

# mid Moulding Innovation Day 2026

Ottimizzare il processo e prevedere il comportamento a fatica nei polimeri a fibra corta: AI e Modellazione multiscala per raggiungere questi obiettivi.

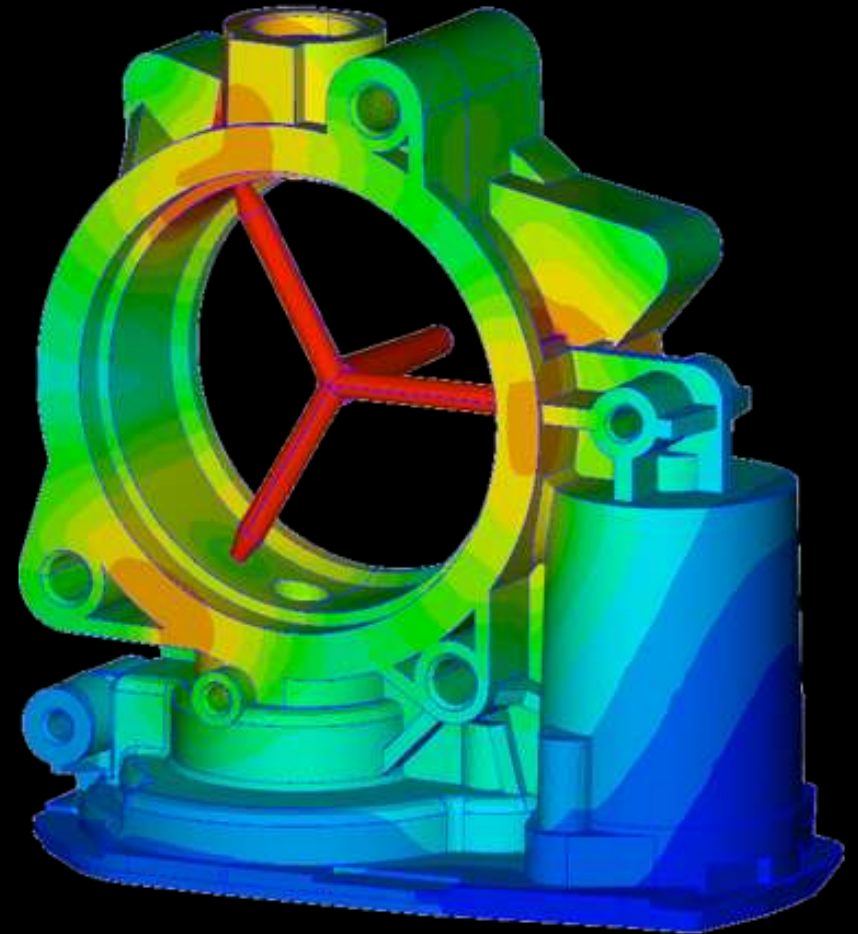
## **Raffaele Russo**

Principal Application Engineer - Physical System  
System Design and Analysis  
MSC Software part of Cadence

**Moldex3D**

# Agenda

- 1. Common Challenges in Fatigue Modeling**  
Customer needs
- 2. Solving These Challenges**  
Streamlined, efficient & accurate solutions
- 3. Case Study**  
Fatigue lifetime & hotspot predictions
- 4. Gate Position Analysis**  
New Capabilities
- 5. Summary**  
Key contributions & industrial impact



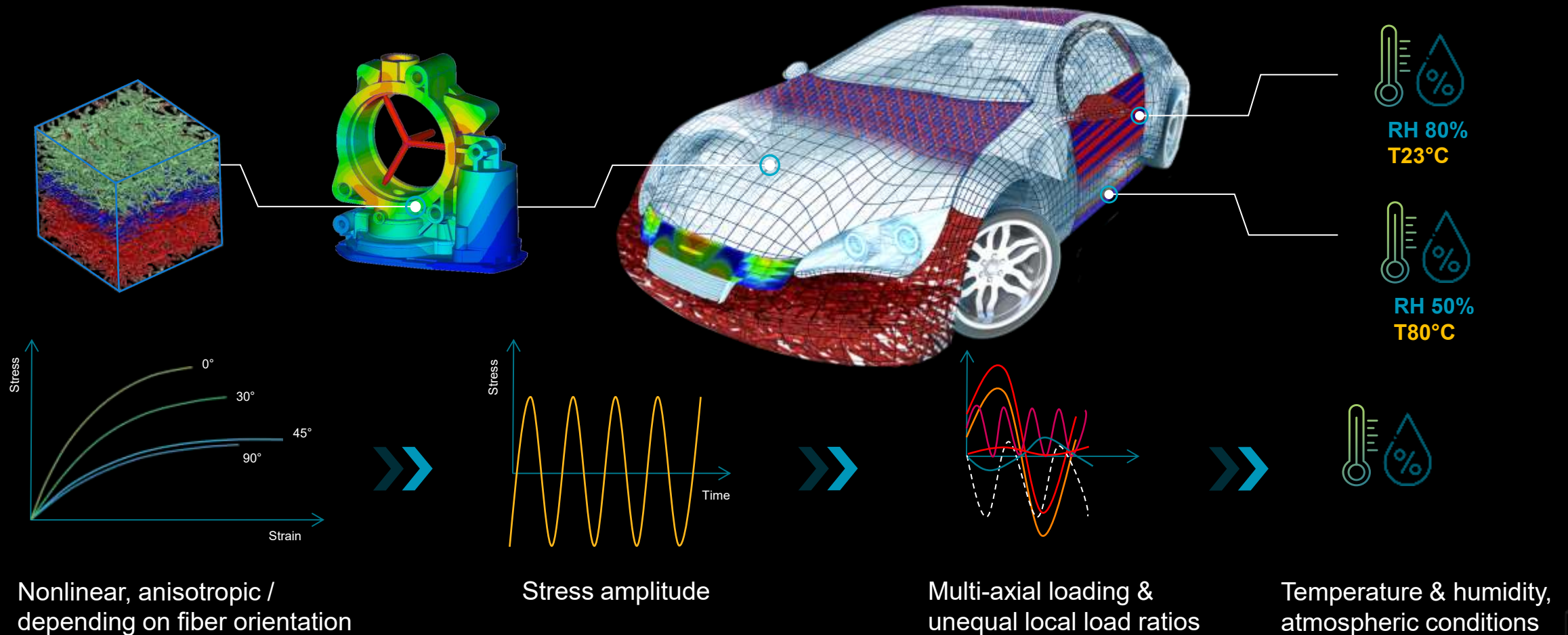


# Common Challenges in Fatigue Modeling

Customer needs

# Common Challenges in Fatigue Modeling

## Challenges in material card generation



# Common Challenges in Fatigue Modeling

Challenges: Limited experimental fatigue data

- Design requirements:

- Part must withstand given number of cycles under fatigue loads at fixed test conditions (T°C/RH)

- Available material data:

- Quasi-static tensile curves at targeted test conditions (T°C/RH)
- Single fatigue curve measured on directly molded bar (R = 0.1)



## CAE Engineer

- Runs fatigue simulation to ensure structural integrity
- Needs additional S-N data to build fatigue card with mean-stress sensitivity
- Works against tight deadlines & cannot afford delays



## Material Engineer

- Limited data available for specific material grades
- Expensive ~\$50k
- Time consuming **3-6 months at best**

# Common Challenges in Fatigue Modeling

## Challenges: Lifetime prediction issues

- Lifetime typically underestimated due to strong local stress gradients caused by:
  - Geometry : Notches, small radii, etc.
  - Mesh : Element size, aspect ratio, etc.
  - Boundary conditions : Fixed locations, point loads, etc.
  - Local plasticity : Early nonlinearity for plastics
- Vibrational fatigue further increases complexity
  - Resonance can amplify structural response
  - Anisotropy influences frequency dependent damping



