MMi TECHNYL® DESIGN

FROM MATERIAL SUPPLIER TO INNOVATION PARTNER

THE POWER OF PREDICTIVE SIMULATION AND FUNCTIONAL PROTOTYPING IN METAL REPLACEMENT.

THE E-MOTOR MOUNT CASE HISTORY

MMi TECHNYL® DESIGN

AGENDA

DOMO Chemicals

- Our company – our presence – our ambitions
- Polyamides – The right choice for demanding applications
- Our way of bringing additional value for our customers
- Stronger together: **HEXAGON** – Our software simulation partner

The virtual prototyping process: Metal replacement in an e-motor mount

- The challenges of metal replacement and how to innovate by predictive simulation
- Introduction into vibrational modelling and why anisotropic damping is key
- Dynamic material models comparison and methodology for assemblies

Conclusions

- HEXAGON and DOMO key insights

Q&A session

DOMO CHEMICALS

A NEW WORLD LEADER IN POLYAMIDES 6 & 66 COMPOUNDS

STRONG INTEGRATED POSITION

… uniquely integrated and connected businesses, from benzene to engineering plastics

SUSTAINABLE INNOVATION

… Proven industrial technology & innovation expertise to better serve our customers, sustainability-driven, customer-centered innovation

Committed to the future of polyamide

BROAD PORTFOLIO

… from producer to solution provider, contributing to Megatrends

GLOBAL SUPPLY AND SERVICES

…to serve growing future markets and applications globally

ENGINEERED MATERIALS

FOR A BROAD BASE OF APPLICATIONS

PRODUCTS

- Extensive standard and customized **PA6** and **PA66**
- Specialties based on **PA6.10 and PA-HT**
- Enhanced performance compounds
- Leader in **sustainable polyamides**

SOLUTIONS FOR

- Lightweight
- Electrification
- CO_2 reduction
- Miniaturization
- Eco-design

AUTOMOTIVE

INDUSTRIAL & CONSUMER GOODS

ELECTRIC & ELECTRONIC

DOMO ENGINEERED MATERIALS

Capacity: 200kT

Recycled material sales (% of 2020 sales volume): 12%

Production units :
Germany – Italy – France – Poland - China – USA - India.

Brand names: Domamid, Econamid and Technyl (EU)

WHERE DOMO POLYAMIDES HELP TO SAVE WEIGHT

EXAMPLES FOR METAL REPLACEMENT IN AUTOMOTIVE APPLICATIONS

EXAMPLES

Cylinder Head Covers

Door Lock Mechanism

EGR Cooler

Fuel and Oil Filters

Engine Mount

Oil Pan

Pedals and Brackets

Seat Pan & Seating Structure

Timing Chain Tensioners

BENEFITS OF **POLYAMIDES**

1. **Thermoplastic semi-crystalline material with easy processing**
2. **High mechanical performance in durability and strength**
3. **Good thermal stability from -40°C to 220°C**
4. **Resistance against many chemicals**
5. **Global availability – no single sourcing**
6. **Balanced cost-to-serve ratio**

HUB by TECHNYL®

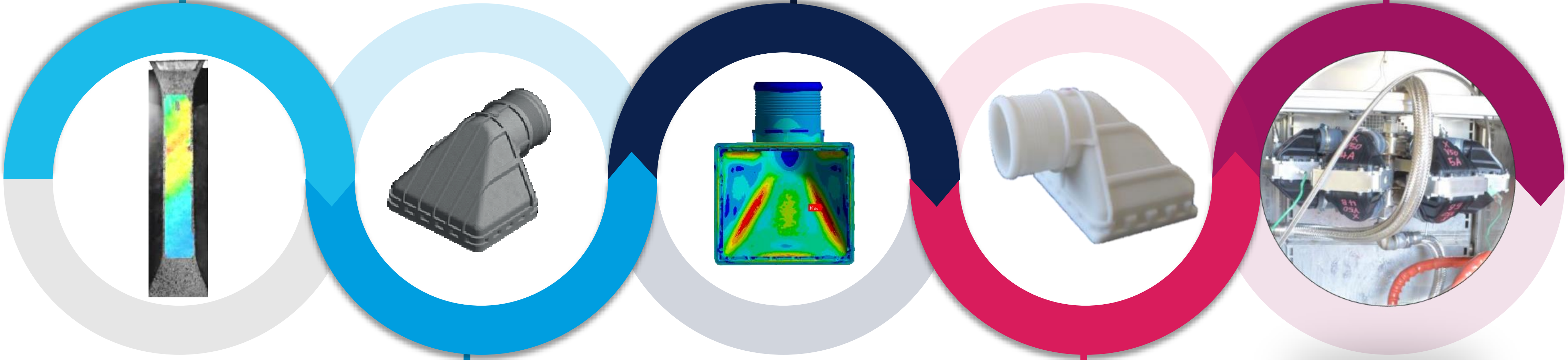
DOMO'S INTEGRATED CONCEPT

LINKING MATERIAL AND INNOVATION

MATERIAL SCIENCE & DATABASE

MMi TECHNYL DESIGN
SIMULATION

APT TECHNYL VALIDATION
APPLICATION PERFORMANCE TESTING



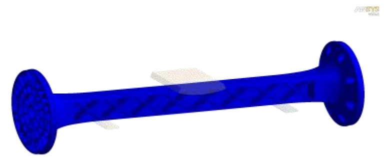
DESIGN OPTIMIZATION

FUNCTIONAL PROTOTYPING
SINTER LiNE TECHNYL PROTOTYPING

THE MMI APPROACH

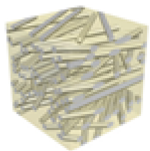
APPLYING FULL ANISOTROPIC MATERIAL DATA IN ALL STAGES OF THE SIMULATION PROCESS

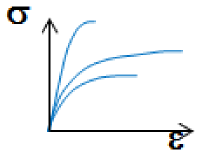
MMI TECHNYL® DESIGN



Mechanical simulation

+

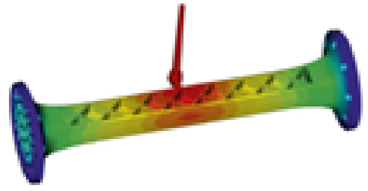




Digimat

Multi-scale Modeling

+



Injection molding

HEXAGON | e-Xstream ENGINEERING

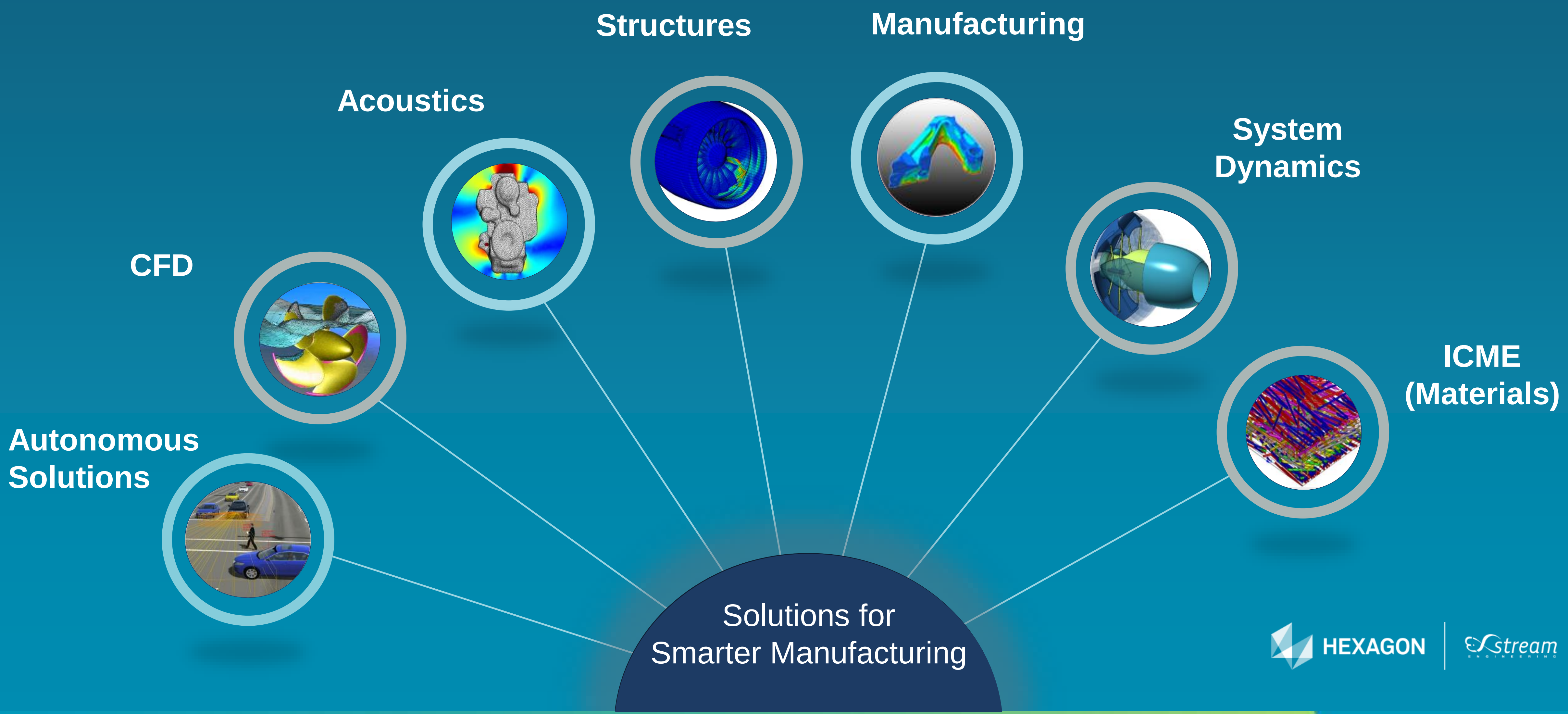
- Implementation of new simulation methods

