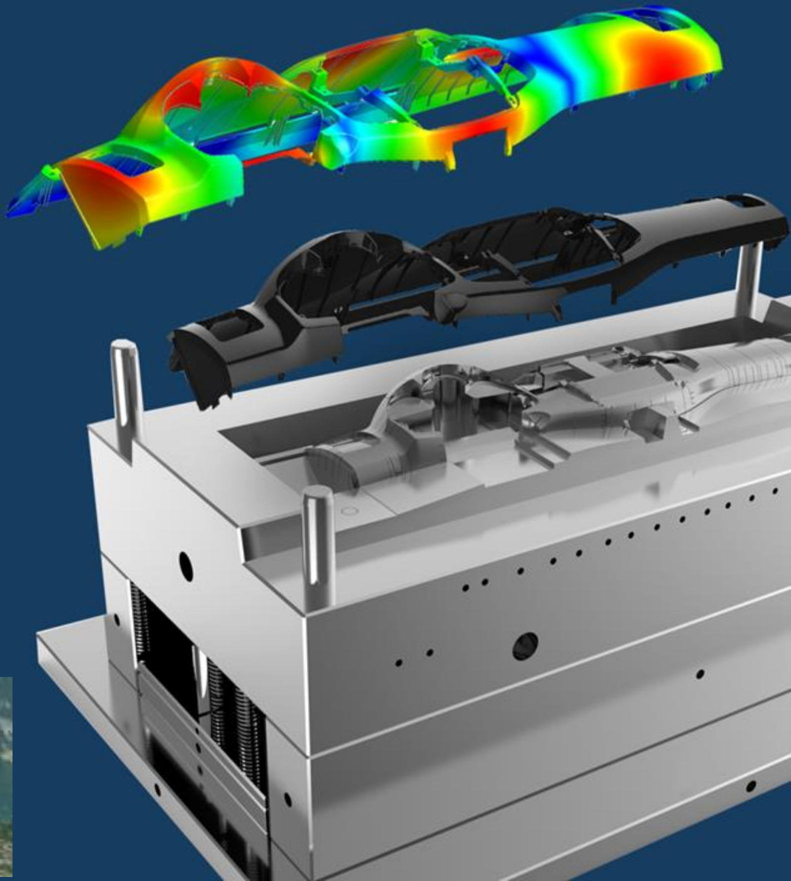
Moldex3D

Titolo: Applicazione dell’analisi di *warpage* al fine di ottimizzare ritiri e deformazioni in un componente di grandi dimensioni in PA66 GF30

Azienda: RadiciGroup Performance Plastics
Relatore: Carlo Grassini
Technical Marketing & CAE Leader

Logo aziendale: RADICI GROUP PERFORMANCE PLASTICS



RadiciGroup Performance Plastics

At a glance

RadiciGroup Performance Plastics

- **RadiciGroup** is an Italian privately hold company acting **worldwide** in Chemical, Textile and Engineering Plastics business sectors
- 40 years experience in polymerization and compounding of all **polyamides** and other **engineering plastics**, for automotive, electrical, industrial and consumer goods markets
- Production, R&D and technical support available locally in EUROPE, NORTH AMERICA, SOUTH AMERICA and ASIA

RADICI GROUP

Turnover: **1147 M€** (2017)
Employees: ra **3000** wwide

EXCELLENCE AND KNOW-HOW IN PERFORMANCE PLASTICS

RADILON	PA6, PA 6.6, PA 6.10, PA6.12, PPA and other High temperature PA
TORZEN	PA 6.6 and other high temperature PA
RADISTRONG	Special and long fibre reinforced PA
HERAMID	Post-industrial recycled PA6 and PA6.6
HERAFORM	POM
RADITER	PBT and PET
RADIFLAM	PA and PBT Flame retardants
HERAFLEX	TPEs

RADICI GROUP

RadiciGroup Performance Plastics : Vision, Mission & Facts

Vision

- To be a leading company in the polyamide engineering plastics production chain

Mission

- Continue to increase global presence with high quality grades
- Offer complete value to customers through products and services
- Strategically working towards meeting and anticipating new demands in the market
- Strategic acquisitions
- Embed sustainability into new product and application development