# Solving These Challenges

Streamlined, efficient, accurate solutions

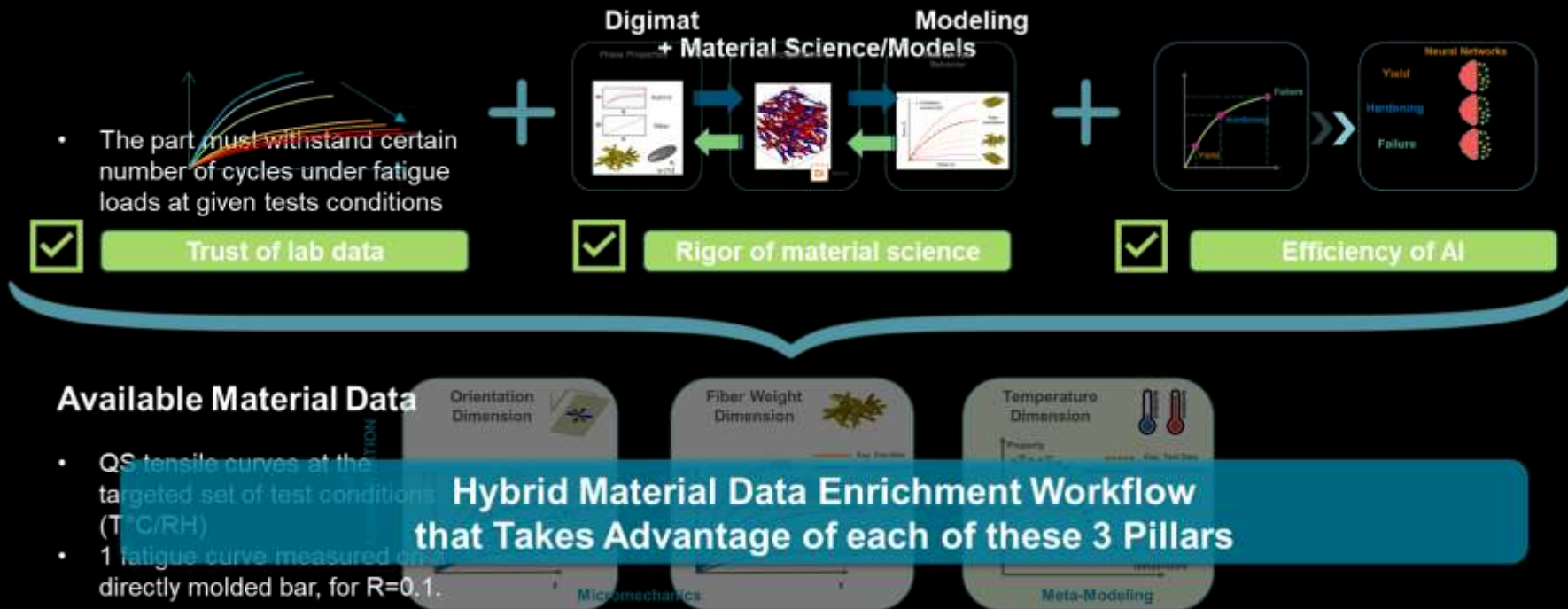
# Solving These Challenges

Challenge: Limited experimental fatigue data



## Materials Enrich

- Cheaper : ~\$3,800
- All fatigue S-N data covering all needs generated **in minutes**

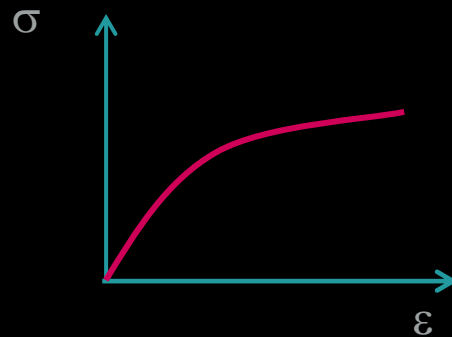


# Solving These Challenges

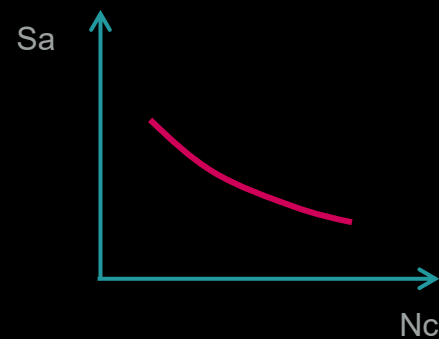
## Physics informed AI approach

- Inputs : Available material data

- Tensile : quasi-static curve



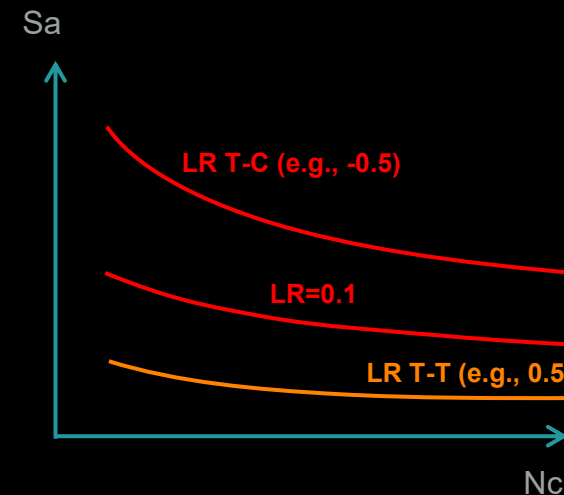
- Fatigue : S-N curve at single load ratio ( $R = 0.1$ )



- Outputs : Missing material data

- Fatigue

- Different fiber orientations
- Different temperatures
- Different mass fractions
- Different load ratios
- Different relative humidities



# Solving These Challenges

## Materials Enrich

A screenshot of the Materials Enrich web application. The interface is clean and modern, with a white background and a light blue header. The header includes the Materials Enrich logo and name on the left, and navigation icons (home, search, grid, user) on the right. The main content area features a "Welcome to Materials Enrich" heading, followed by a sub-heading "Your total time and money saved by using Materials Enrich instead of experimental tests." Below this, there are two data points: "271 weeks" with a clock icon and "\$230,845" with a dollar sign icon. A prominent "Create Campaign" button with a plus sign and a hand icon is centered. At the bottom, there is a section titled "Nexus Materials Enrich scope" with a list of current capabilities and limitations.

Materials Enrich

### Welcome to Materials Enrich

Your total time and money saved by using Materials Enrich instead of experimental tests.

271 weeks    \$230,845

**Create Campaign**

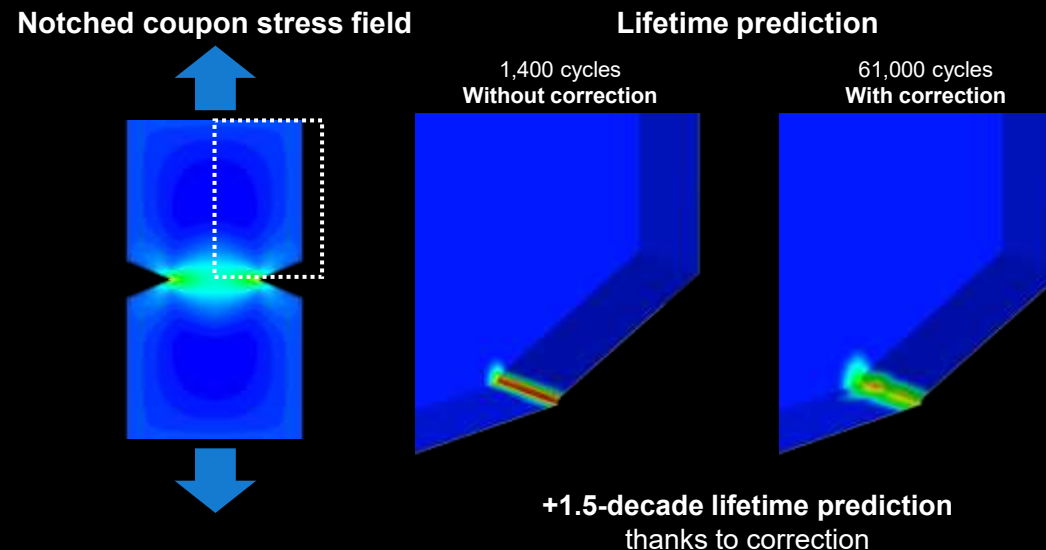
**Nexus Materials Enrich scope**

- Currently, Materials Enrich
  - supports only data from unreinforced and short fiber reinforced plastic materials, and
  - interpolates only tensile curves of directly injected coupons with dependency to temperature, moisture content and strain rate.

# Solving These Challenges

## Underestimated fatigue lifetime predictions

- Numerical correction allows influence of local stresses from mesh size to be overcome
  - Why is this needed?
    - Local stresses are sensitive to mesh size
    - Lower radius = higher mesh sensitivity
    - Small discrepancy in numerically predicted stress can induce discrepancy of several decades in lifetime prediction

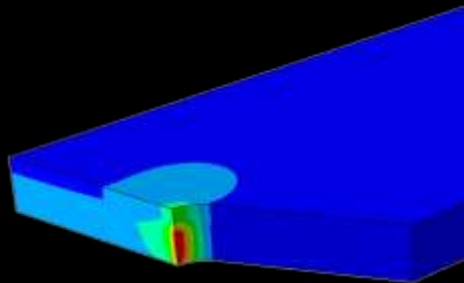


# Solving These Challenges

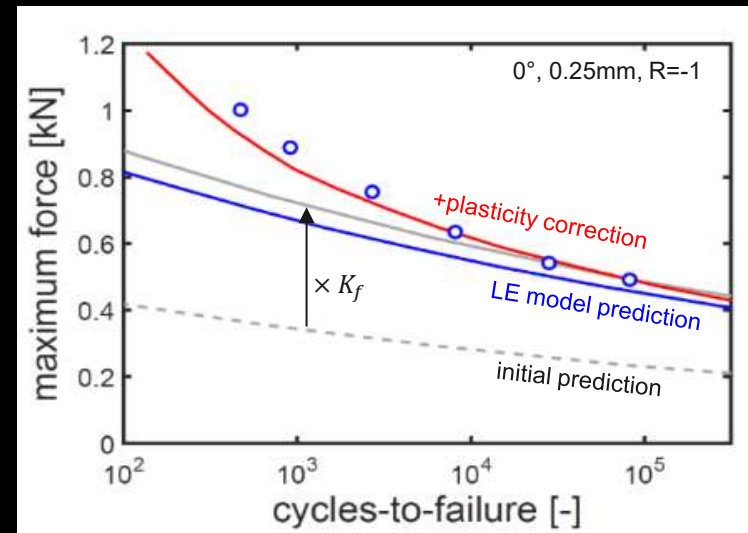
## Underestimated fatigue lifetime predictions