DOMO

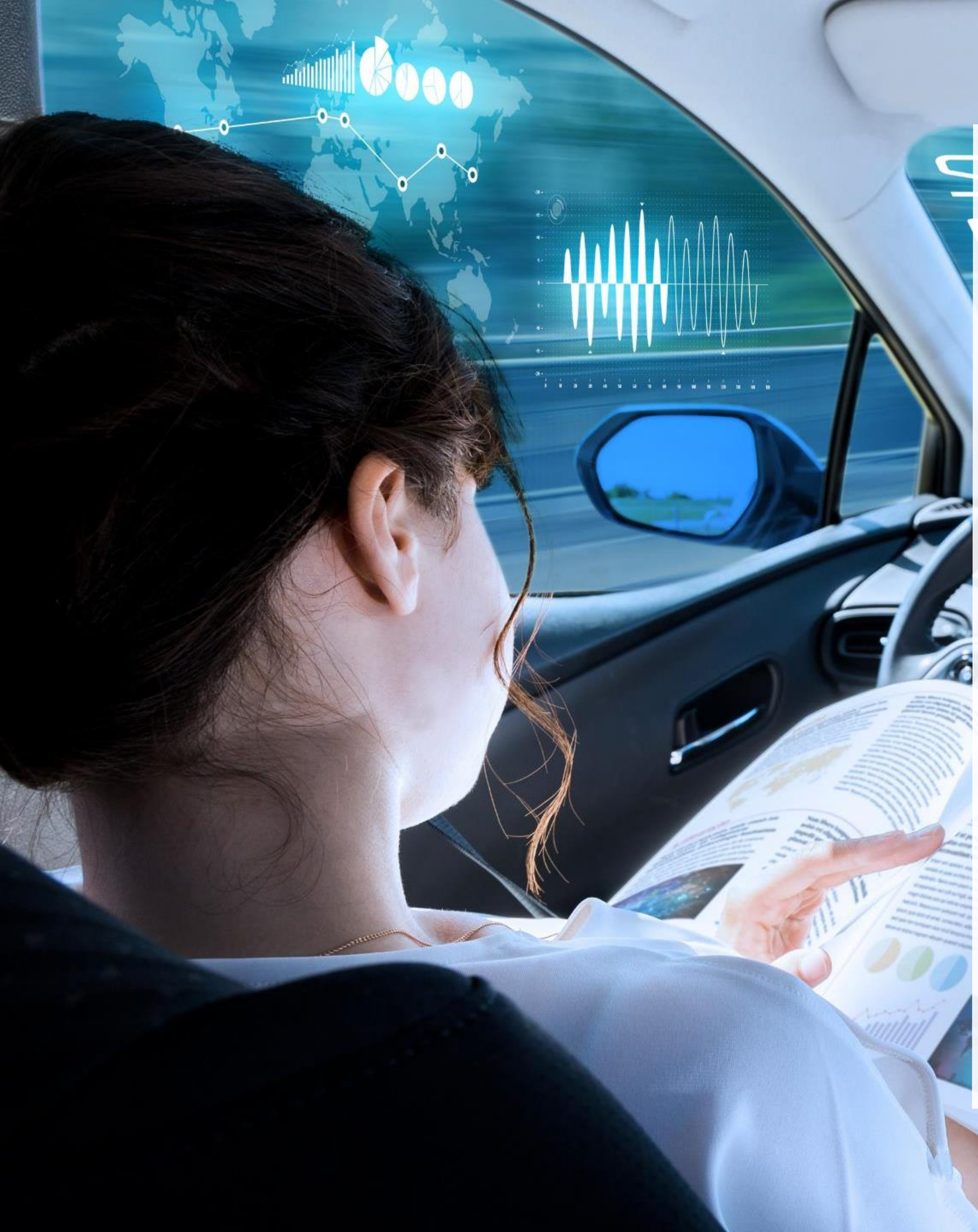
- Material data generation
- Material modelling
- Full simulation capabilities for customer projects

Hexagon MSC’s portfolio of technology & expertise

Providing state of the art solutions for Design & Engineering challenges



HEXAGON | Stream



THE VIRTUAL PROTOTYPING PROCESS:

METAL REPLACEMENT IN AN E-MOTOR MOUNT

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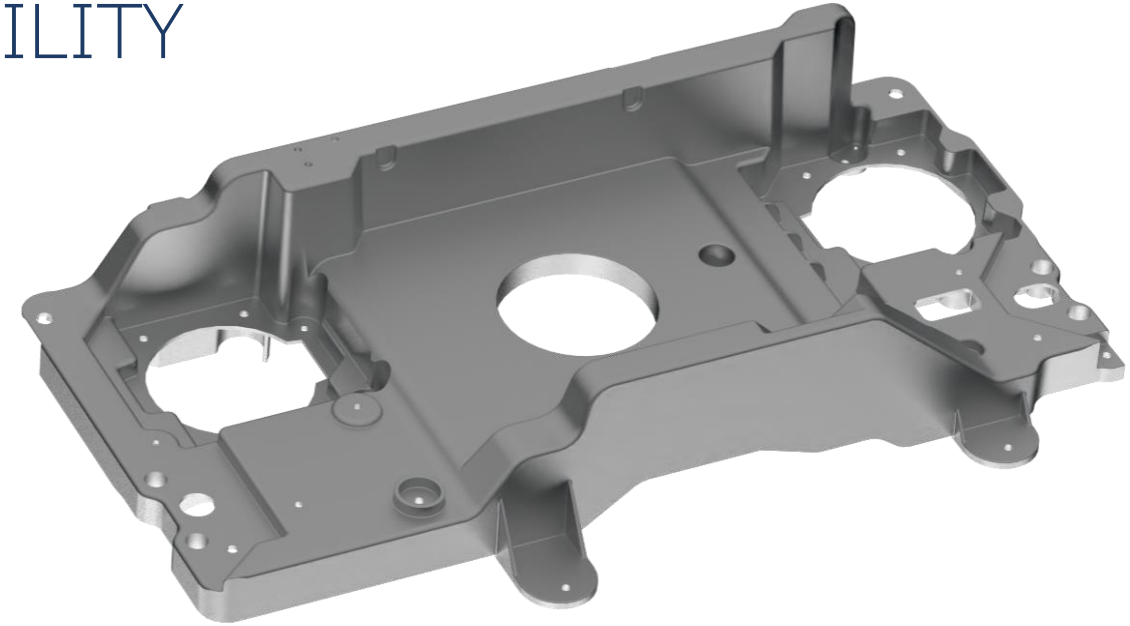
HEXAGON | e-Xstream

THE CHALLENGE

METAL REPLACEMENT FOR E-MOBILITY



THE MOTIVATION FOR METAL REPLACEMENT:

1. Weight reduction
2. Less vibration and less noise inside the car
3. Simplified processing and production
4. Optimized total cost of ownership

PART SPECIFICATION NEED TO BE FULFILLED FOR:

1. Static and dynamic load cases
2. Fatigue
3. **Vibration and damping behavior of assembly**

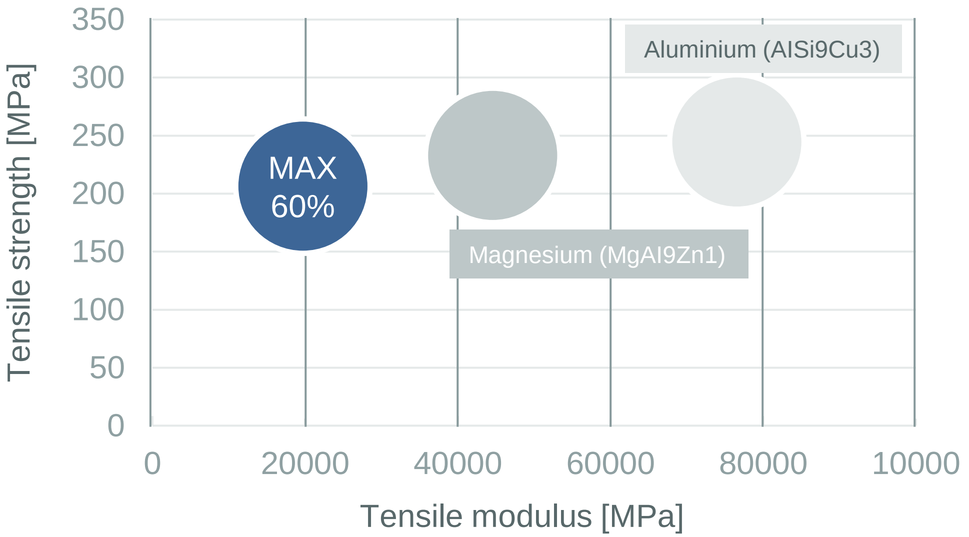
ELECTRICAL MOTOR MOUNT

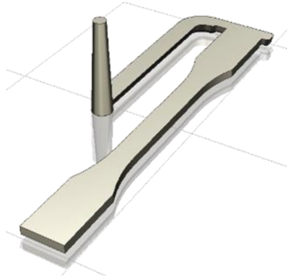
Aluminum die-casting part

Dimensions:	Weight:
710mm x 420mm x 150mm	5,7 kg

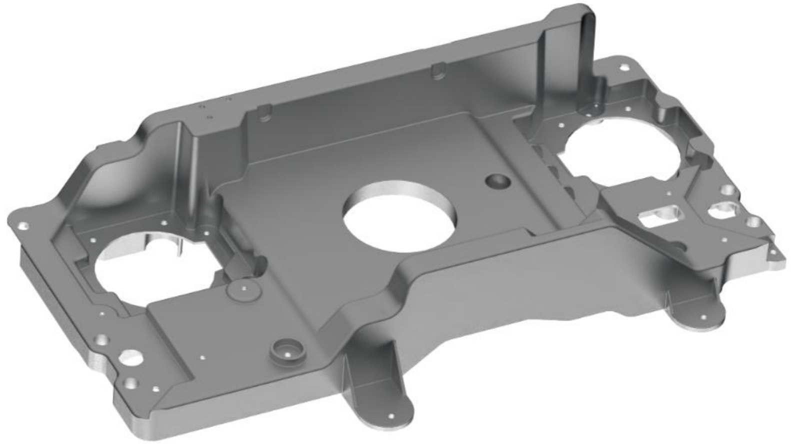
THE CHALLENGE

METAL REPLACEMENT FOR E-MOBILITY





Tensile properties
23°C, conditioned



Property	Al AlSi9Cu3	Mg MgAl9Zn1	PA66-GF60*	Comparison Al and PA66-GF60
Density [g/cm³]	2.70	1.81	**1.70**	→ PA66-GF density is **40% lighter**
Tensile modulus [MPa]	76000	45000	**17400**	→ Aluminum is **4x stiffer**
Tensile strength [MPa]	240	230	**200**	→ Material tensile strength is **similar**
Damping factor [%]	0.01		**1**	→ PA66-GF damping is **100x better**

Resulting **part stiffness is a question of design**
while **noise damping is a question of material choice**

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* Grade in comparison: TECHNYL MAX AF 218 XV60 black 21N

HEXAGON | Stream ENGINEERING

PREDICTING THE VIBRATIONAL BEHAVIOR OF POLYAMIDES

MICROMECHANICAL MODELLING TO DETERMINE HARMONIC FREQUENCY RESPONSES

Electric vehicle structural and vibrational loads

Induced by:

- **E-Motor**
  - Electrical lines
  - Power electronics
- **Gearbox**

Definition of relevant EV frequency range and accelerations

MMI modelling of polyamide part response

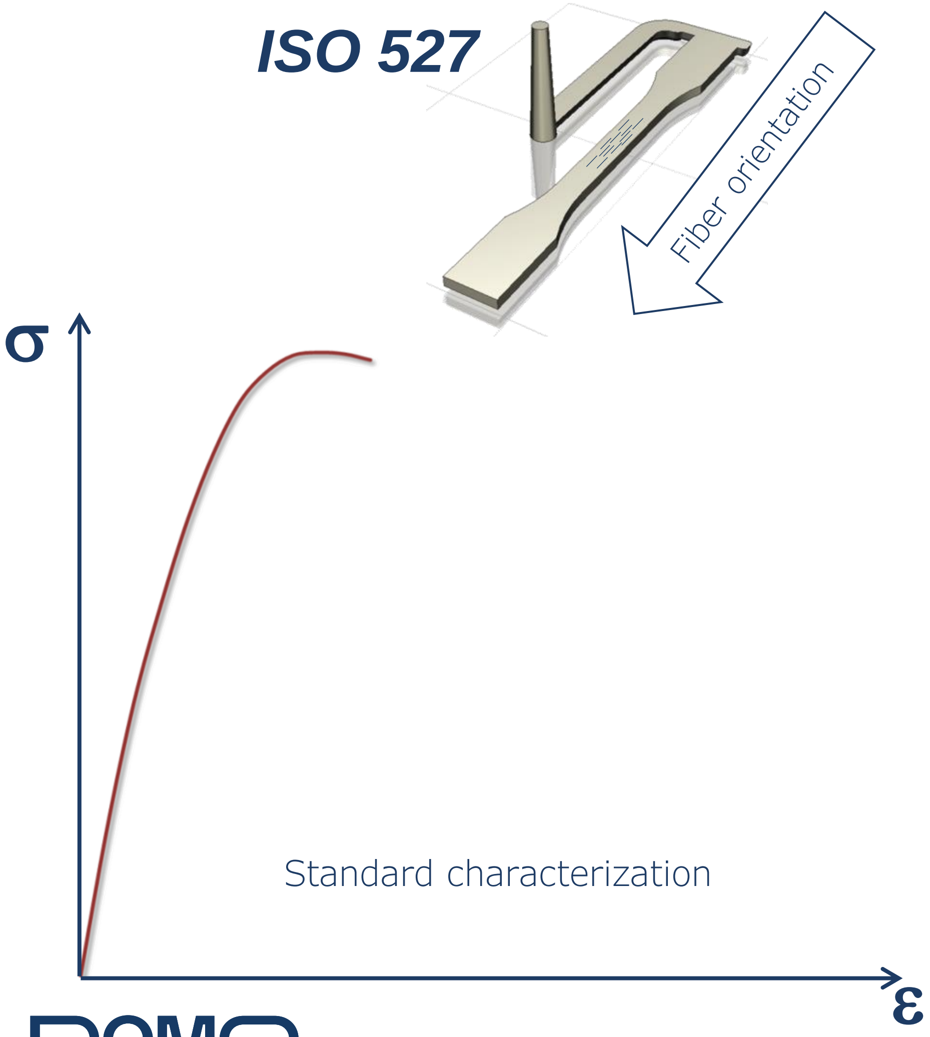
Non-linearities to consider:

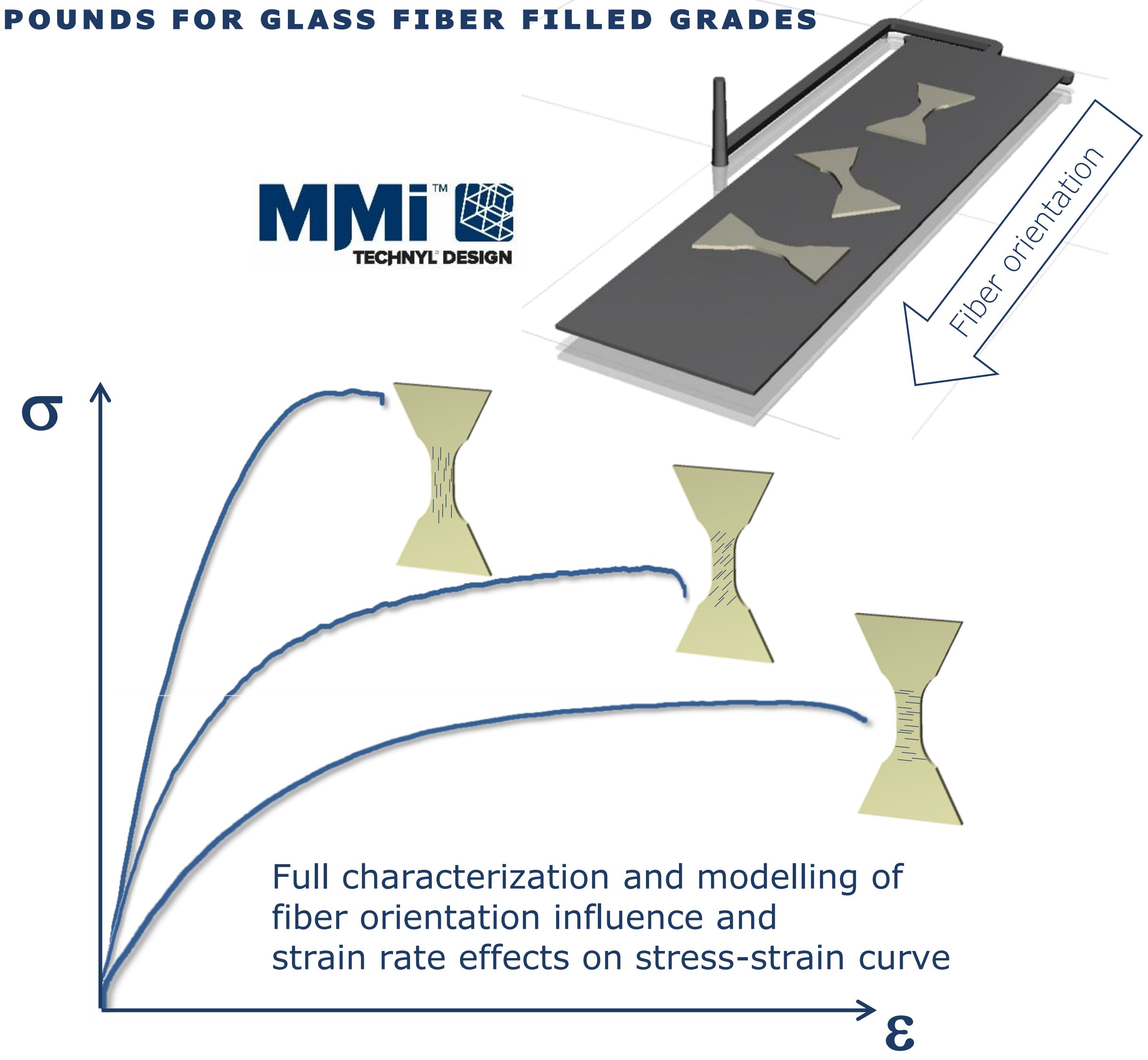
- Visco-elastic anisotropic material behavior
- Frequency dependent material damping

Unlike combustion engines, the e-powertrain emits high frequency and low amplitudes harmonic noise
Correctly modelled polyamide components are the basis of system modelling

MATERIAL MODELLING FOR SIMULATION

TO USE THE FULL POTENTIAL OF TECHNYL COMPOUNDS FOR GLASS FIBER FILLED GRADES

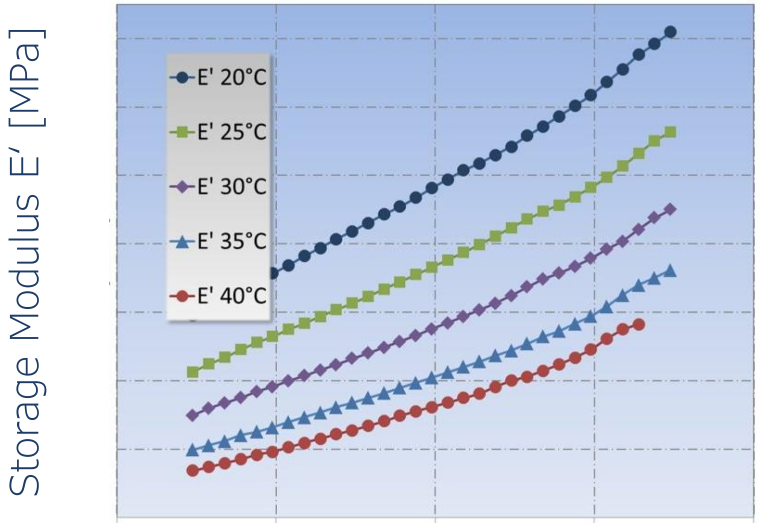




POLYAMIDES – MECHANICAL BEHAVIORS TO MODEL

CREATING A FULL SET OF DATA FOR VIBRATIONAL BEHAVIOR CALCULATION

DMA – Dynamic mechanical analysis
at various temperatures



Typical test frequency range: 0.1 … 20 Hz

Application of calibrated temperature shift

Full material understanding

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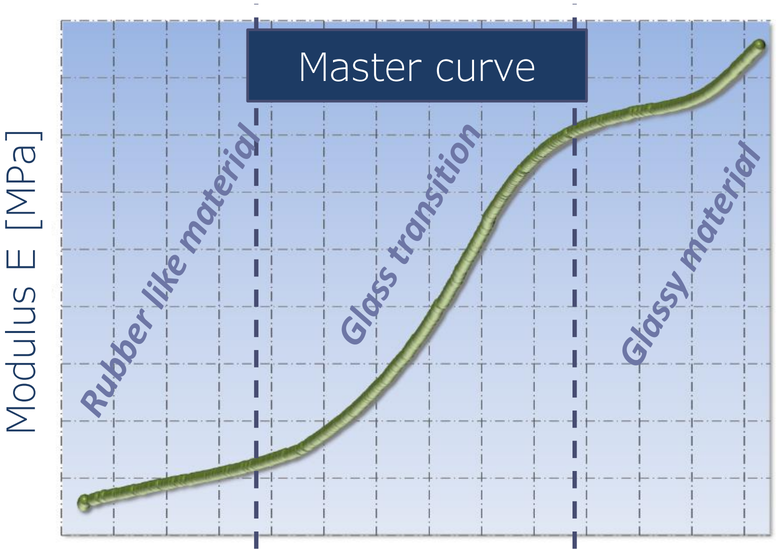


Full frequency range: 0.1 … 1000 Hz

Material master curves are built as basis of anisotropic visco-elastic models considering GF orientations and included in MMI

MMI™ TECHNYL® DESIGN

THE MOST EXHAUSTIVE AND RELIABLE DATABASE OF DIGIMAT MATERIAL CARDS

Files

> 34 000

- **Multiple material behavior**
- **3 matrix: PA6, PA66, PA-HT**

Temperature

-40 to 210 °C

EH

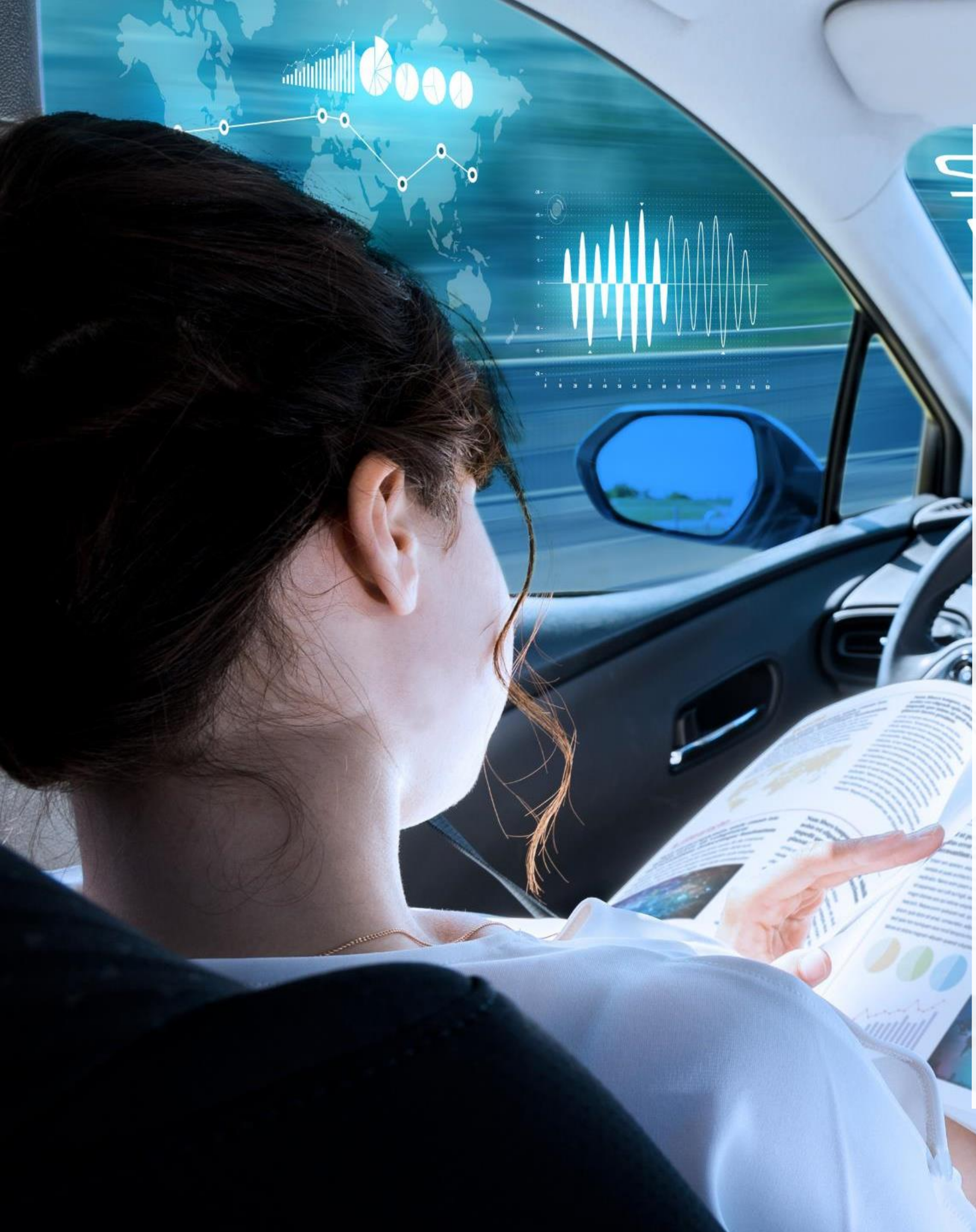
0% to 100%

GF

15% to 60%

- **Static load and failure**
  Deformation under load for elastic and elasto-plastic behaviors, permanent deformation, prediction of failure
- **Impact, Crash**
  Strain-Rate dependent elasto-plasticity (short-term)
- **Modals, Vibration and Damping**
  Visco-elastic behavior (short-term)
- **Fatigue**
  Consider effect of alternate loading, with frequency and load ratio, for elastic and visco-elastic behavior
- **Thermal dilatation and warpage**
  Thermo-elastic and thermo-elasto-plastic behavior
- **Effect of moisture and glycol**
  Elastic and elasto-plastic behavior at various humidity rates and glycol content to take into account the plasticization phenomena