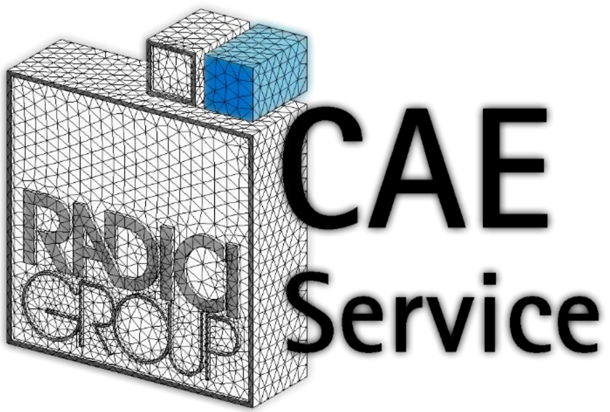
Facts

- ✓ Worldwide production and sales network
- ✓ Global R&D, Technical Service and Application Development Support
- ✓ A complete portfolio based on PA6, PA6.6, copolymers, PA6.10, PA6.12, high temperature PA and PPA
- ✓ A wide range of innovative materials for metal replacement, high temperature applications, resistance to flame, high chemical resistance, water management
- ✓ Advanced CAE support for more reliable virtual simulation results
- ✓ Sustainability: EPD certified company
- ✓ Acquisition of Invista Engineering Polymers Solutions

RadiciGroup Performance Plastics is a partner for developing projects

Through its Global ***Marketing and Applications Development*** team and capillary ***Sales Network***, Radici Plastics can also provide **professional support to customers** during **all phases of the design process**, including:

- **Concept phase: proposals and consulting**
- **Translation of Functional Requests into Material Properties**
- **Selection of optimal material, either Standard or Special, among our outstanding range of Engineering Plastics grades**
- **Support and consulting for comparative cost analysis**
- **Support and consulting during re-design phase**
- **Support with CAE analysis, process simulation and structural simulation, with integrated approach available for advanced projects**
- **Environmental impact and LCA analysis: full and certified support for the material side**
- **Technical service support during prototyping, molding trials, test on final parts**



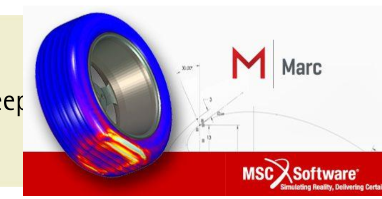
Radici CAE service: capabilities

Process Simulation

- Injection molding and derived technologies (injection-compression, GAIM, micro-foaming…)
- Flow, Packing, Cooling, Warpage analysis
- Prevision of process-related defects and parameters

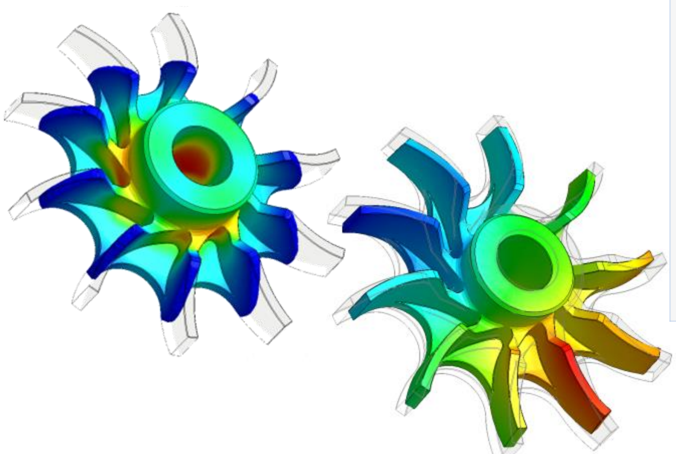
Structural Simulation

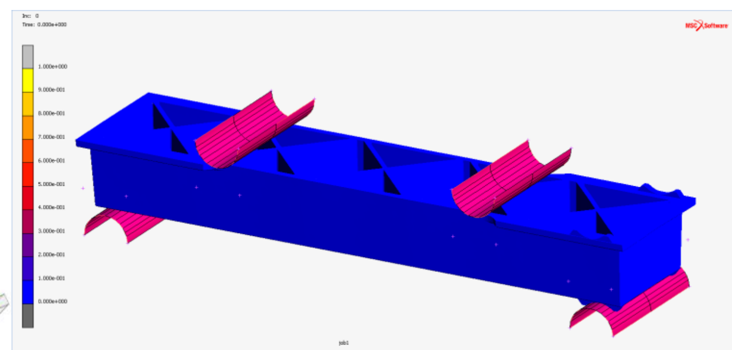
- Static non-linear analysis, multi body contact, stress and strain fields prevision
- Failure estimation, Thermo-mechanical effects, long-term behavior (creep fatigue)
- Dynamic analysis, natural frequencies