- Physical correction allows conversion of elastic stress/strain into plastic stress/strain when plastic deformation occurs
  - Why is this needed?
    - Geometric discontinuities generate local stresses greater than material yield stress
    - Elastic material model causes artificially high stresses = underestimation of fatigue lifetimes

FEA results



Fatigue data notched specimens





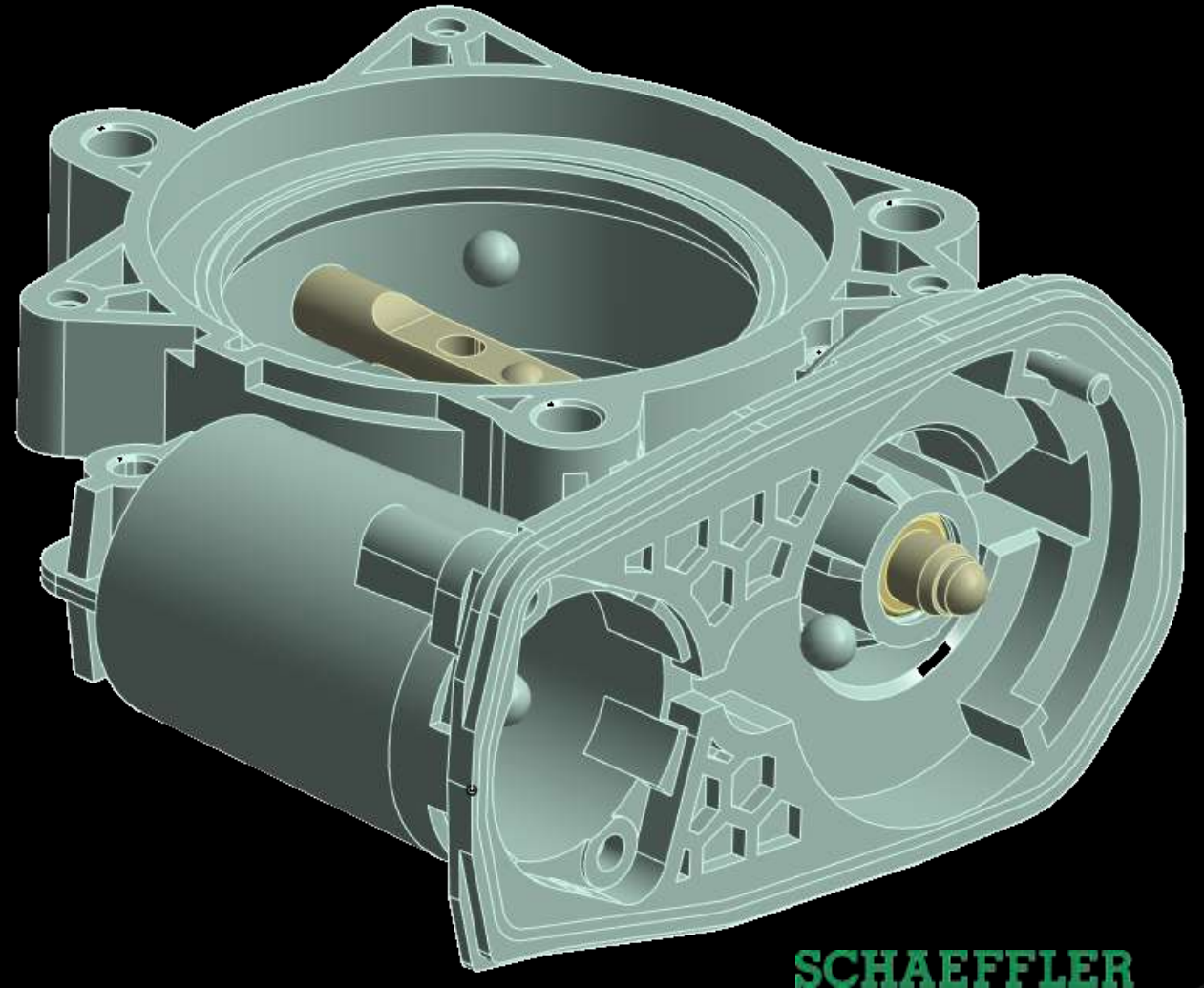
# Case Study

## Fatigue lifetime & hotspot predictions

# Case Study

## Throttle valve

- Part : Throttle valve
- Manufacturing : Injection molding
- Material
  - Reinforcement : 30% short glass fiber
  - Matrix : Polyketone
- Loading
  - Continuous vibration
  - High-frequency excitation
  - Localized fatigue hotspots



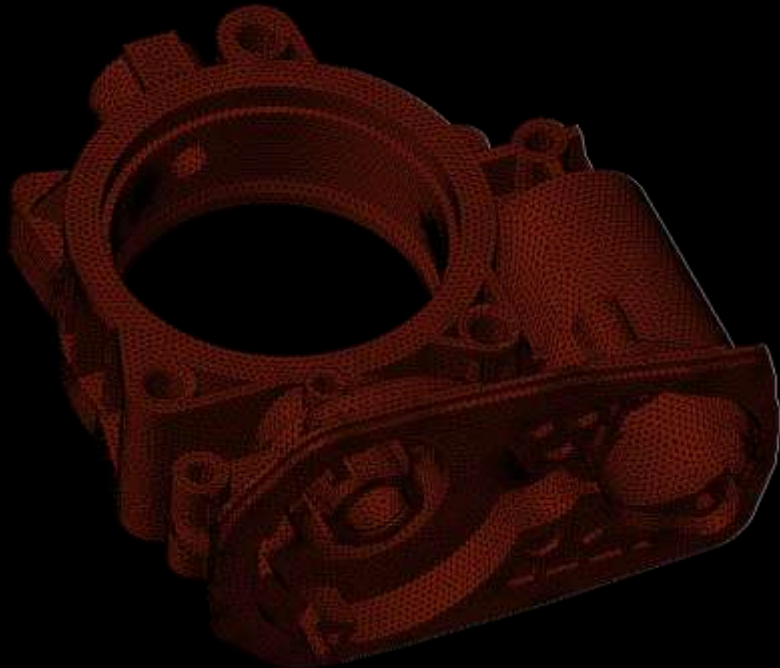
SCHAEFFLER

# Case Study

## Structural model

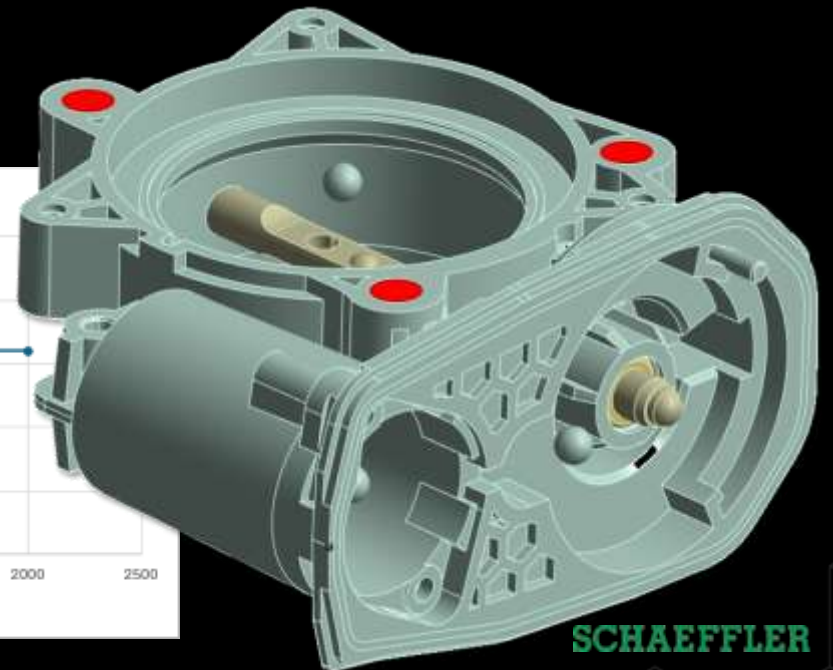
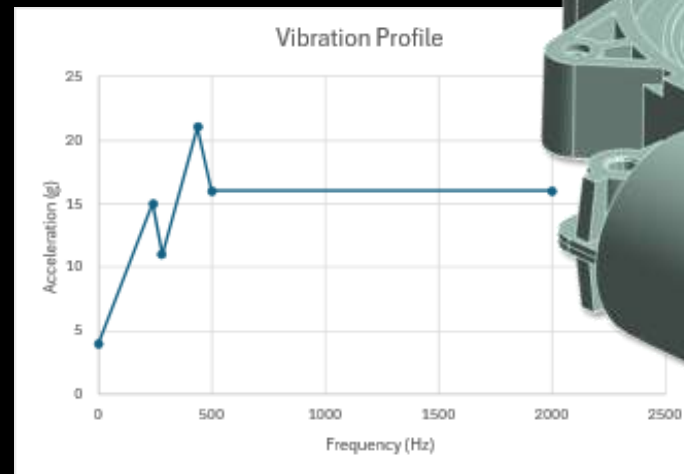
- Meshing