THE VIRTUAL PROTOTYPING PROCESS: FROM METAL TO PLASTICS STEP BY STEP



STEP 1:

IDENTIFYING PROMISING MATERIAL CANDIDATES

TECHNYL A 218 V50 black 21N	TECHNYL MAX AF 218 XV60 black 21N
Standard PA66-GF50	**High performance PA66-GF60**
• Short glass-fiber reinforced grade • Market standard for structural parts • **Enhanced stiffness >16GPa** • Good fatigue behavior	• Innovative glass-fiber technology • Reduced anisotropy • Improved processing • Massive warpage reduction • **High-stiffness >22GPa** • Good fatigue behavior

Anisotropic visco-elastic effects measured taken into account for MMI simulation

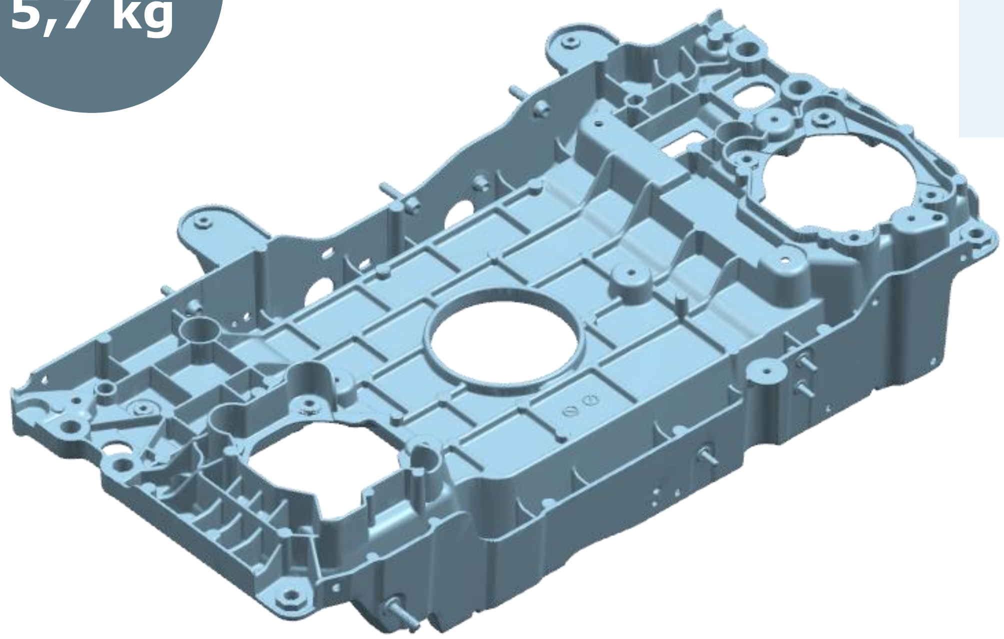
HUB by TECHNYL®

STEP 2:

REDESIGN AND OPTIMIZATION OF RELEVANT STRUCTURES

Die-cast aluminium part

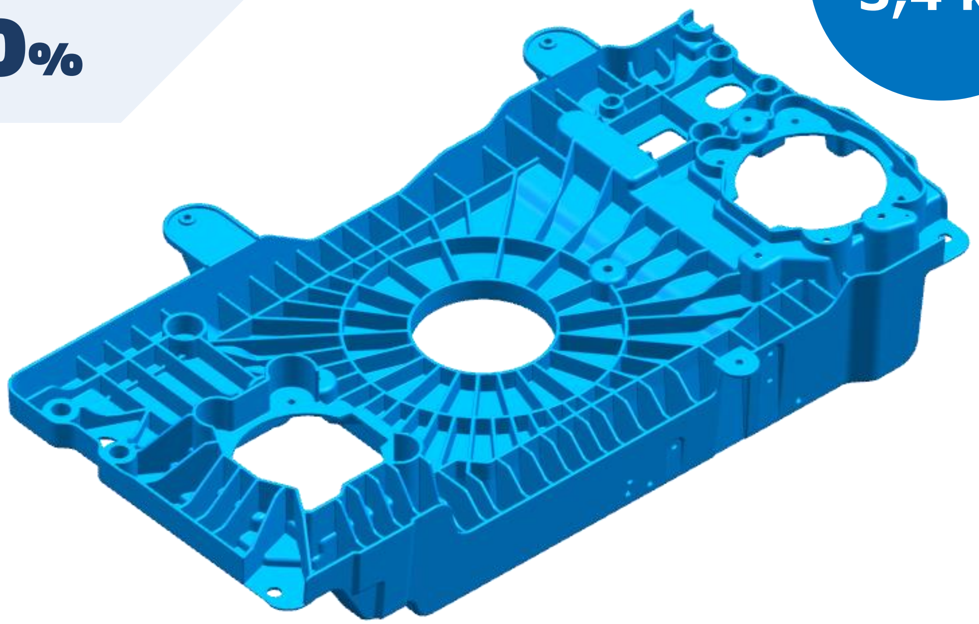
Weight:
5,7 kg



Topological optimization of design
Weight reduction of 40%

PA66-GF part

Weight:
3,4 kg

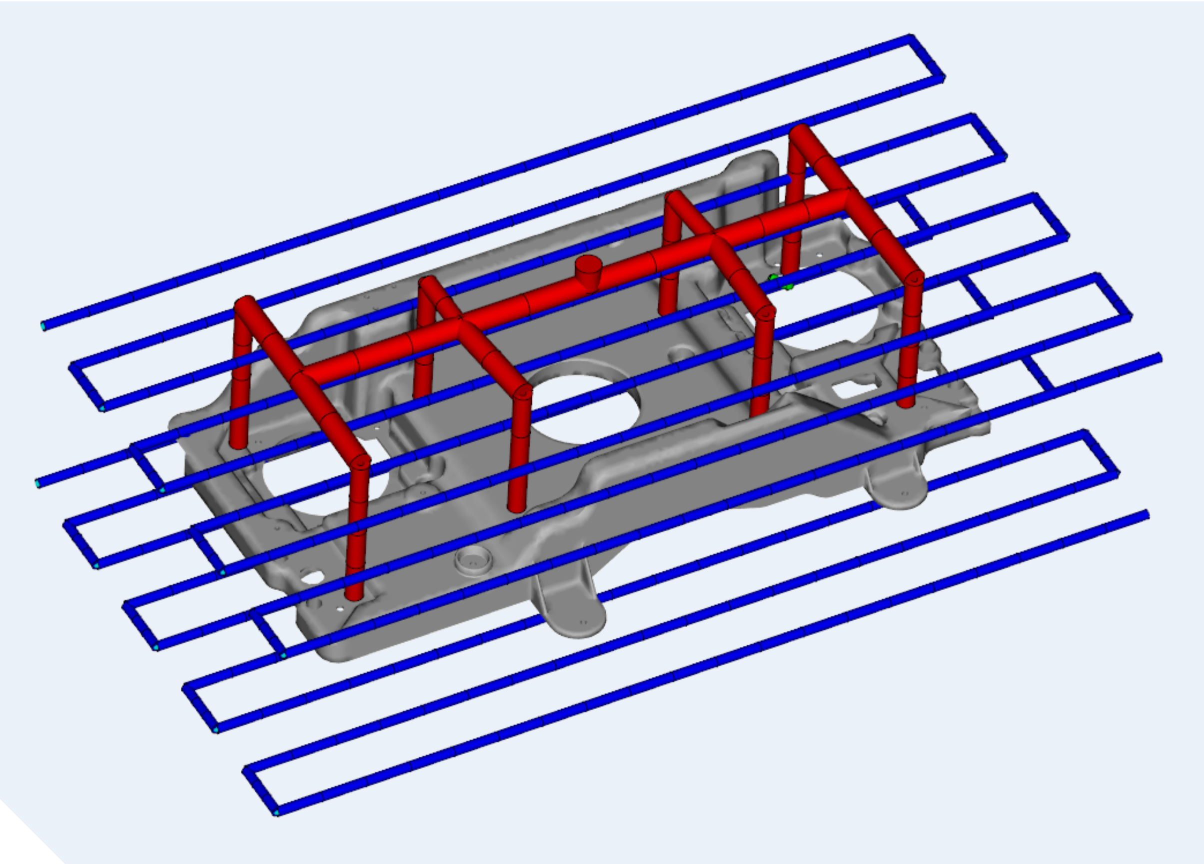


STEP 3:

ASSESSMENT AND OPTIMIZATION OF MOLDING PROCESS

Targets of optimization process:

- Stable filling and packing process
- Homogeneous packing pressure distribution
- Reduced clamp forces
- Load adapted glass-fiber orientations
- Control of weld line areas
- Low warpage of part
- Further customer input possible

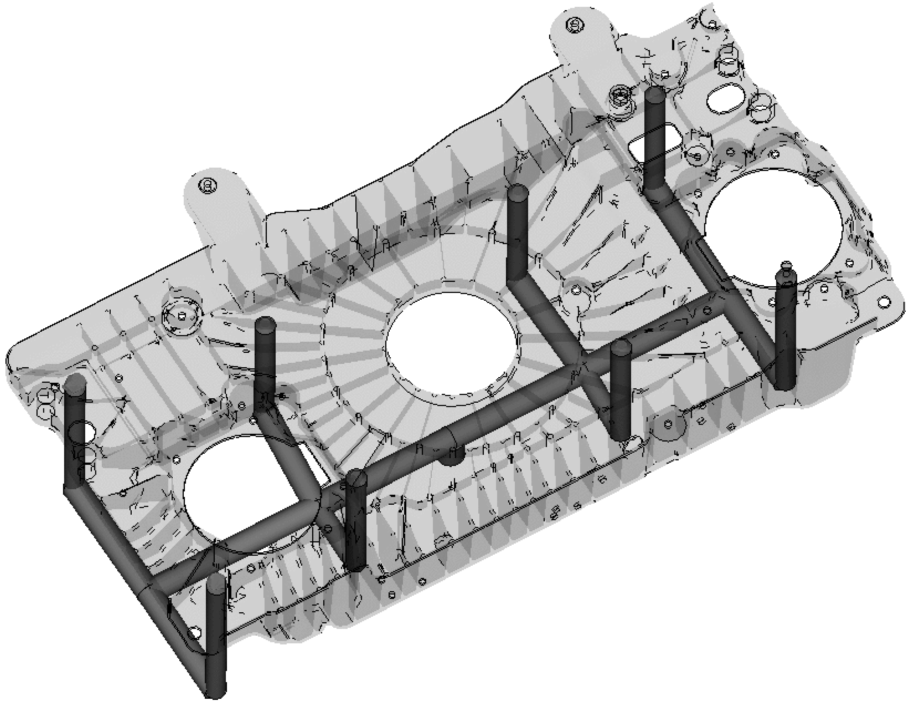


Parameters:

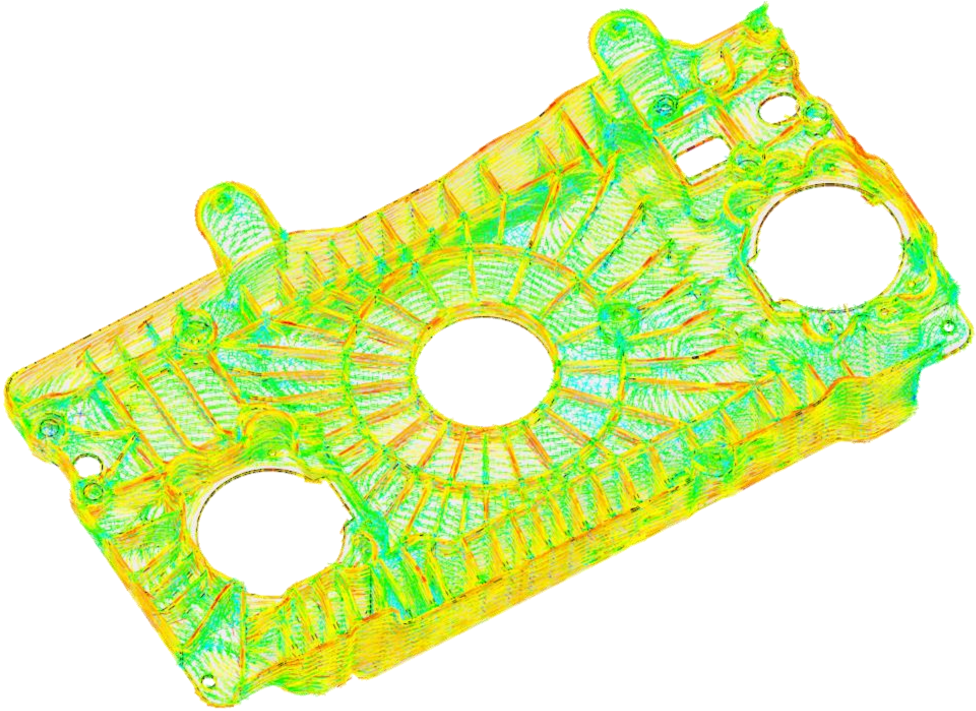
- Layout of gating positions and cooling channels
- Process conditions

STEP 4:

OPTIMIZING PRODUCTION PROCESS TO MAXIMIZE MATERIAL PERFORMANCE IN PART



Injection molding simulation



Load-adapted glass fibre orientation

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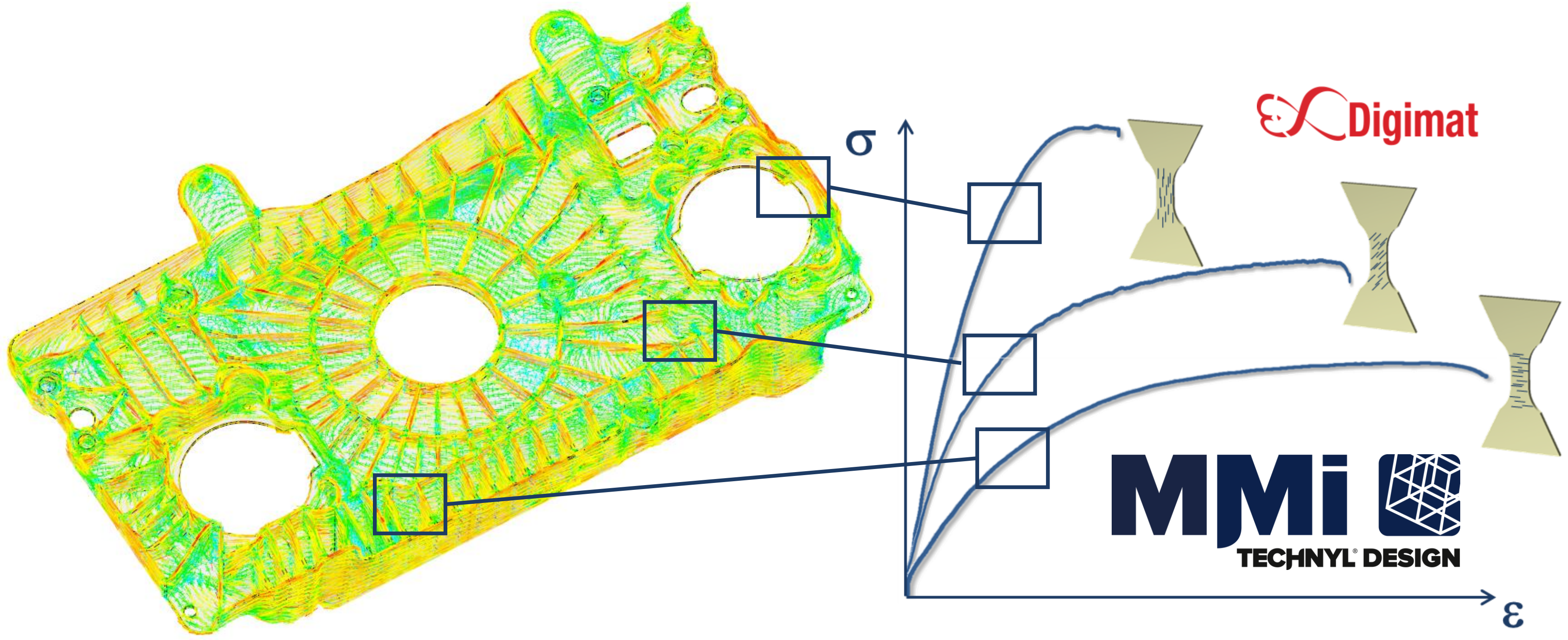
STEP 5:

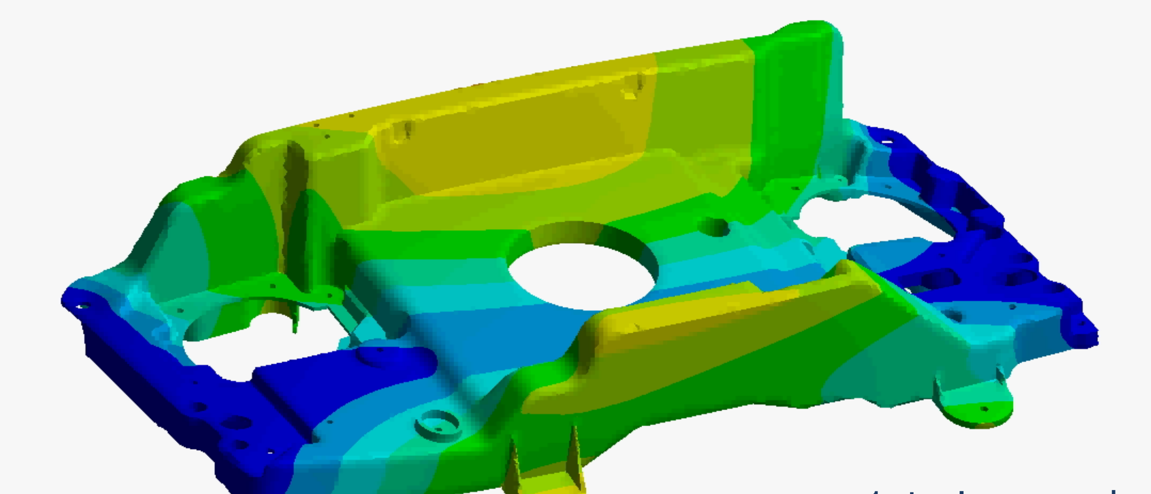
LINKING LOCAL GF ORIENTATIONS WITH MICROMECHANICAL MODEL



GF orientation specific material properties including damping for each element provided to the FE-Solver

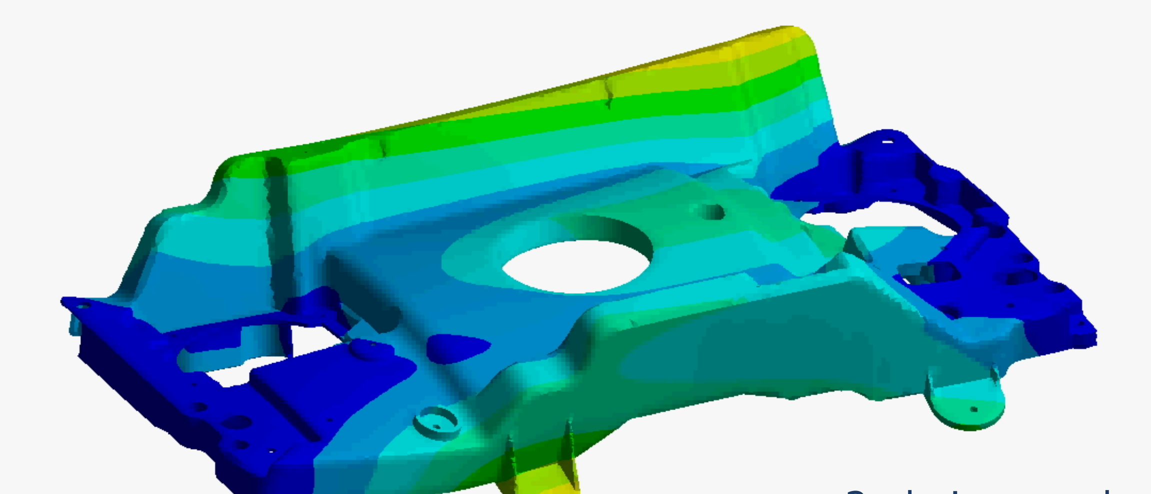
STEP 6:

EVALUATION OF MECHANICAL PERFORMANCE
THE BASIC EIGENMODE CASE



1st eigenmode
Twisting of middle section

Material	Hz	%
TECHNYL A 218 V50	46	-
TECHNYL MAX AF 218 XV60	**64**	**+33%**
Aluminum alloy	135	+110%



2nd eigenmode
Bending of wall structure

Material	Hz	%
TECHNYL A 218 V50	127	-
TECHNYL MAX AF 218 XV60	**169**	**+33%**
Aluminum alloy	327	+93%

The first plastic design already reduced the factor 4 e-modulus gap by 50%

TOOLS AND MODELS PREPARATION

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HEXAGON | eXstream

MANAGING VIBRATION IN E-MOBILITY IS KEY

SOLVING HARMONIC FREQUENCY RESPONSE

In order to capture the noise emitted by vibrational structures, harmonic simulation is used, to compute vibration amplitudes of parts.

This type of simulation aims at delivering the amplitude and phase of vibration along a frequency range.

Usual harmonic simulation are performed with isotropic elastic material assumptions, and a constant damping ratio.

BUT

Anisotropy can lead to 50% stiffness variation over the part.

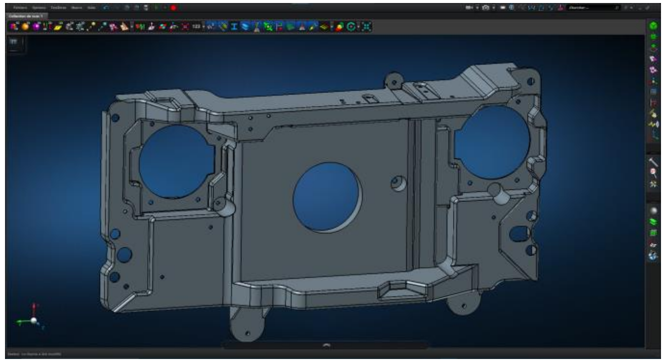
It has a tremendous effect on mode shapes and natural frequencies.