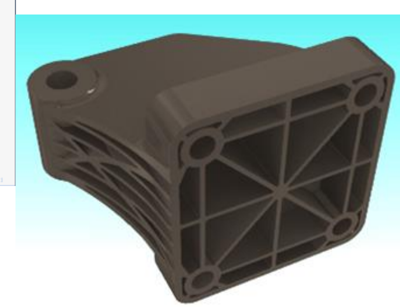


Integrated approach

- Taking into account process-induced microstructural properties in a structural study
- Anisotropic mechanical behavior (GF orientation), welding lines, residual stresses, warpage effects
- Multi-scale and multi-purpose material modeling





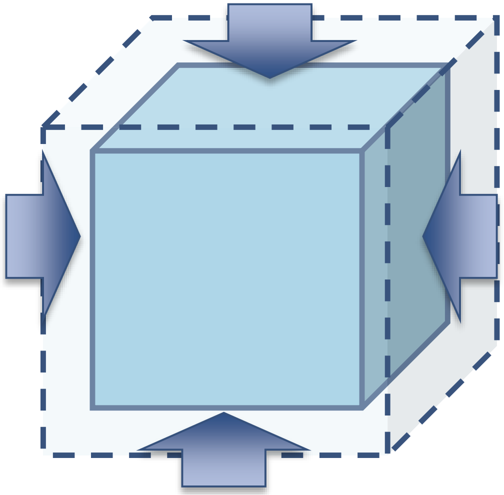


Shrinkage and Warpage

Introduction

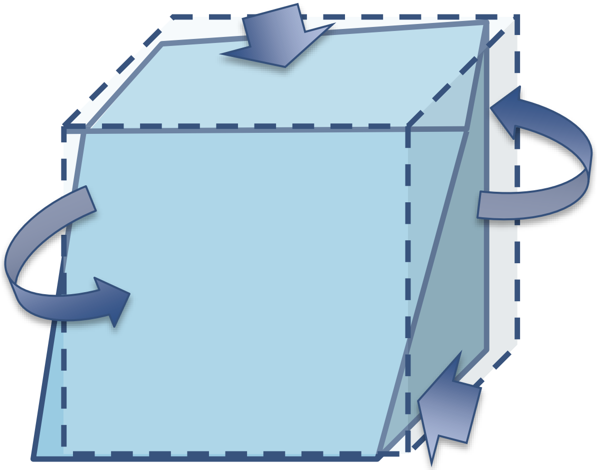
Injection Molding Shrinkage/Warpage

- One of the most common problems to face when designing plastic products is the prevision of **shrinkage** and **warpage**
- **Shrinkage** -> *Homothetic, even* reduction of dimensions associated to change of phase (solidification/crystallization) and cooling of the part

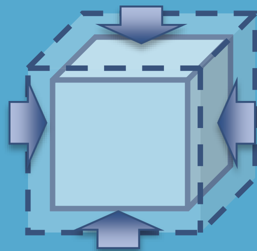
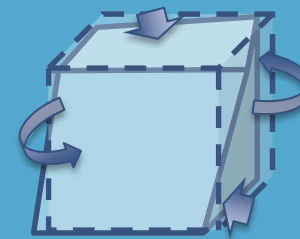


Injection Molding Shrinkage/Warpage

> **Warpage** **-> Change of *shape* of the part during solidification and cooling phase, due to various physical phenomena interacting in a very complex way (uneven packing, uneven cooling, uneven shrinkage, anisotropic material properties, …)**



Injection Molding Shrinkage/Warpage

Shrinkage 	Warpage 
Homothetic and even: scales down only the dimensions	Changes the **shape** of the component in a complex way
Unavoidable, associated to physics of materials	A proper design of geometry and control of process parameters can **limit** it or even **eliminate** it at all
Can be easily **compensated** in toolmaking, knowing the expected % value	**Difficult** to compensate by modifying the cavity shape – requires a delicate work (reverse engineering)
Standard methods available to measure and predict it for a specific material (eg ISO 294)	Each molding has its own behavior

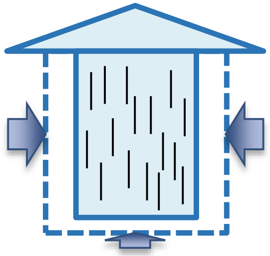
BOTH do affect the dimensions of the part and can create issues with linear and geometric tolerances!