- Tet10 elements
  - 428,082 elements
  - 177,342 nodes



- Loading

- Harmonic excitation applied in Z-direction at bolts marked in red
- Part fixed on vibrating shaker table

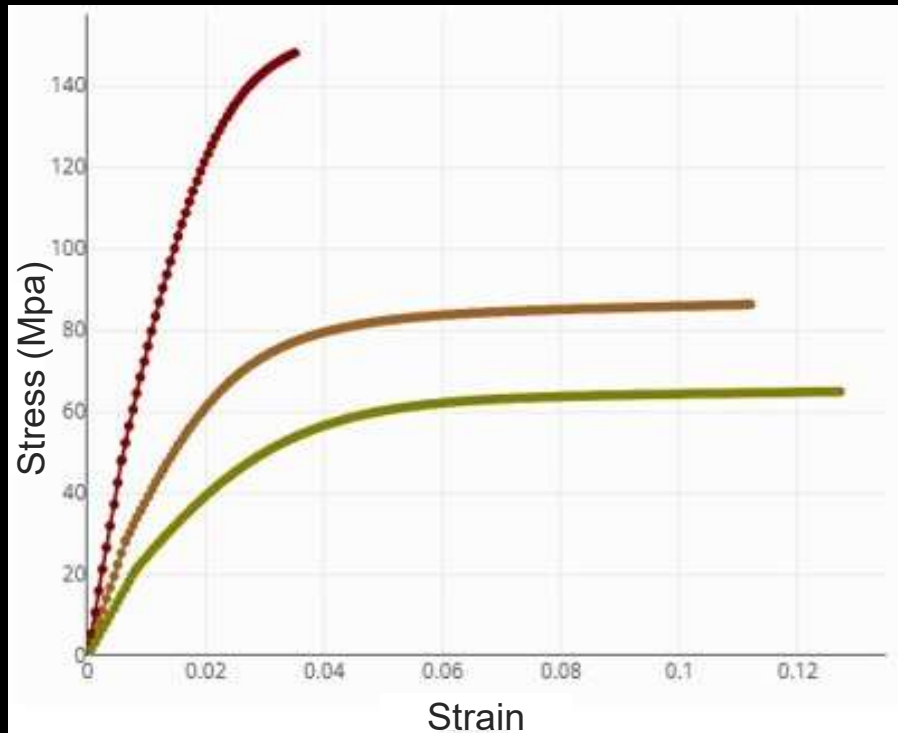


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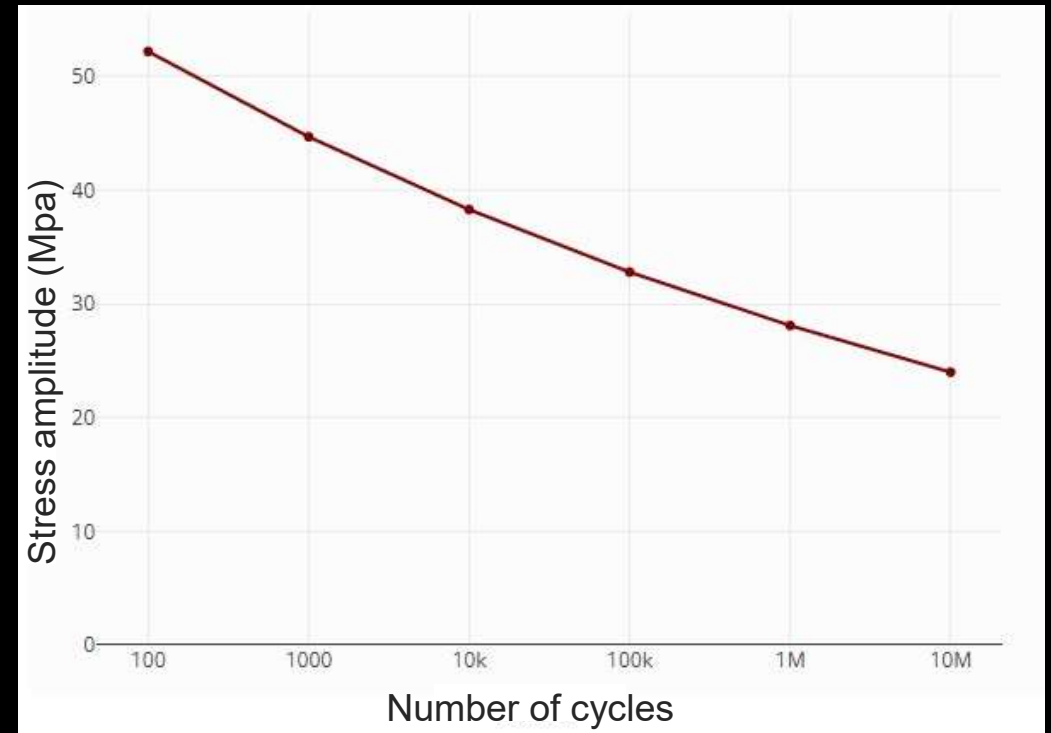
# Case Study