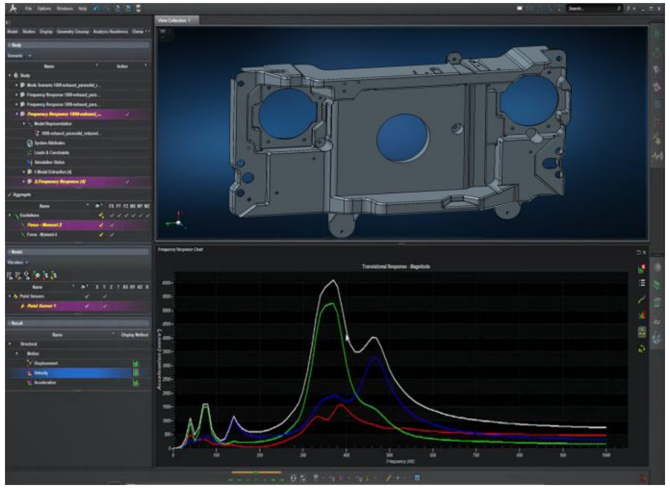
Visco-elasticity may bring damping variation of factor 10.

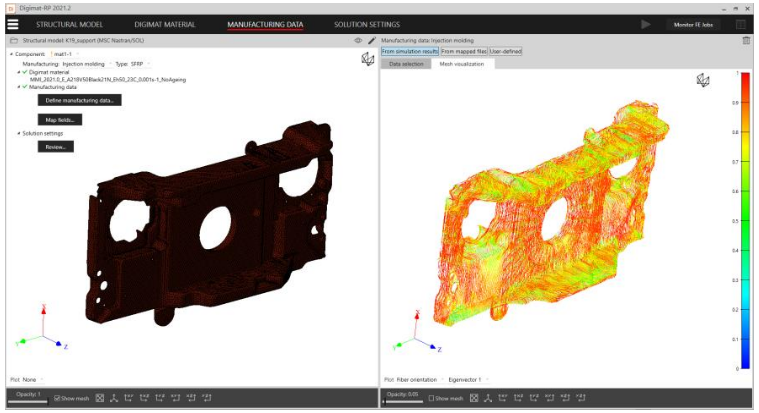
It has a tremendous effect on harmonic response amplitude, and in a lower manner, on natural frequencies.

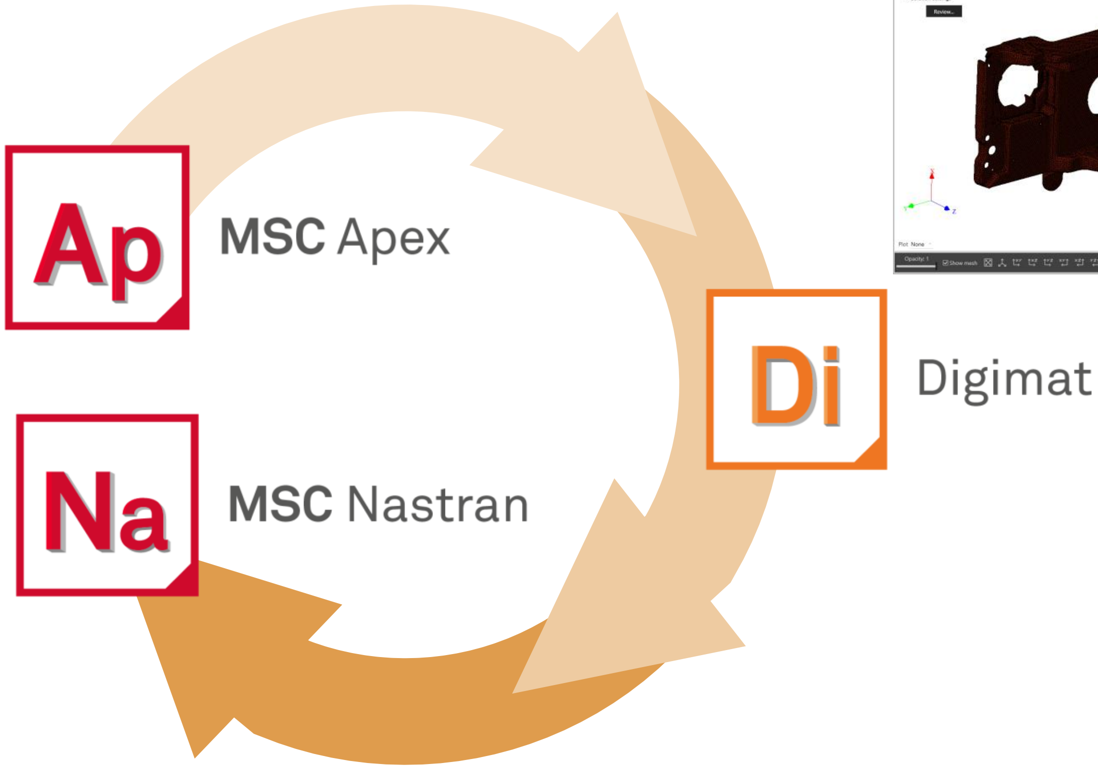
THE LEADING SOLUTION FOR PREDICTIVE NVH ANALYSIS

APEX / DIGIMAT / NASTRAN WORKFLOW SUPPORTED BY MSC ONE LICENSING







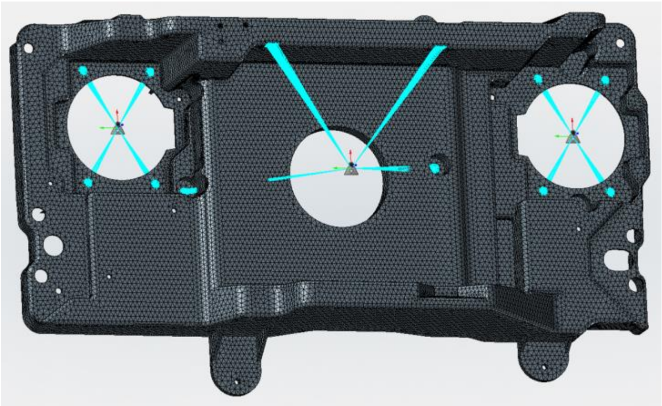


DIGIMAT-RP: MODEL PREPARATION

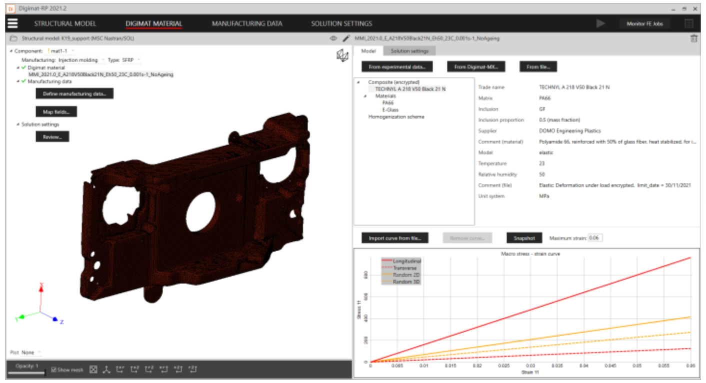
VISCO-ELASTIC MATERIAL

Material damping: Tan δ = E′/E″
Damping is not a constant value over frequency range!

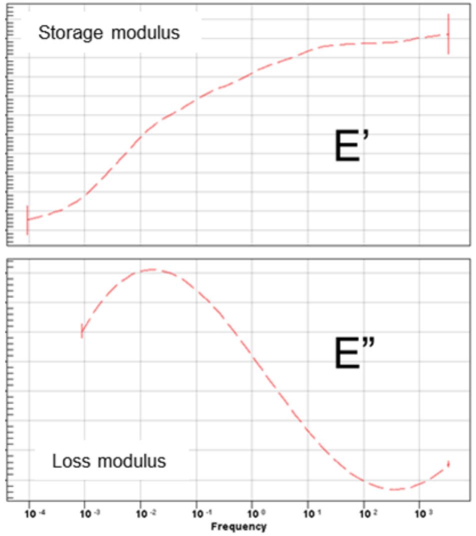
APEX Input deck for Nastran



Assign Digimat material properties



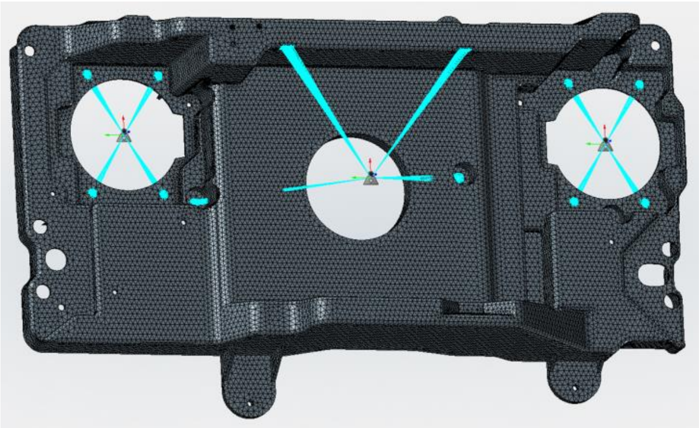
Digimat material model



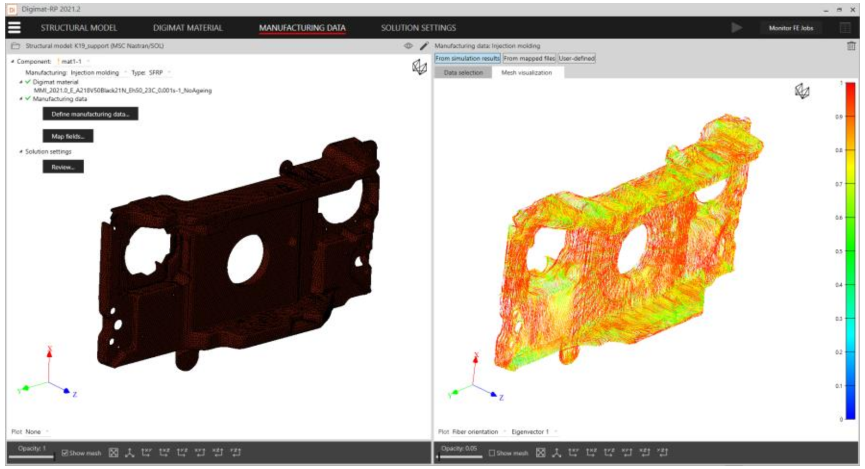
DIGIMAT-RP: MODEL PREPARATION

MANUFACTURING DATA DEFINITION

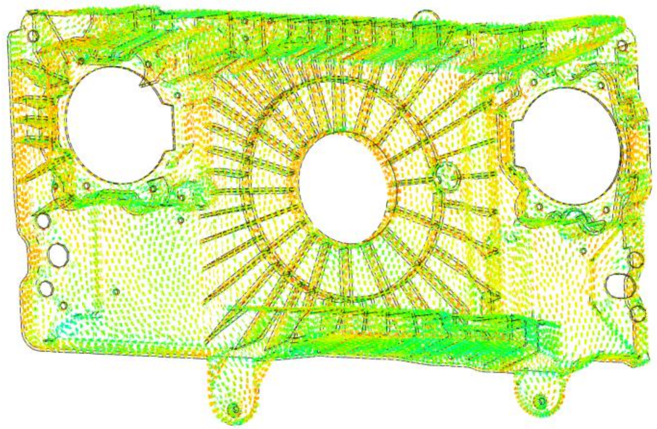
APEX Input deck for Nastran



Assign fiber orientation tensor



Manufacturing data (fiber orientation)



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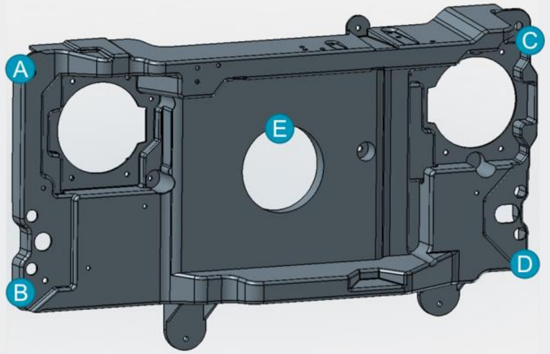
RESULTS

STIFFNESS SHIFTS FREQUENCY, DAMPING SHIFT AMPLITUDE.