Injection Molding Shrinkage/Warpage

> The simplest way for a toolmaker to account for shrinkage is to look on material TDS for the **measured linear shrinkage % value**, and increase the cavity linear dimensions of the same amount

PROPERTY		*STANDARD*	*UNIT*	*VALUE* DAM* Cond**
Physical Properties				
Density		ISO 1183	Kg/m^3	1400
Moulding shrinkage – Parallel / Normal	300/90/60***	ISO 294-4	%	0,3 / 1
Moisture absorption 23°C – 50%RH	2mm thk	ISO 62	%	1.5

> But here we have a first problem: especially for GF reinforced grades, we have sensibly different values for **longitudinal** and **transversal** shrinkage! Which one to choose?



> Moreover, this is just a simplification. In a real part, GF can orient in virtually infinite different ways!

Injection Molding Shrinkage/Warpage

- If the part has a very simple geometry with easily predictable predominant direction of flow, one can choose a value closer to the Longitudinal or Transversal flow, or intermediate, according to experience
- More likely the part geometry will be much more complex and the prediction of flow direction not banal at all. **Shrinkage is not an intrinsic property of the material!**
- Usually, toolmakers tend to select a **single «global» value of shrinkage** to apply to the whole component, and handle afterwards the possible issues on critic dimensions

- **Injection simulation** can help identifying which is the optimum value to apply, in order to preserve the functional dimensions / the most important tolerances

Shrinkage/Warpage in simulation

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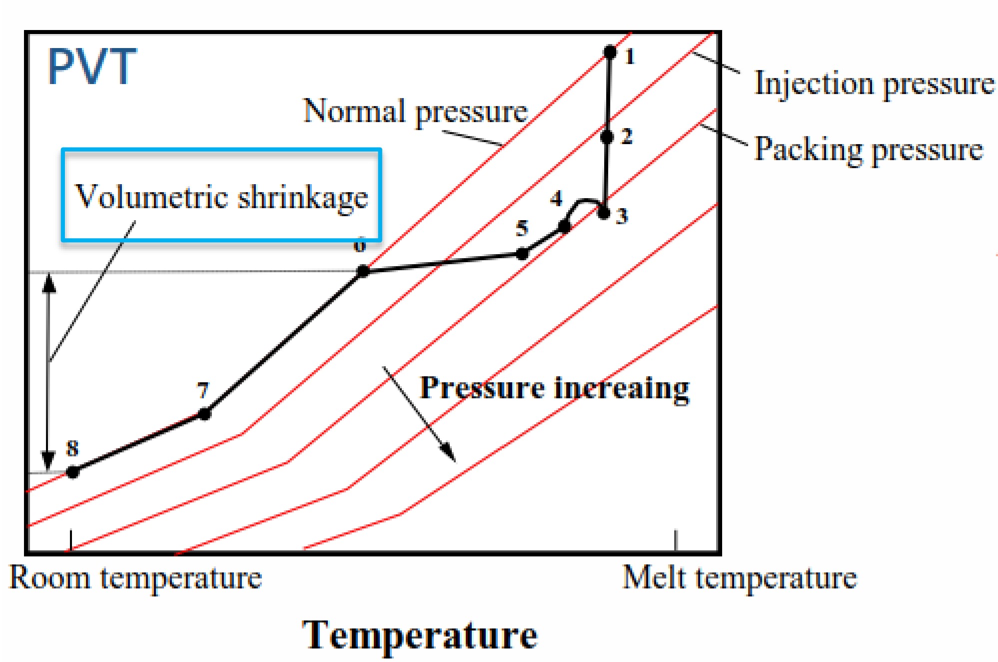
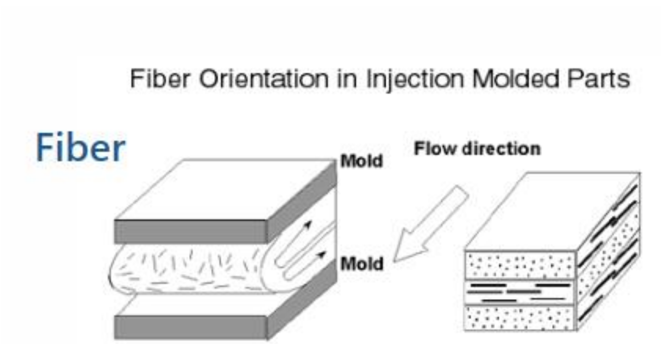
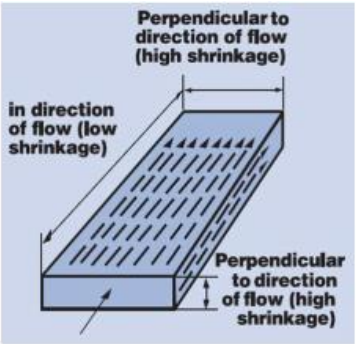


The **PVT curves** of the material are the primary source, for the material, to assess element by element the volumetric shrinkage caused by injection molding process.