## Input experimental data

- Tensile data at 23°C, DAM: 0°, 30° & 90°



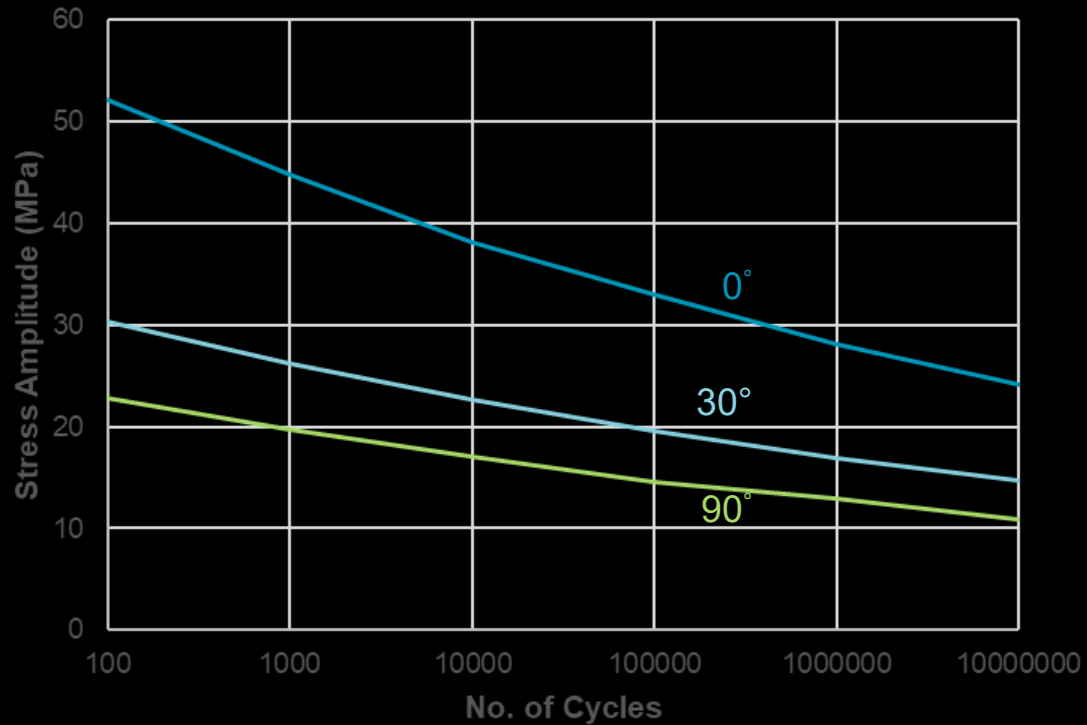
- S-N Curve at 23°C, DAM: R = 0.1



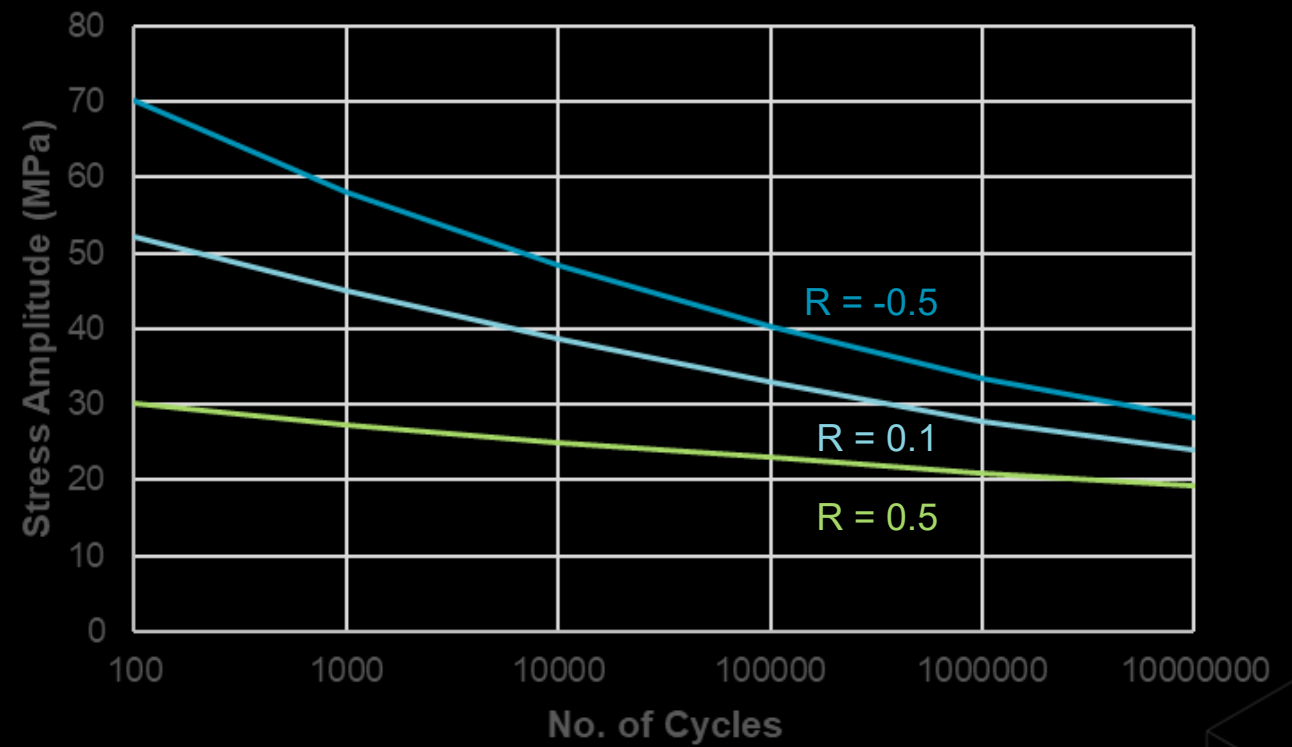
# Case Study

## Enriched experimental data

- S-N curves at  $R = 0.1$ :  $0^\circ$ ,  $30^\circ$  &  $90^\circ$

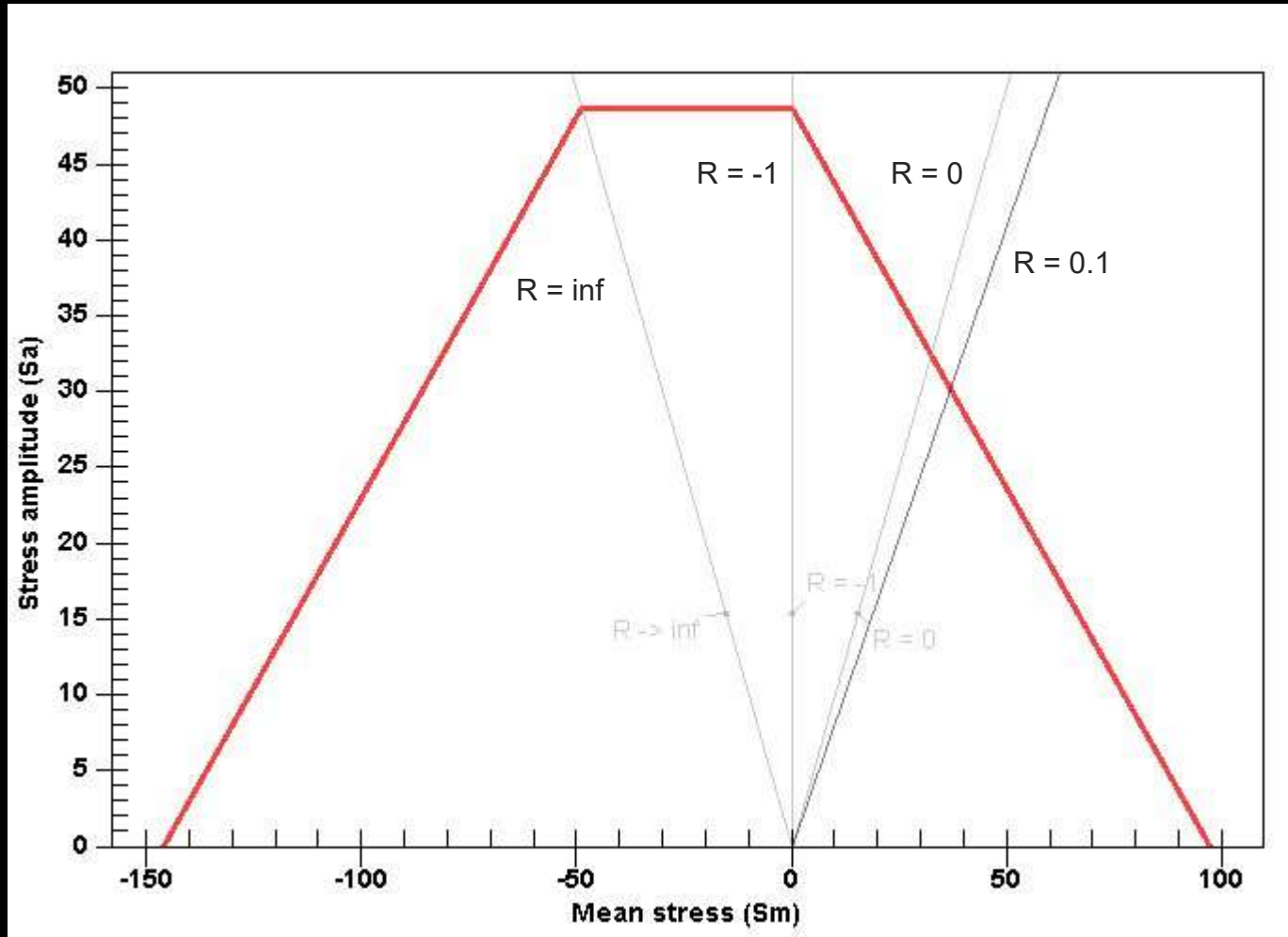


- S-N curves at  $0^\circ$ :  $R = -0.5$ ,  $0.1$  &  $0.5$



# Case Study

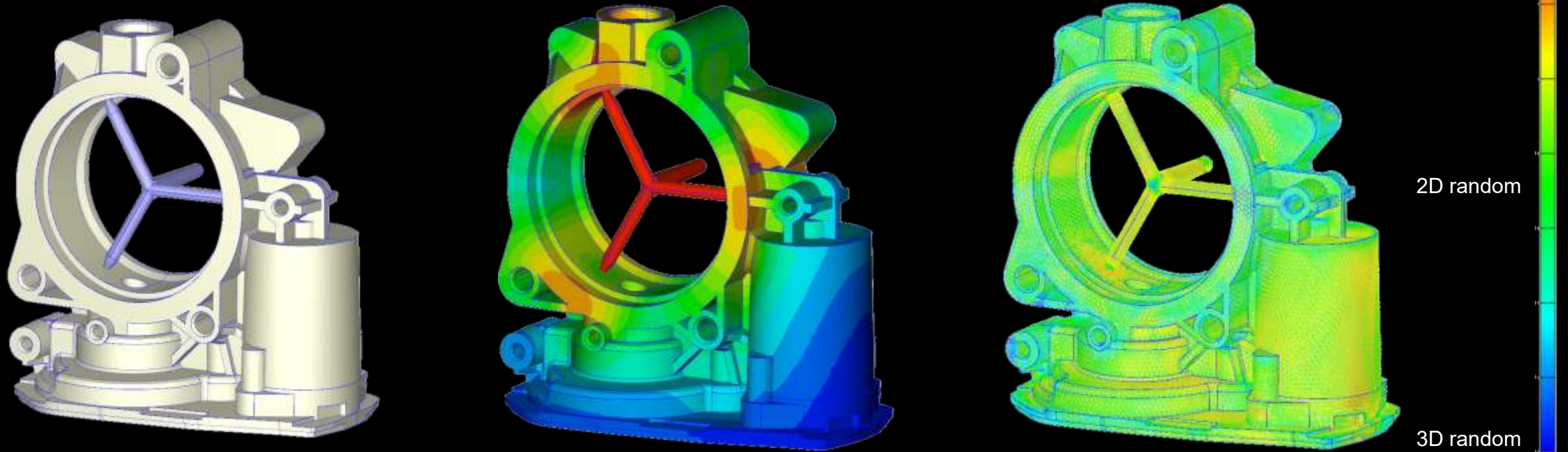
## Constant life diagram (CLD)



