP-SMC (Carbon fiber reinforced thermoplastics sheet molding compound)	Continuous Iaminates
Fiber continuity	Discontinuous	Discontinuous	Discontinuous	Continuous
Fiber volume fraction V_f	<5%	Around 10 to 30%	≥50%	≥50%
Fiber Length	Around 1 mm or less	Several millimeters	Around 10 to 100 millimeters	Continuous
Complex Design	Suitable	Possible	Suitable	Difficult
Anisotropy	Process dependent	In-plane isotropic Out-of-plane orthotropic	In-plane isotropic Out-of-plane orthotropic	Designable



[4] Yamashita S, Hashimoto K; Suganuma H; Takahashi J Experimental characterization of the tensile failure mode of ultra thin chopped carbon fiber tape reinforced thermoplasitcs Journal of Reinforced Plastics and Composites, 35, 18, pp.1342 1352, (2016)



Research purpose







[5] Yamashita S, Hashimoto K; Suganuma H; Takahashi J Experimental characterization of the tensile failure mode of ultra thin chopped carbon fiber tape reinforced thermoplasitcs Journal of Reinforced Plastics and Composites, 35, 18, pp.1342 1352, (2016)

Monte Carlo Simulation



The method involves generating a large number of random samples or scenarios from inputs or parameters that describe <u>inner structure</u> of CFRTP-SMC material







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SMC Model Program Design





Class Definition - Tape







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Class Definition - Layer & Specimen



Tape Distribution







Tape Overlapped in Multiple Layers



Calculate tape overlapped in three or more layers

Based on Sinking Algorithm

(Operated by Recursive Algorithm & Generated by Sweep Line Algorithm)





Overlap Area Calculation



Visualization





Following from overlap matrix:

- Overlap Area Position
- Each Area Value
- Overlap Area Distribution



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Overlap Layers Distribution



Overlap Area Ratio in mass simulation (n=50)

INNOVATION



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Result Comparison – Overlap in Different Length



Result Comparison – Overlap in Different Length



Result Comparison – Overlap in Different Width



Overlap Area Distribution with Tape Width





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Overlap Area Calculation Result

Besides of the peak around 0, which is normal, there is also a peak around area of $25 mm^2$. This area is close of the square area of 5 mm, which is the width of tape. Therefore, we assume the frequency of this peak (y-axis) is determined by the length of tape.







Overlap Area Calculation Result

With tape length increasement, the sum of overlap area increase, which is majorly contributed by the second peak.

Compared to experiment data along with our simulation data, we assumed that the most optimized tape length-width tends to be around 6 (30mm / 5mm).





However

Longer tape length problem:

- Lower Vf rate
- High variance



[6] Wan, Yi, and Jun Takahashi. "Tensile and compressive properties of chopped carbon fiber tapes reinforced thermoplastics with different fiber lengths and molding pressures." *Composites Part A: Applied Science and Manufacturing* 87 (2016): 271-281.





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Conclusion

Summary:

- ✓ Monte Carlo Simulation Model for CFRTP-SMC.
- ✓ Analysis of the distribution of SMC tape and overlap.
- ✓ Best tape length-width ratio.

Future Task:

- a. Tensile strength prediction and comparison with different tape shapes.
- b. More experiments for verification and optimization.





Presentations from Takahashi-Wan lab

Name	Date	Venue	Room	Title
Zhiyu WANG	Mon	Process modelling - S1	Studio	A state-based peridynamic model for progressive damage analysis of CFRTP-SMC base
Peng XUE	Mon	Structural analysis and optimization - S2	3B	Optimization of floating vertical axis wind turbine structures using recycled carbon fiber reinforced thermoplastic
Xiaohang TONG	Tue	Mechanics of composites - S2	3A	The influence of tape geometry on the mechanical performance of bolted CFRTP-SMC joints
Zihao ZHAO	Tue	Liquid composites moulding - S2	2A	Simulation of fiber orientation during compression molding process of CFRTP-SMC
► Ruochen XU	Wed	Multiscale modelling - S5	Studio	Morphology analysis and shape optimal of CFRTP-SMC based on Monte-Carlo simulation
Qian GAO	Wed	Recycling and sustainability - S3	1B	Prediction of strength and its variation of carbon fiber mat reinforced thermoplastics using Monte-Carlo method
Weizhao HUANG	Thu	Structural health monitoring - S1	Arc	Inversing spatial modulus distribution of cfrtp by a vibrational method and its hydrothermal aging application







Thank you for your attention!

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