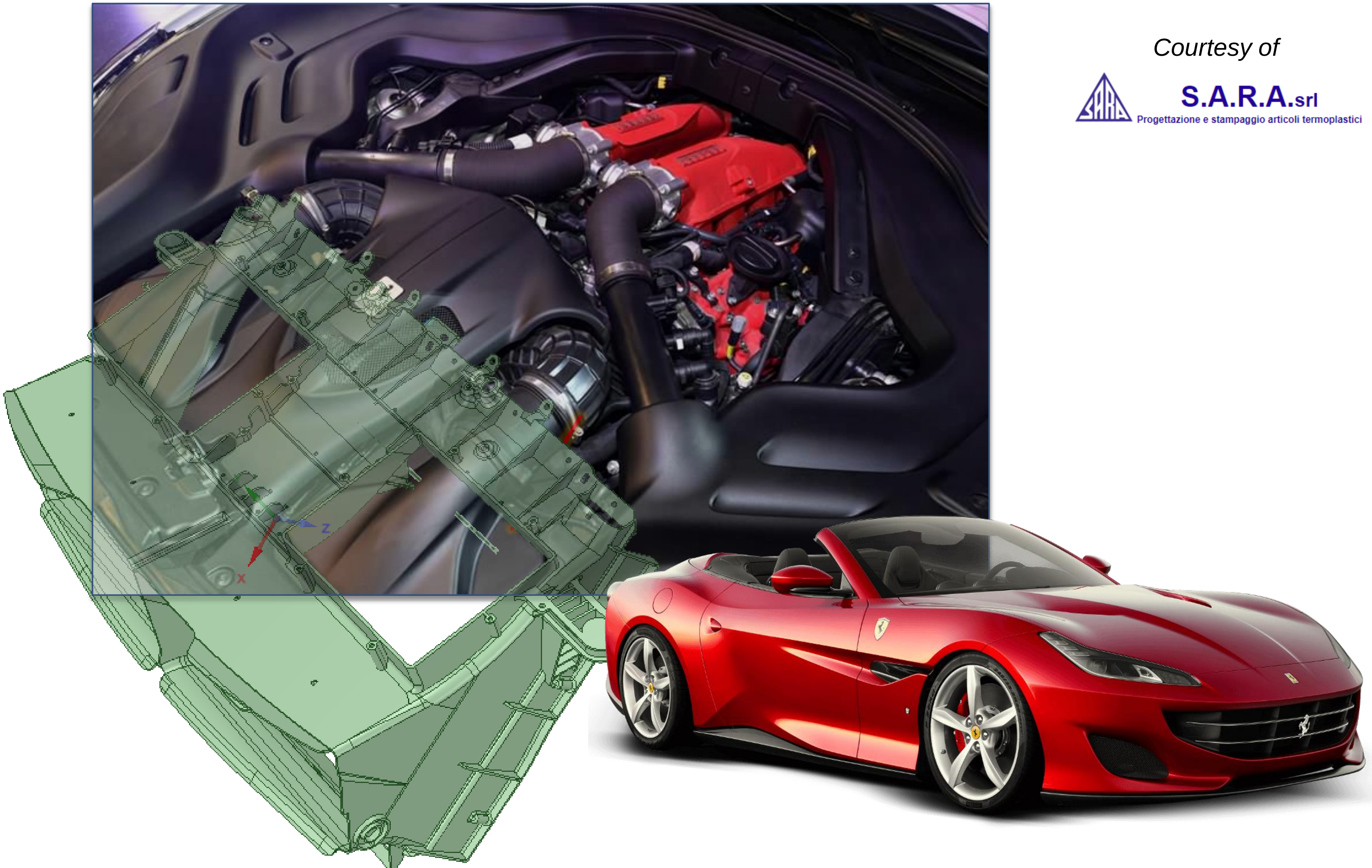
Anisotropy is taken into account by considering the crystallinity and the different GF orientation (Longitudinal and transversal E-modulus, and CLTE)

A case history

Ferrari Portofino air conveyor

Moldex3D

The component – Engine air conveyor



Courtesy of

S.A.R.A.srl
Progettazione e stampaggio articoli termoplastici

The component – Engine air conveyor

> Material: PA66 GF30, heat stabilized – RADILON A RV300W 333 BK

RADILON® A RV300W | PA66-GF30 | RadiciGroup Performance Plastics

Product Texts

DESIGNATION
Thermoplastics ISO1874-PA66,MHR,14-100,GF30

BRIEF DESCRIPTION
PA66 30% glass fiber reinforced injection moulding grade. Heat stabilized. Natural colour.