# Case Study

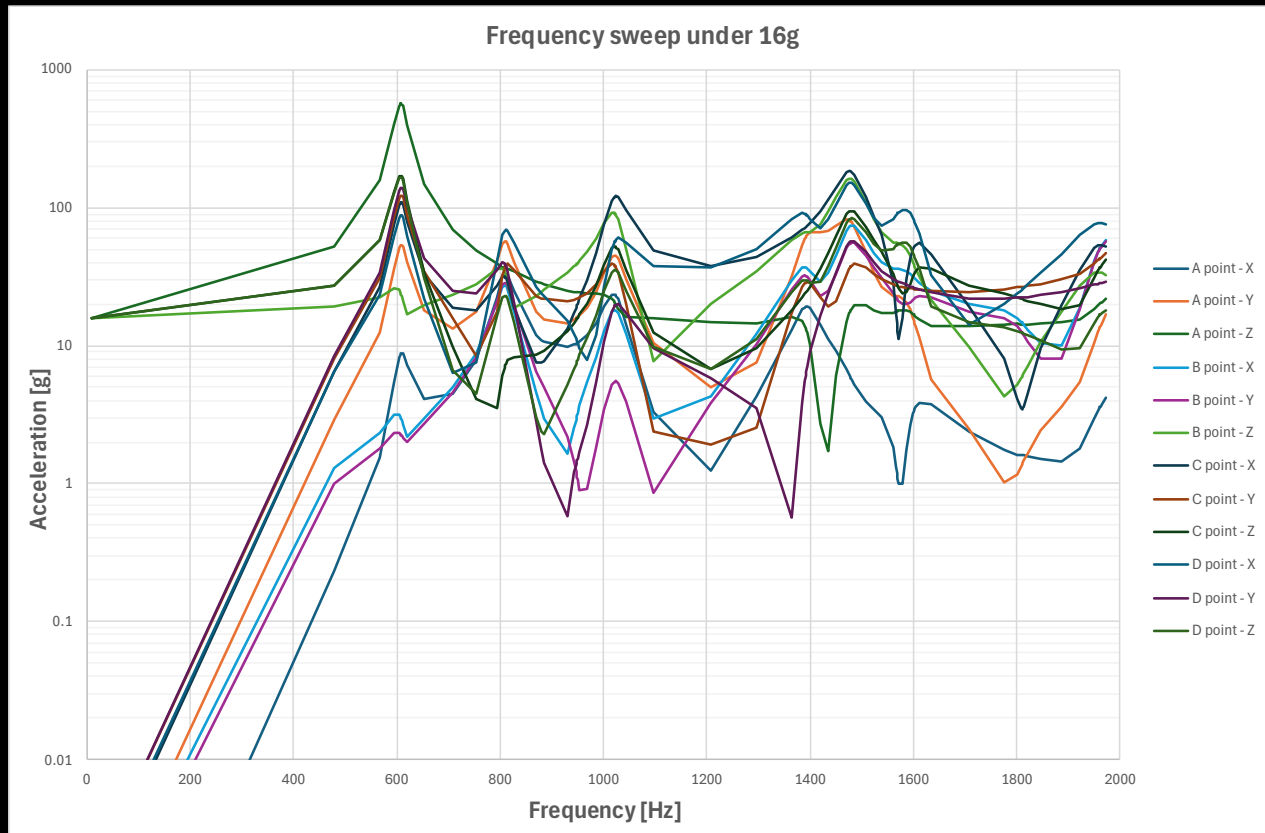
## Manufacturing data

### Injection Molding Simulation Results



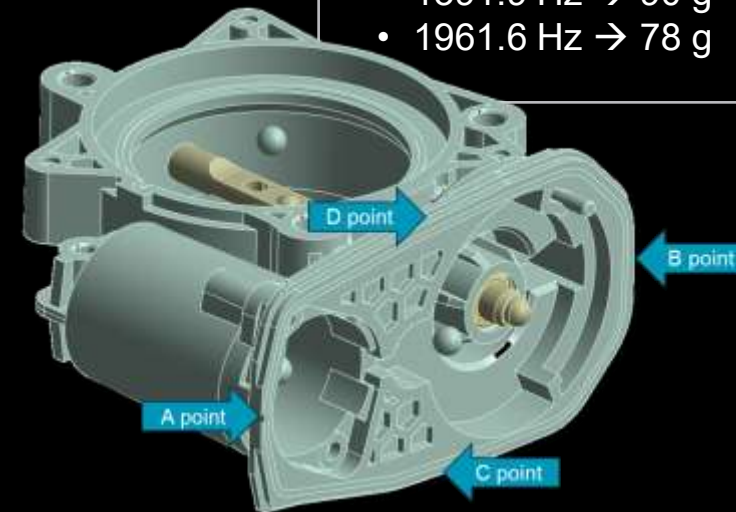
# Case Study

## Harmonic response: Frequency sweep under constant acceleration in Z



Significant frequencies peaks are:

- 607.7 Hz → 567 g
- 809.51 Hz → 69 g
- 1022.4 Hz → 120 g
- 1391.9 Hz → 90 g
- 1961.6 Hz → 78 g



# Case Study

Harmonic response: Frequency sweep under constant acceleration in Z

Isotropic Simulation		Digimat Anisotropic Simulation	
Mode [-]	Frequency [Hz]	Mode [-]	Frequency [Hz]
1	821.79	1	607.69
2	1104.8	2	809.51
3	1335.4	3	948.78
4	1437.1	4	1022.4
5	1859.1	5	1391.9
6	1897	6	1478.1
7	2095.9	7	1536.9
8	2198.6	8	1600.7
9	2313.1	9	1795.5
10	2639.8	10	1958.5

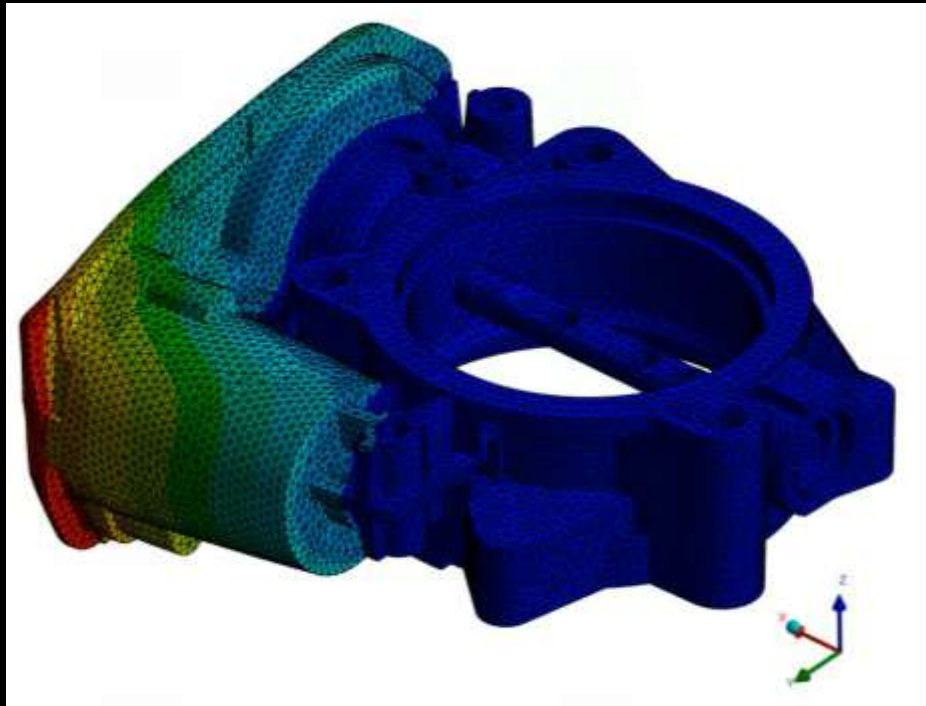
Isotropic Simulation		Digimat Anisotropic Simulation	
Mode [-]	Frequency [Hz]	Mode [-]	Frequency [Hz]
11	2670	11	2070
12	2730.6	12	2206.7
13	2969.9	13	2274.8
		14	2330
		15	2457.6
		16	2486.9
		17	3015.5
		18	3057.8

# Case Study

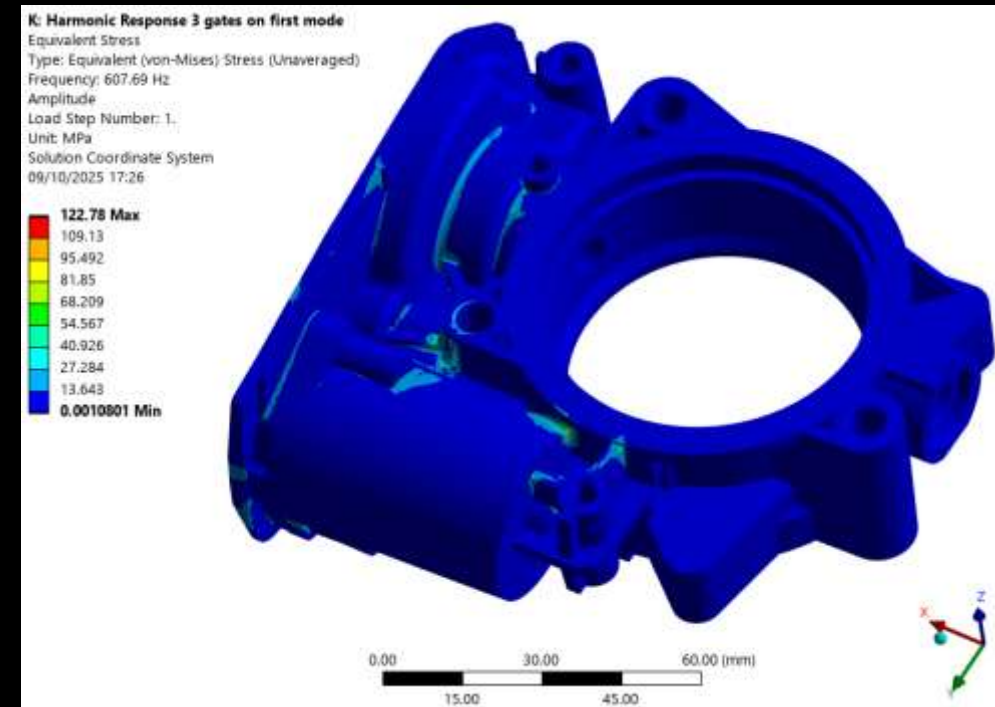
## Mode shape & harmonic stress

- Harmonic stress (123 MPa) < Static strength (130 MPa)

