

# **Failure behavior of unidirectional Carbon Fiber-Reinforced Composite (CFRP): Experimental investigation and comparison with an existing failure criterion**

Roman Rüttimann

Semester Thesis  
Autumn Semester 2019

Arthur Girard

Prof. Dr. Dirk Mohr



## **Abstract**

...

Lorem ipsum dolor sit amet, consectetur adipiscing elit. Ut purus elit, vestibulum ut, placerat ac, adipiscing vitae, felis. Curabitur dictum gravida mauris. Nam arcu libero, nonummy eget, consectetur id, vulputate a, magna. Donec vehicula augue eu neque. Pellentesque habitant morbi tristique senectus et netus et malesuada fames ac turpis egestas. Mauris ut leo. Cras viverra metus rhoncus sem. Nulla et lectus vestibulum urna fringilla ultrices. Phasellus eu tellus sit amet tortor gravida placerat. Integer sapien est, iaculis in, pretium quis, viverra ac, nunc. Praesent eget sem vel leo ultrices bibendum. Aenean faucibus. Morbi dolor nulla, malesuada eu, pulvinar at, mollis ac, nulla. Curabitur auctor semper nulla. Donec varius orci eget risus. Duis nibh mi, congue eu, accumsan eleifend, sagittis quis, diam. Duis eget orci sit amet orci dignissim rutrum. Nam dui ligula, fringilla a, euismod sodales, sollicitudin vel, wisi. Morbi auctor lorem non justo. Nam lacus libero, pretium at, lobortis vitae, ultricies et, tellus. Donec aliquet, tortor sed accumsan bibendum, erat ligula aliquet magna, vitae ornare odio metus a mi. Morbi ac orci et nisl hendrerit mollis. Suspendisse ut massa. Cras nec ante. Pellentesque a nulla. Cum sociis natoque penatibus et magnis dis parturient montes, nascetur ridiculus mus. Aliquam tincidunt urna. Nulla ullamcorper vestibulum turpis. Pellentesque cursus luctus mauris. Nulla malesuada porttitor diam. Donec felis erat, congue non, volutpat at, tincidunt tristique, libero. Vivamus viverra fermentum felis. Donec nonummy pellentesque ante. Phasellus adipiscing semper elit. Proin fermentum massa ac quam. Sed diam turpis, molestie vitae, placerat a, molestie nec, leo. Maecenas lacinia. Nam ipsum ligula, eleifend at, accumsan nec, suscipit a, ipsum. Morbi blandit ligula feugiat magna. Nunc eleifend consequat lorem. Sed lacinia nulla vitae enim. Pellentesque tincidunt purus vel magna. Integer non enim. Praesent euismod nunc eu purus. Donec bibendum quam in tellus. Nullam cursus pulvinar lectus. Donec et mi. Nam vulputate metus eu enim. Vestibulum pellentesque felis eu massa.

## Failure behavior of unidirectional Carbon Fiber-Reinforced Composite (CFRP): Experimental investigation and comparison with an existing failure criterion

### Background

Composite materials offer an extremely wide range of tailorable properties for specific applications and therefore a need for extensive mechanical characterization as well as efficient mechanical behavior modeling arises. Although composite materials have been studied for decades, only a limited amount of reliable experimental load cases exist and several studies show that failure criteria perform better depending on the load case applied.

### Motivation

Taking advantage of a reliable automated testing system, a large database of tensile experiment has been created using off-axis unidirectional lamina specimen. This specimen uses the material anisotropy to create different stress states inside the lamina by changing the angle between the fiber and the tensile direction. The results of these experiments show a poor fitting between experimental data and theoretical failure criteria at low off-axis angle, leading to possible premature failure of the composite structure.

### Thesis Objectives

This work is aimed at enlarging the failure database already created with data extracted from compressive tests. Several mechanical tests will be performed on a uniaxial compression machine. The tests will be post-processed and data extracted will be added to the existing database. The experimental data should be compared with several failure criteria in an attempt to assess them. The best failure criterion is to be implemented in an Abaqus Subroutine and validated using the experimental data. Other CFRP could be used to validate the failure criteria.

### Tentative Timeline

The tentative timeline presented corresponds to 6 weeks of full-time work but can be adapted according to the student's preferences.

Week	Topic
1	Literature review + Existing database presentation
2	Experimental Testing
3	Post-processing
4	Database + FE Simulation
5	Failure criteria definition + FE Simulation
6	Writing

### Contact

Arthur Girard - [agirard@ethz.ch](mailto:agirard@ethz.ch) – Technopark PFA G21



# Contents

<b>1</b>	<b>Hello There</b>	<b>1</b>
	<b>List of figures</b>	<b>3</b>
	<b>List of tables</b>	<b>5</b>
<b>A</b>	<b>Appendix</b>	<b>9</b>





## Hello There

This is a minimal document to test KOMA-script with biblatex/biber:

\cite: <sup>|daniel2007failure</sup>[3]

\textcite: <sup>|daniel2018new</sup>Daniel, Daniel, and Fenner [4]

\parencite: <sup>|calsson2014experimental</sup>[1]

\footcite:<sup>1</sup>

\fullcite: <sup>|gurit2017guide</sup>*Guide to composites*. Gurit. 2017

Creation of the PDF-file:

```
pdflatex bibtex-minimal-example
biber bibtex-minimal-example
pdflatex bibtex-minimal-example
pdflatex bibtex-minimal-example
```



## List of Figures



## List of Tables



# Bibliography

experimental

5641standard

L2007failure

aniel2018new

rit2017guide

[1] Leif A Carlsson, Donald A Adams, and R Byron Pipes. *Experimental characterization of advanced composit materials*. Fourth. Taylor & Francis Group, 2014.

[2] *Standard test method for compressive properties of polymer matrix composite materials using a combined loading compression (CLC) test fixture*. Standard. ASTM International, Mar. 2016.

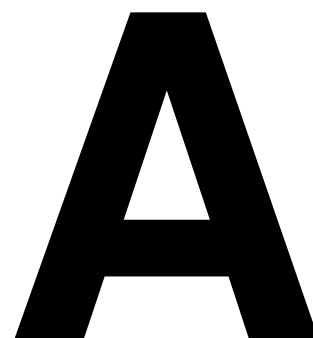
[3] Isaac M Daniel. “Failure of composite materials”. In: *Strain* 43.1 (2007), pp. 4–12.

[4] Isaac M Daniel, Sam M Daniel, and Joel S Fenner. “A new yield and failure theory for composite materials under static and dynamic loading”. In: *International Journal of Solids and Structures* 148 (2018), pp. 79–93.

[5] *Guide to composites*. Gurit. 2017.







## **Appendix**