Suitable for parts requiring high stiffness, good mechanical resistance and excellent heat ageing properties retention.

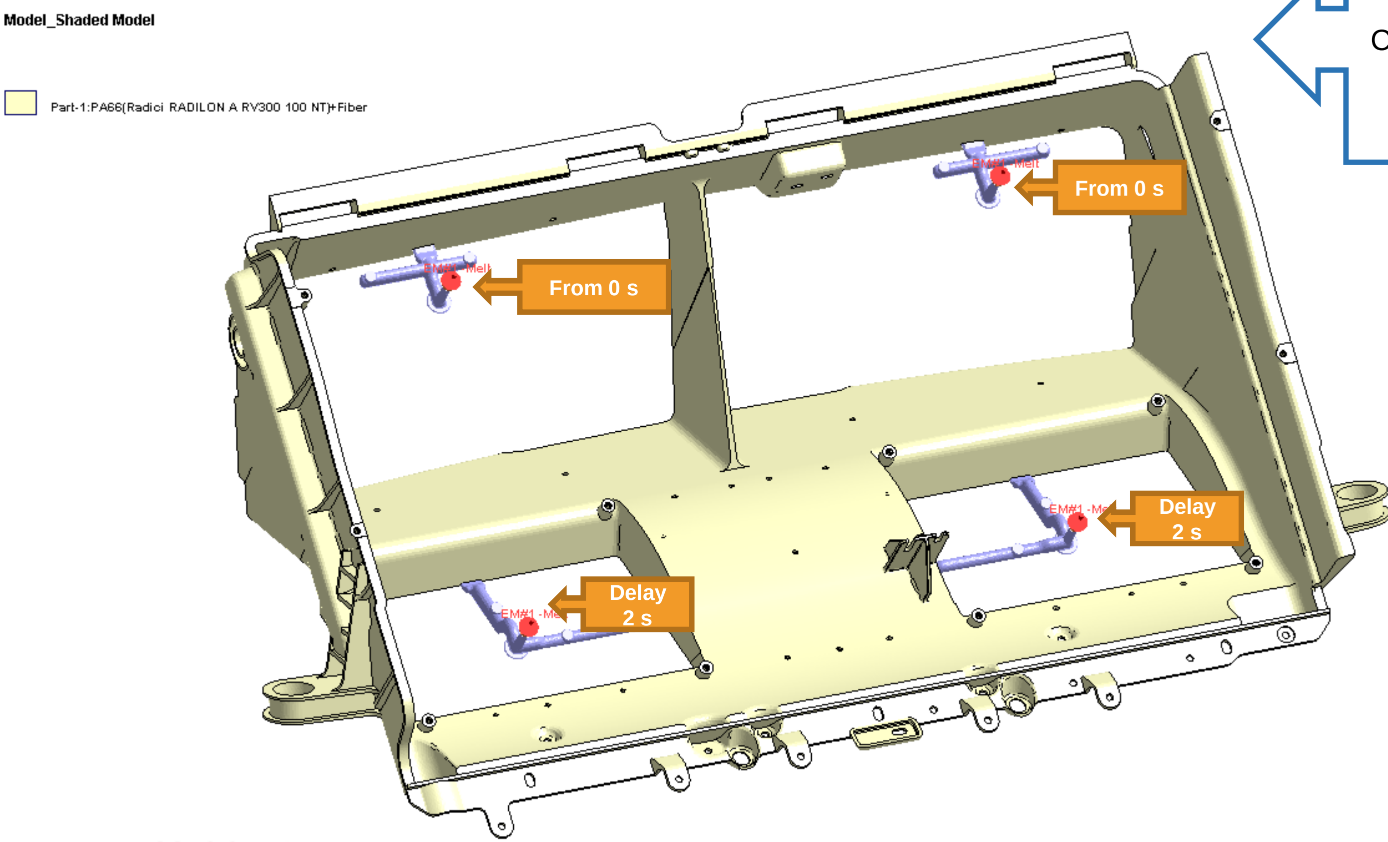
Rheological properties	dry / cond	Unit	Test Standard
Molding shrinkage, parallel	0.3 / *	%	ISO 294-4, 2577
Molding shrinkage, normal	1.0 / *	%	ISO 294-4, 2577

