Life prediction of composite materials

Creating a digital-twin framework

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Introduction

In the transition to a climate-neutral economy, composite materials can play a big role due to their high strength-to-weight ratio. However, reliable fatigue evaluation methods must be found to ensure long-term integrity of the designs. In aid, a digital-twin framework will be build to predict the residual lifetime of composite materials subjected to vibration fatigue.

Background

Previous research [1], [2] has shown applications of **near-resonance fatigue testing**. This shows a phase degradation up to a critical event, causing a sudden stiffness drop, see Figure 1.
This is used for two important parameters:

- the **crack propagation** up to point (a),
- a **failure criterion** between (a) and (b).

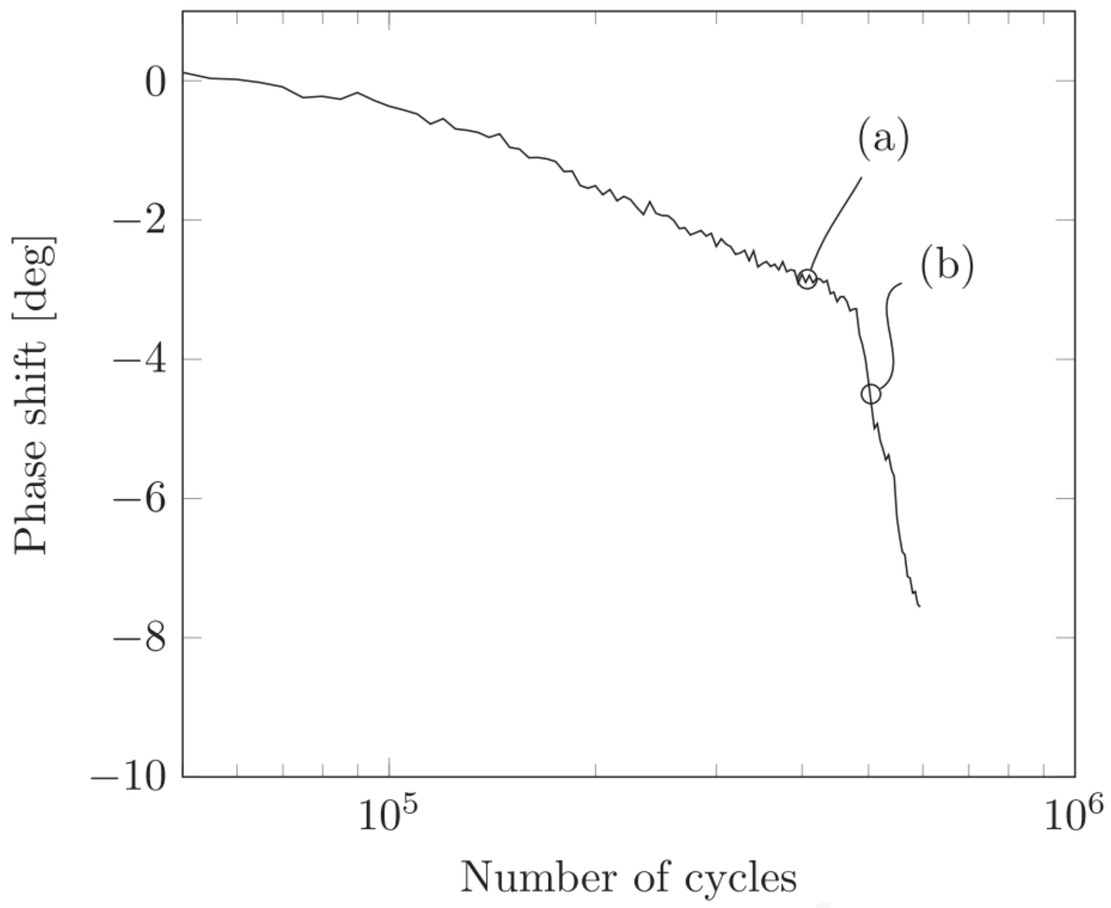

Figure 1 The phase decay and critical event [1].

The crack propagation is used to create **Paris' Law**, containing material parameters C and m.

$$\frac{da}{dN} = C(\Delta K)^m$$

This can be combined with the critical event between point (a) and (b) in Figure 1 to create an **SN-curve** for the material, where rapid delamination after point (b) indicates failure.

Method

Experimental results will be used as input parameters for the framework. The analysis steps for the framework can be seen in Figure 2.

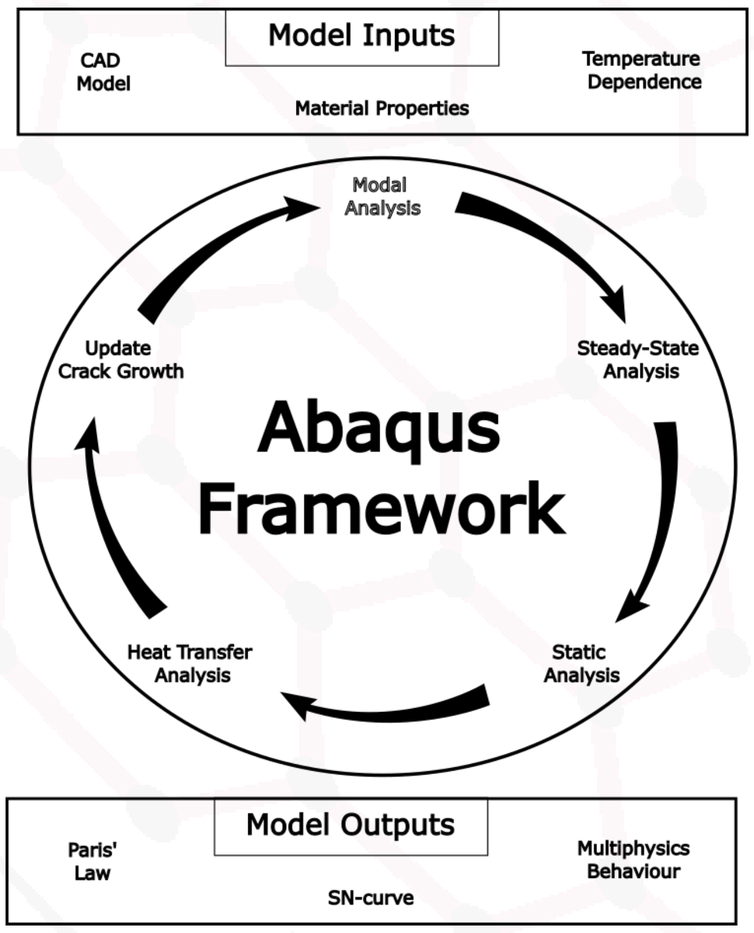

Figure 2 Different analysis steps to create the digital-twin framework in Abaqus.

Limitations

There are several limitations that must still be accounted for:

- **Self-heating behaviour** must be understood,
- The physics of large delaminations,
- Idealization of material properties,
- Focus on **mesoscale.**

Conclusion

A **digital-twin framework** will be created to predict the **residual life** of composite materials that are subjected to **vibration fatigue**. This can significantly **speed up** conventional fatigue testing methods for composite materials.

Future work

- Build the digital-twin framework,
- investigate temperature dependence,
- validate the model experimentally.

References

[1] Magi et al., Composites Sci. & Tech., 132 (2016) 47-56.
[2] Di Maio et al., I. J. Fatigue, 155(2022)106617.

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