HARMONIC RESPONSE CURVES (INERTANCE)



Response points location

Aluminum*:

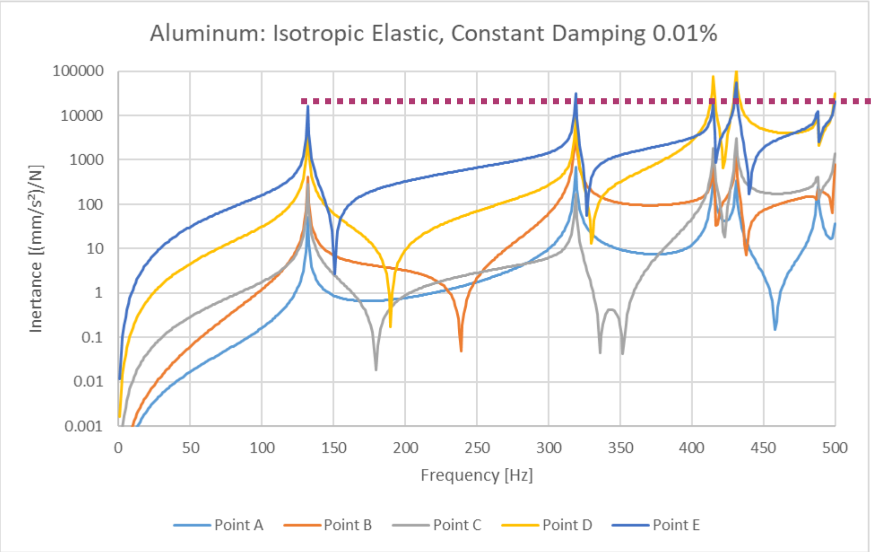
Isotropic elastic with constant damping 0.01%

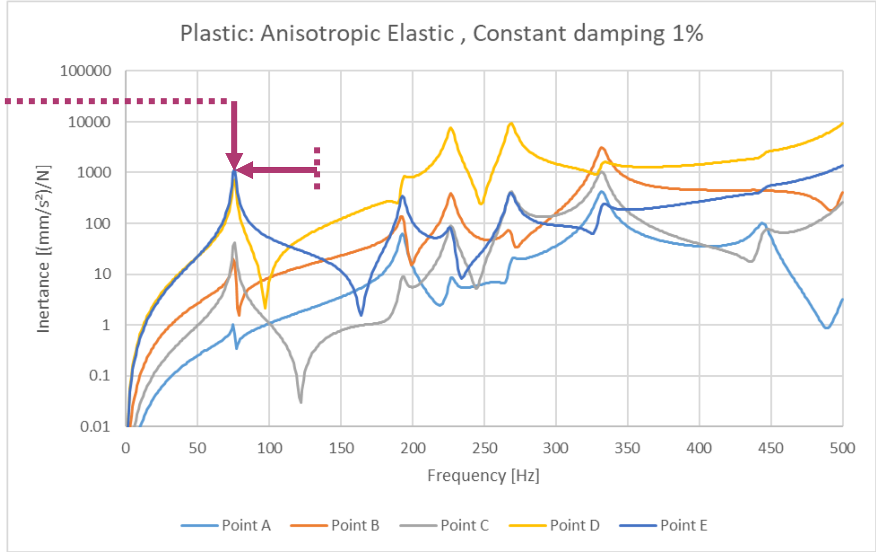
1st mode 135 Hz
Sharp peaks ⇔ low damping

Plastic:

Isotropic elastic with constant damping 1%

1st mode 75 Hz ⇔ lower stiffness
Smooth peaks ⇔ higher damping (factor of 100)



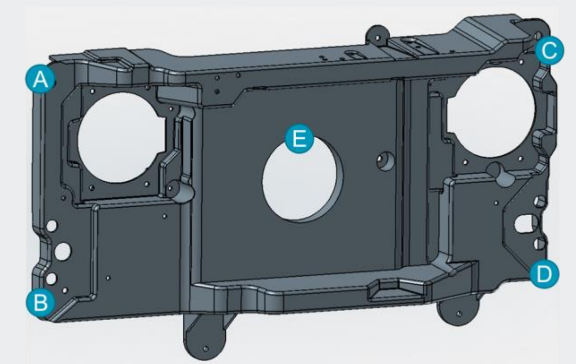


Car passenger's acoustic comfort is **positively influenced by high damping.**

*Aluminum part do not have ribs and is thicker than plastic part

ANISOTROPY INFLUENCE STIFFNESS AND SHIFTS FREQUENCY

HARMONIC RESPONSE CURVES (INERTANCE)

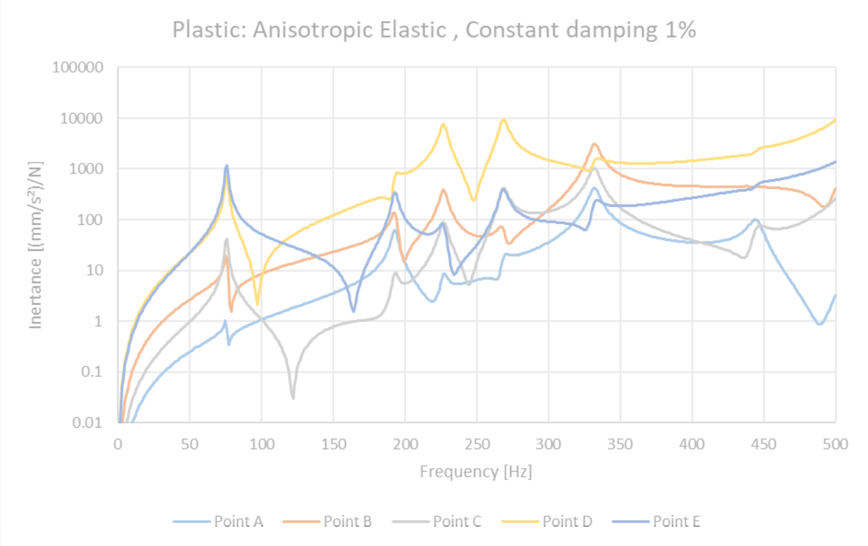


Response points location

Plastic:

Isotropic elastic
with constant damping 1%

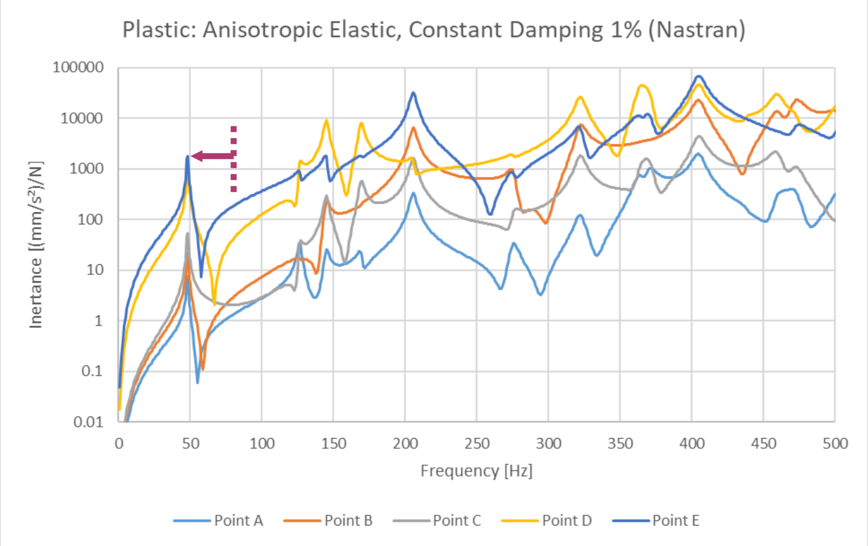
1st mode 75 Hz
Smooth peaks ⇔ high damping



Plastic:

Anisotropic elastic
with constant 1% damping

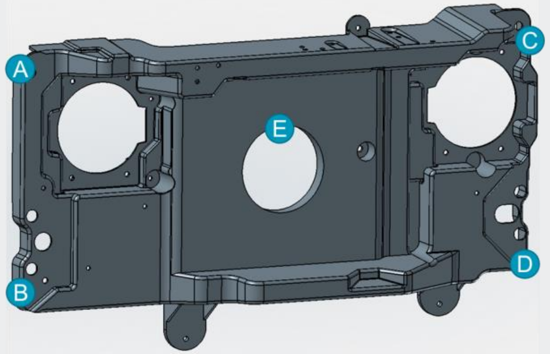
1st mode 46 Hz ⇔ anisotropic stiffness
Same damping ⇔ More natural frequencies under 500 Hz



Integrative simulation required to account for anisotropy effect.

VISCO-ELASTICITY ENHANCE DAMPING PREDICTION

HARMONIC RESPONSE CURVES (INERTANCE)

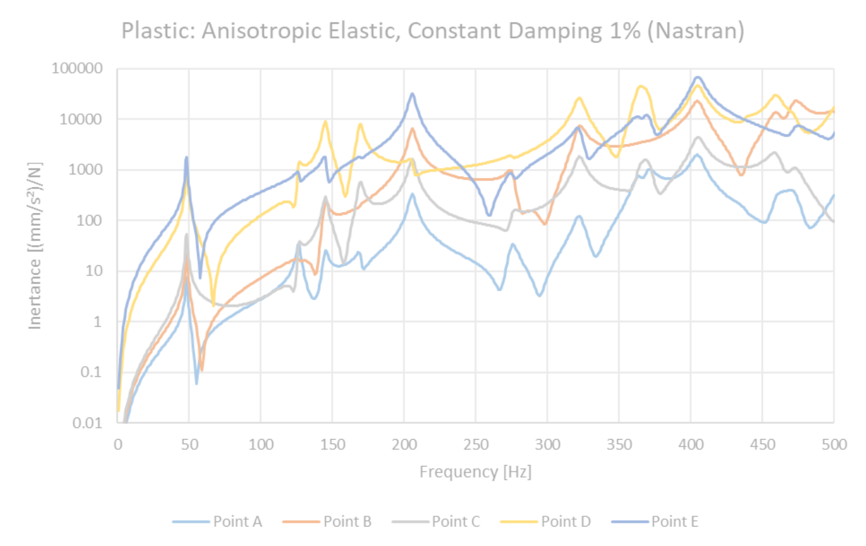


Response points location

Plastic:

Anisotropic elastic
with constant 1% damping

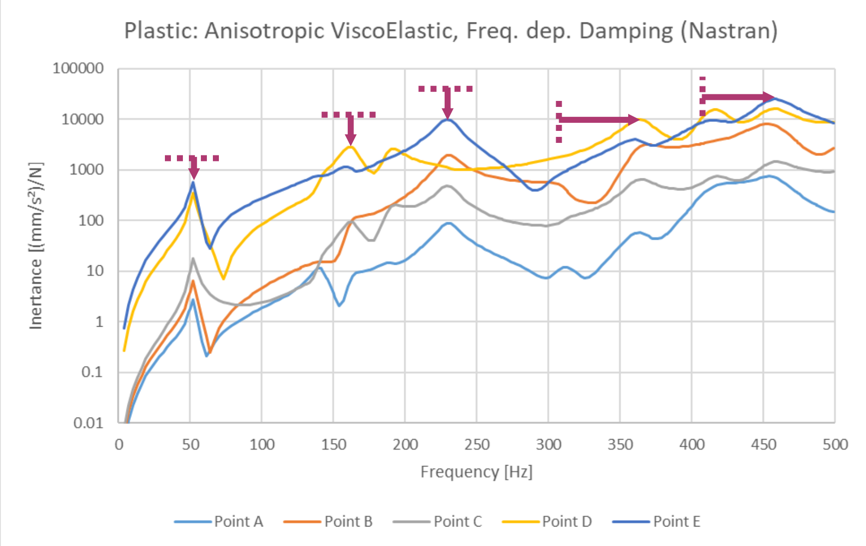
1st mode 46 Hz ⇔ anisotropic stiffness
Same damping ⇔ More natural frequencies under 500 Hz



Plastic:

Anisotropic **Visco-Elastic**
with **frequency dependent damping**

1st mode 46 Hz ⇔ anisotropic stiffness
Smoother peaks ⇔ Much higher damping



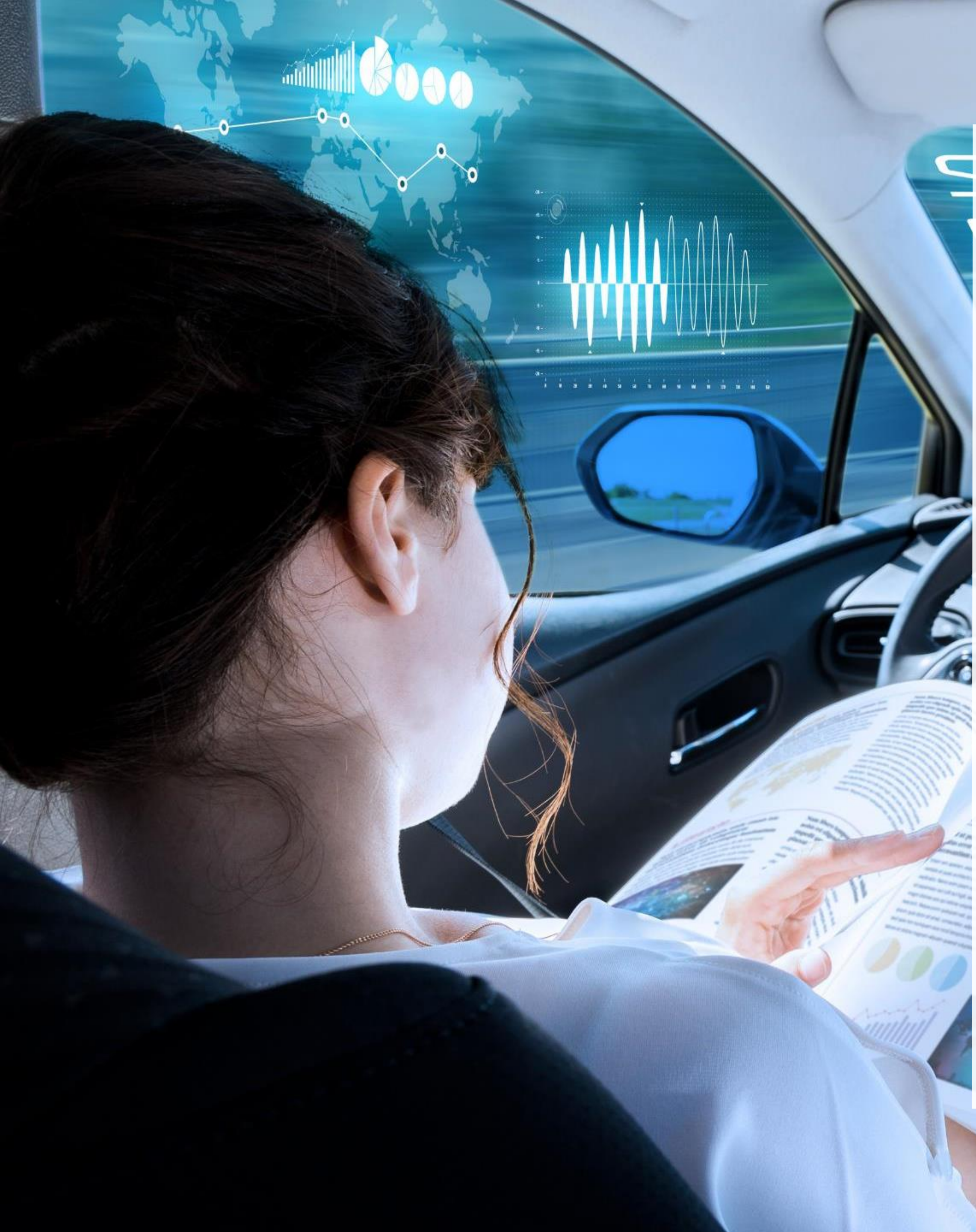
Above anisotropy,
a physics-based model
of the matrix, brings
additional reliability.

Standard solver, only direct method : 9h00
NASTRAN, modal superposition possible : 1h30

DOMO

HEXAGON | e-Xstream engineering

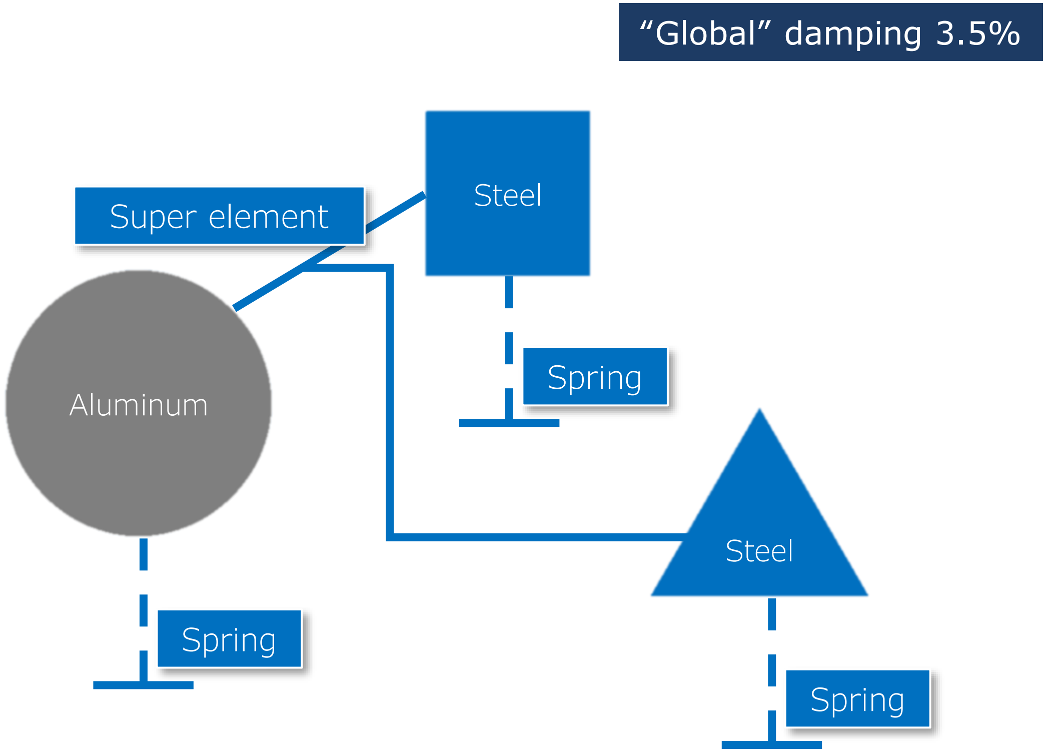
SOME METHODOLOGY



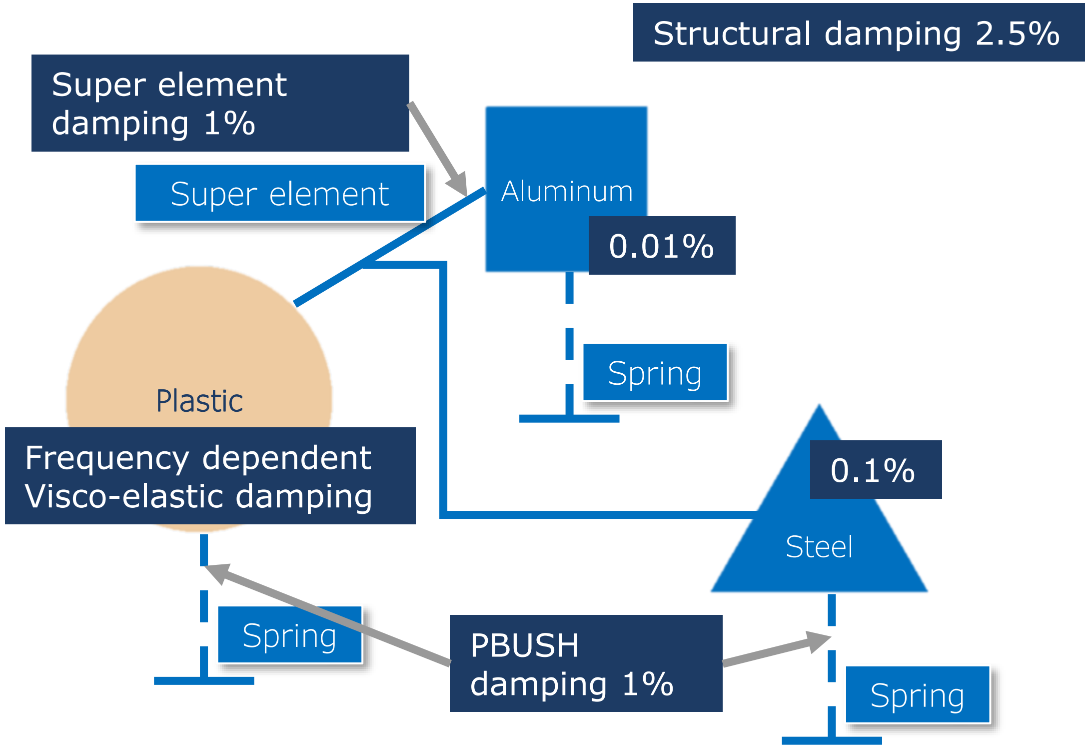
VIBRATION ASSESSMENT OF ASSEMBLIES

DAMPING MANAGEMENT MUST BE REVIEWED.

On complex assemblies, global structural damping is generally based on return from experiment.
It is an average value applied on all components.



To account for damping of visco-elastic materials, global damping must be divided material damping and structural damping.



CONCLUSIONS

DOMO

HEXAGON | Exstream

HEXAGON: OUR CONCLUSIONS

Visco-Elastic NVH simulation

get’s the best

of NASTRAN and DIGIMAT

- **Combining DIGIMAT material modeling techniques and NASTRAN solver,** we obtain a predictive virtual prototype.
- In assemblies, some changes of methodology must apply **to get the full value of this new technique.**
- **The combination of HEXAGON simulation technology and DOMO material modeling** know how is a win.

DOMO: OUR CONCLUSIONS

- **DOMO‘s can provide a wide set of PA compounds** with tailored properties for metal replacement.
- **Our materials come with detailed mechanical data** needed for simulation of e-mobility applications.
- The unique TECHNYL HUB brings **the full service from design, simulation and part testing.**
- In the example e-motor mount case, **a 40% lighter TECHNYL prototype was designed**.
- Further optimization steps or hybrid technology can use this weight potential to offer **a better cost-to-serve ratio compared with aluminum reference.**

Q&A SESSION

DOMO

Where innovative, efficient and sustainable solutions in the field of engineering plastics are required, we provide the perfect fit for your needs.

CONTACT DOMO

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THANK YOU FOR YOUR ATTENTION

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