> Requirements of dimensional and geometric tolerances exist to ensure assembly with the other components nearby

> The customer asked to have some help from CAE to assess:

- The average molding shrinkage % to increase the dimensions in toolmaking
- The warpage overall of the component, so to control the critical dimensions

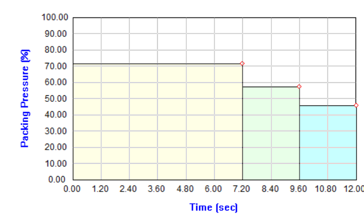
Engine air conveyor - Simulation



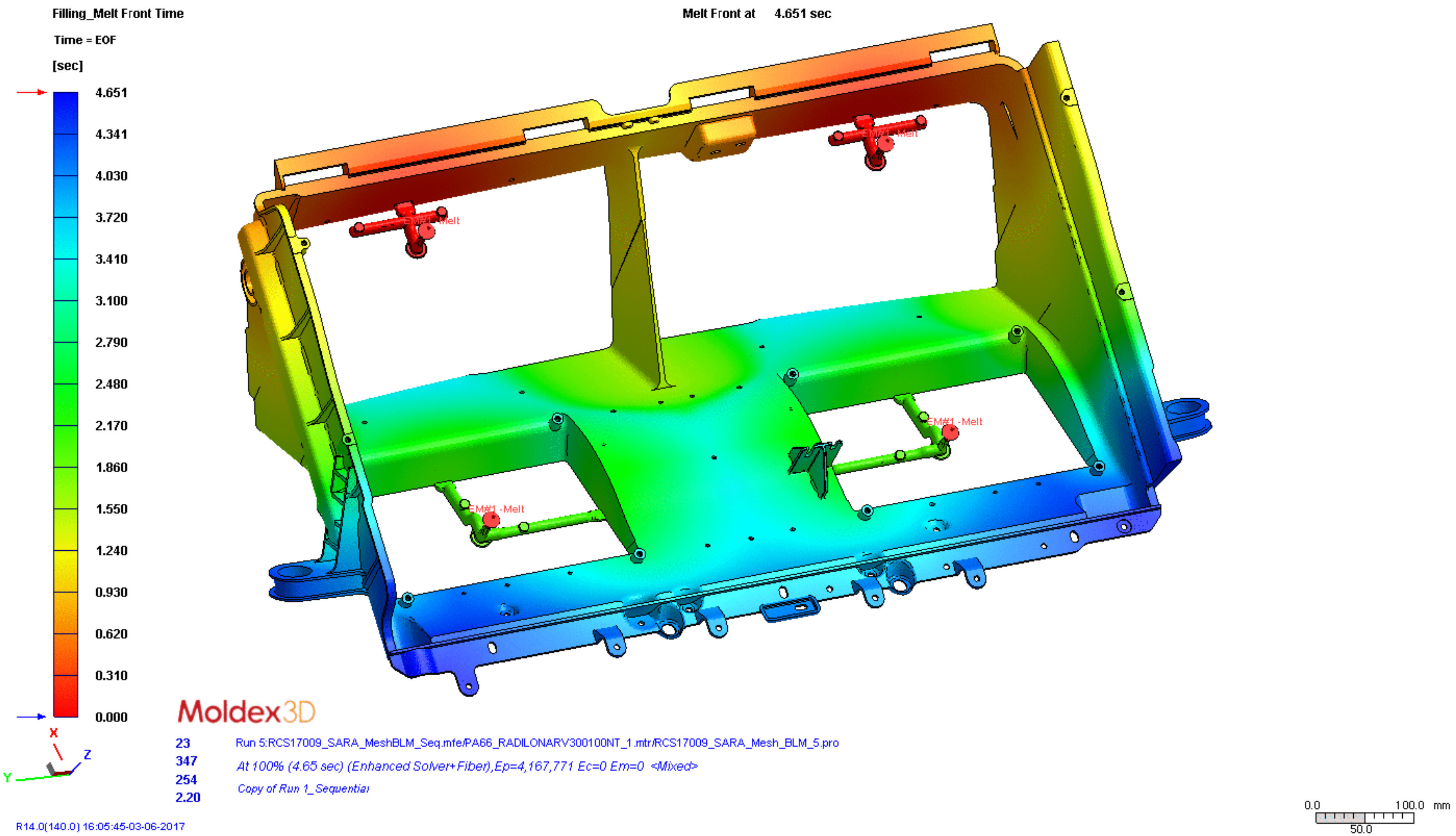
Mesh: **4164k** 3D elements (BLM 5-layer)
Cold runner: as per geometry provided by customer
Gate: 6x Film Gate