### Fundamental Mode Shape



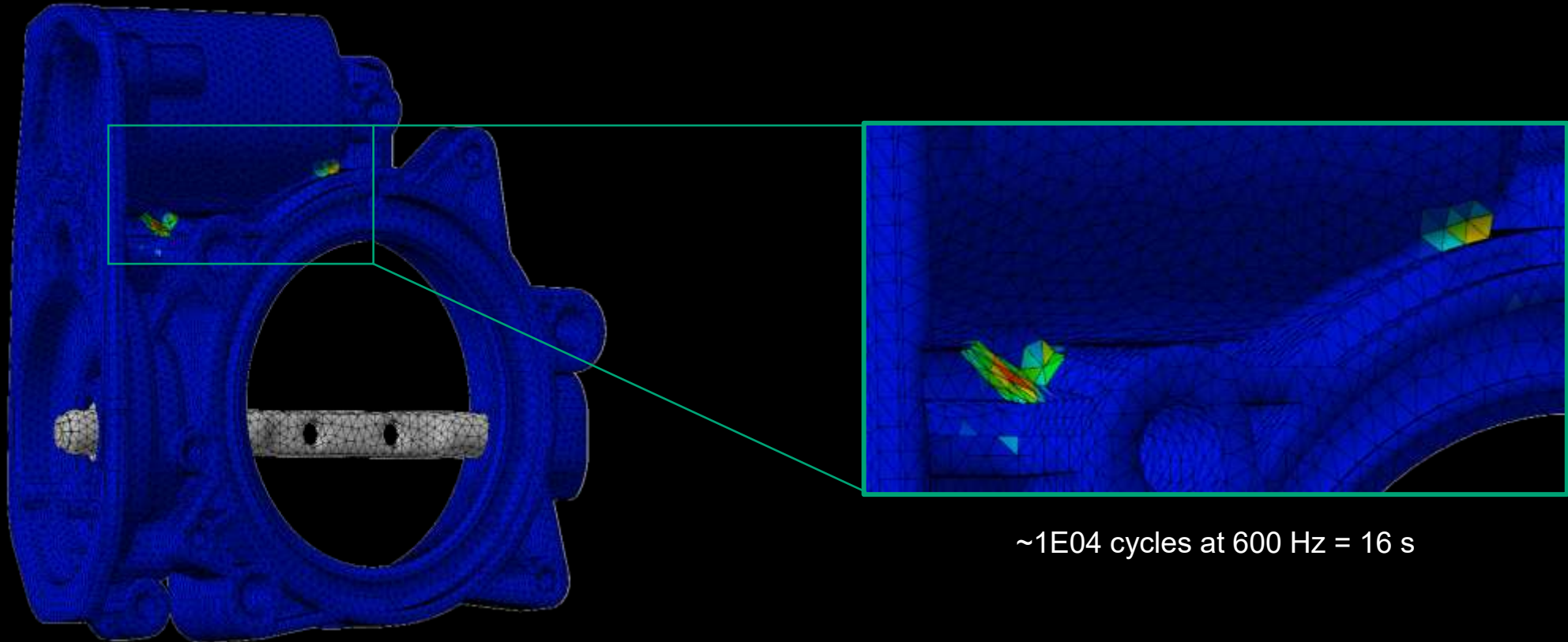
### Harmonic Stress



# Case Study

## Lifetime & hotspots

- Numerical correction applied





# Gate Position Analysis

New Capability

# Gate Position Analysis

- Capability

## Description:

The goal of this feature is to Evaluate the impact of the Gate position on the structural performance .

- *Injection molding DOE using your injection molding software*
- *Definition of KPI based on failure, displacement, reaction force and more.*

## Benefits:

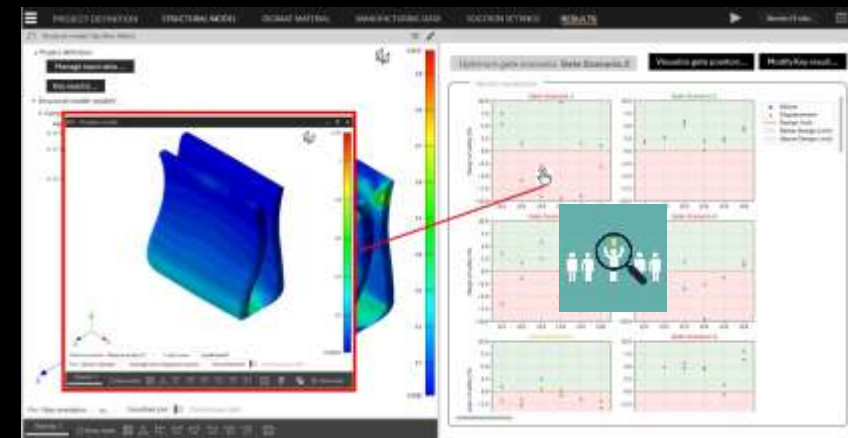
Detect the best Gating strategy:

- *Automatic job submission*
- *Automatic Post-processing of the results*
- *Fringe plot and graphs*
- *Objective review*
- *Possible objective revision without rerun*

## Who needs it:

Design/Structural engineers in coordination with the process engineers

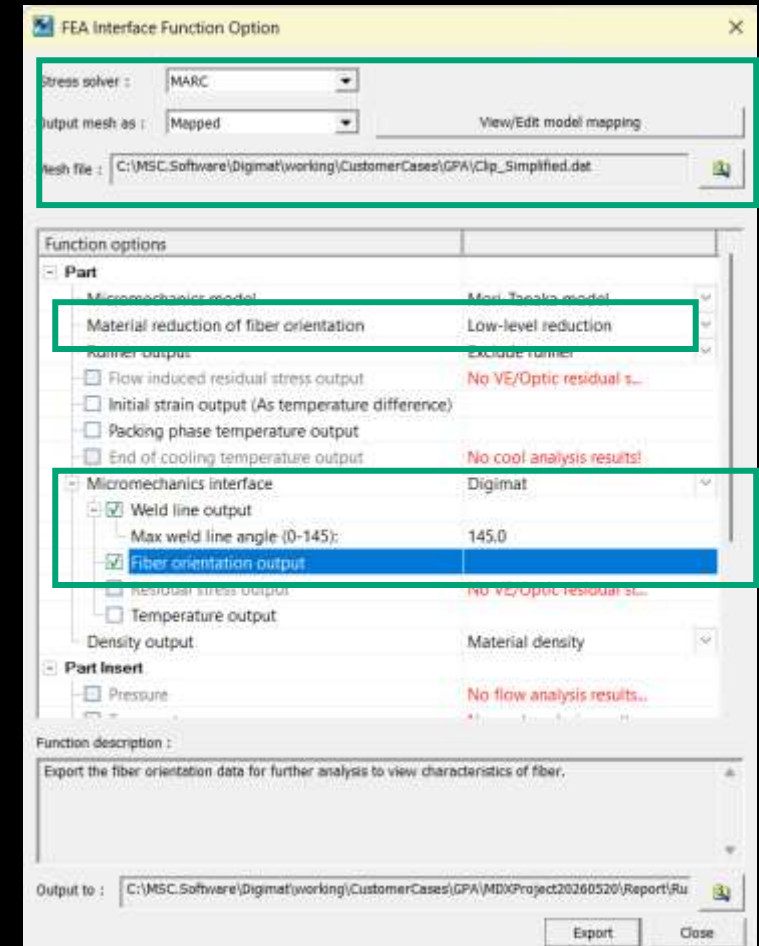
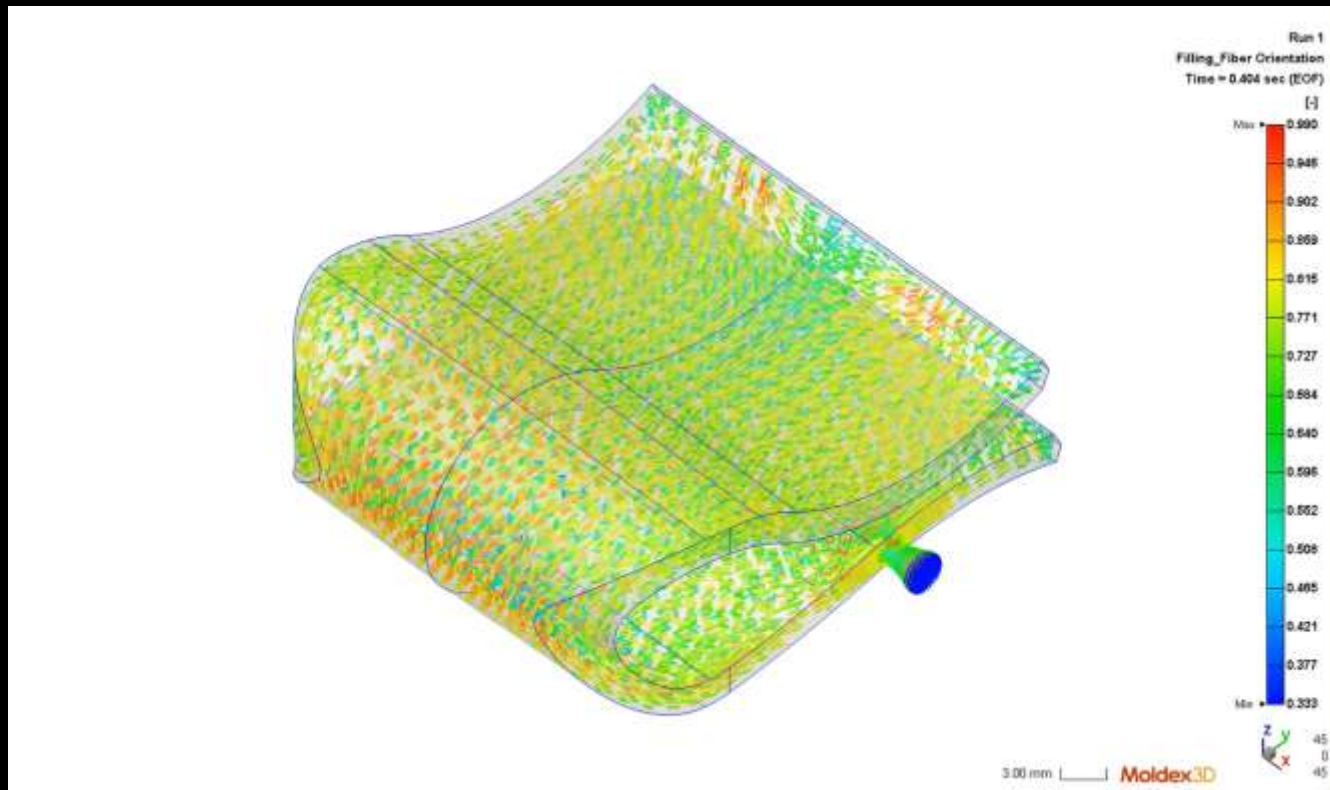
Scenario name	Melt Temperature	Mold Temperature	Fill Time	Gate 1	Gate 2	Gate 3	Gate 4	Gate 5	Gate 6
Gate scenario 1	285	75	75	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Gate scenario 2	285	75	75	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Gate scenario 3	285	75	75	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Gate scenario 4	285	75	75	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Gate scenario 5	285	75	75	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>
Gate scenario 6	285	75	75	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>
Gate scenario 7	285	75	75	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>



# How to Do It?

## Injection Molding Simulation with Different Gate Scenarios

- Moldex3D Simulation



# How to Do It?

## Choose the Best Gate Scenario based on Structural KPIs

- Digimat-MS Gate Position Analysis

Manage input data | Key results

Note: this project contains simulation results. To edit the key results and key results assignments, go to the Results section and use the Revise Key results button.

Define key results

Add new Key result...

KR1_FI	KR2_APS
Name: KR1_FI	Name: KR2_APS
Type: Failure Indicator (Element)	Type: Accumulated plastic strain (Element)
Rule: % Integration points 0.02 %	Rule: % Integration points 1 %
Acceptance: < 0.5	Acceptance: < 0.0004

Delete

Assign key results

Name	Load case	Key result	Element or node set	Simulation time
KRA1	Loadcase1	KR1_FI	(all elements)	1
KRA2	Loadcase1	KR2_APS	(all elements)	1

Visualize gate scenarios

Gate_Center	Tip	Side	OffsetBase	BothSides	Base_BothSides
<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>
<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

OK

Gate 4  
Gate 3  
Gate 1

# How to Do It?

## Create the DoE in Digimat

- Digimat-MS Gate Position Analysis

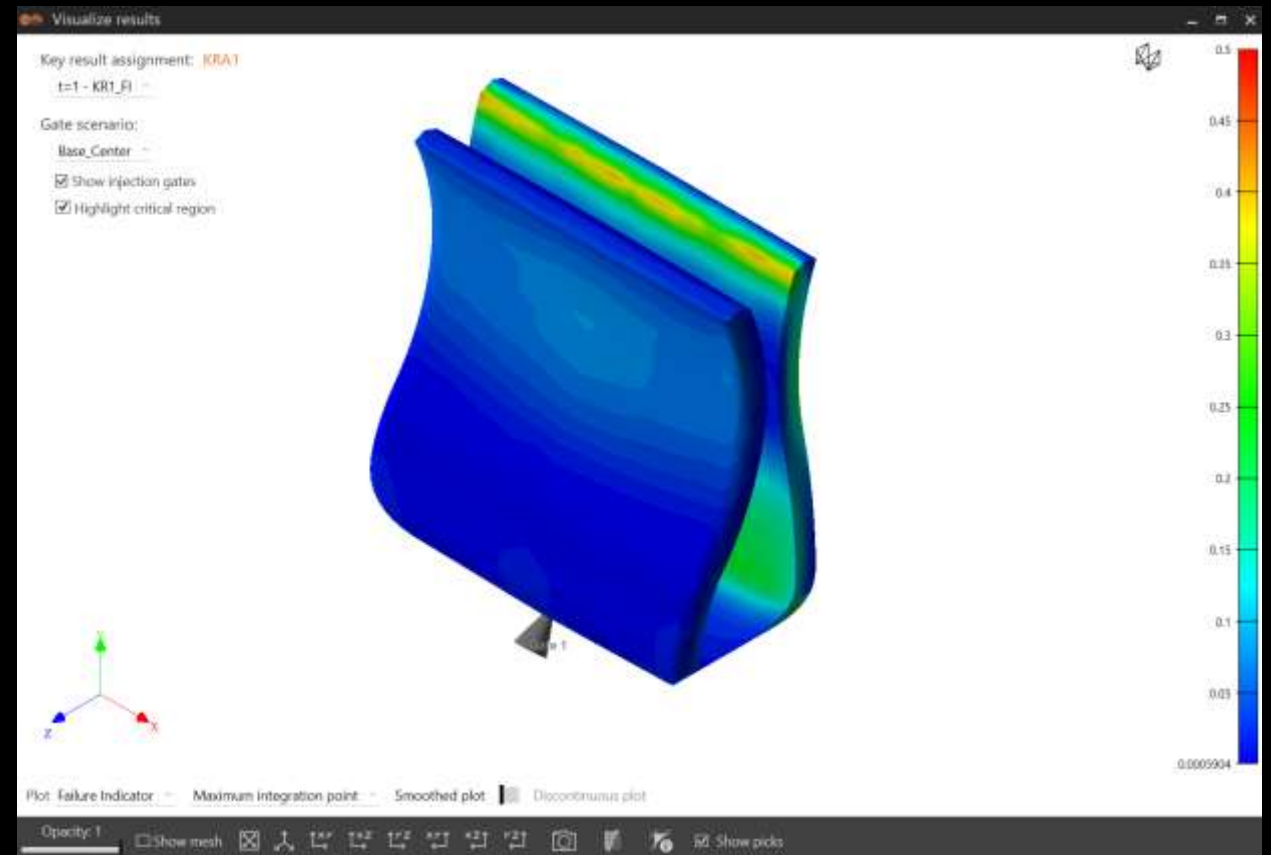
Name	X (mm)	Y (mm)	Z (mm)
Gate1	-6.0531	0.15823	7.1787
Gate2	7.0636	0.17809	7.161
Gate3	-10.5	32.414	9.5078
Gate4	10.5	32.414	9.5078
Gate5	10.5	32.928	1.8943
Gate6	-10.5	32.928	1.8944

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# How to Do It?

Analyze the Results based on Defined DoE and KPIs

- Digimat-MS Gate Position Analysis





# Summary

Key contributions & industrial impact

# Summary

- Key contributions
  - Physics-informed AI calibrated fatigue material card from limited data
  - Process-aware multiscale fatigue workflow
  - Industrial application of lifetime & hotspot prediction of a component under vibration fatigue
- Industrial impact
  - Faster design iteration
  - Reduced testing cost
  - Empowering users with improved confidence in short fiber reinforced plastic fatigue prediction

# Useful Resources

**White Paper**  
with Sabic



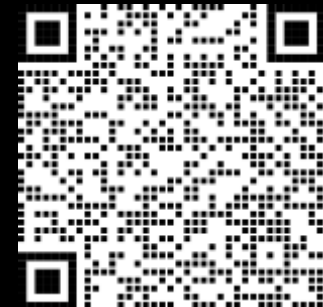
**Fatigue Webinar**  
with GM



**Webinar Series**  
with Schaeffler



**Flyer on**  
Materials Enrich



# Thank you

## **Raffaele Russo**

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