Processing conditions

- Filling Time: 4.43 s
- Melt Temperature: 280°C
- Mold Temperature: 90°C
- Sequence of valve opening: see pic
- Post-Pressure: see profile below (% refers to filling pressure peak)
- Cooling time: 60 s



Engine air conveyor – Fill Time



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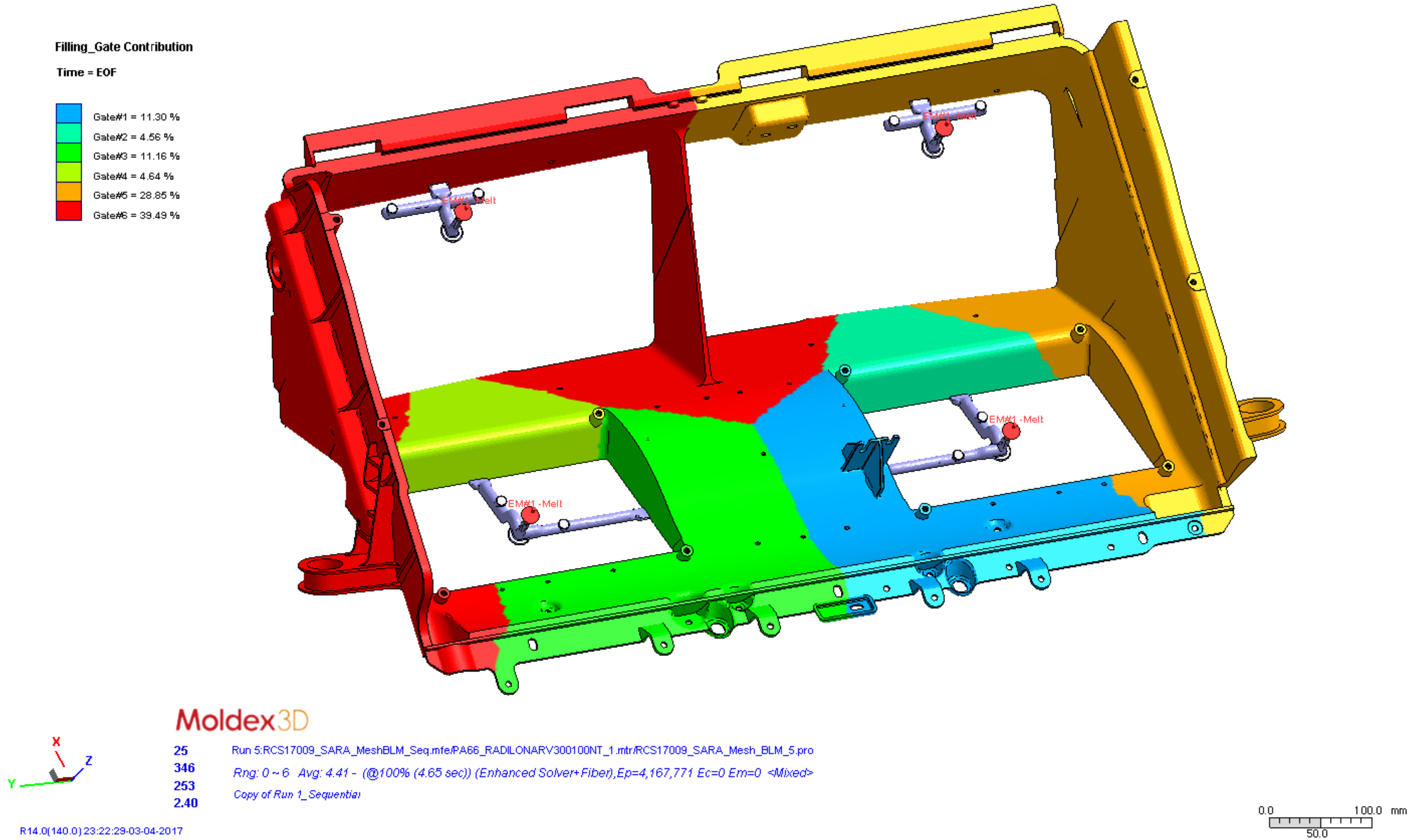
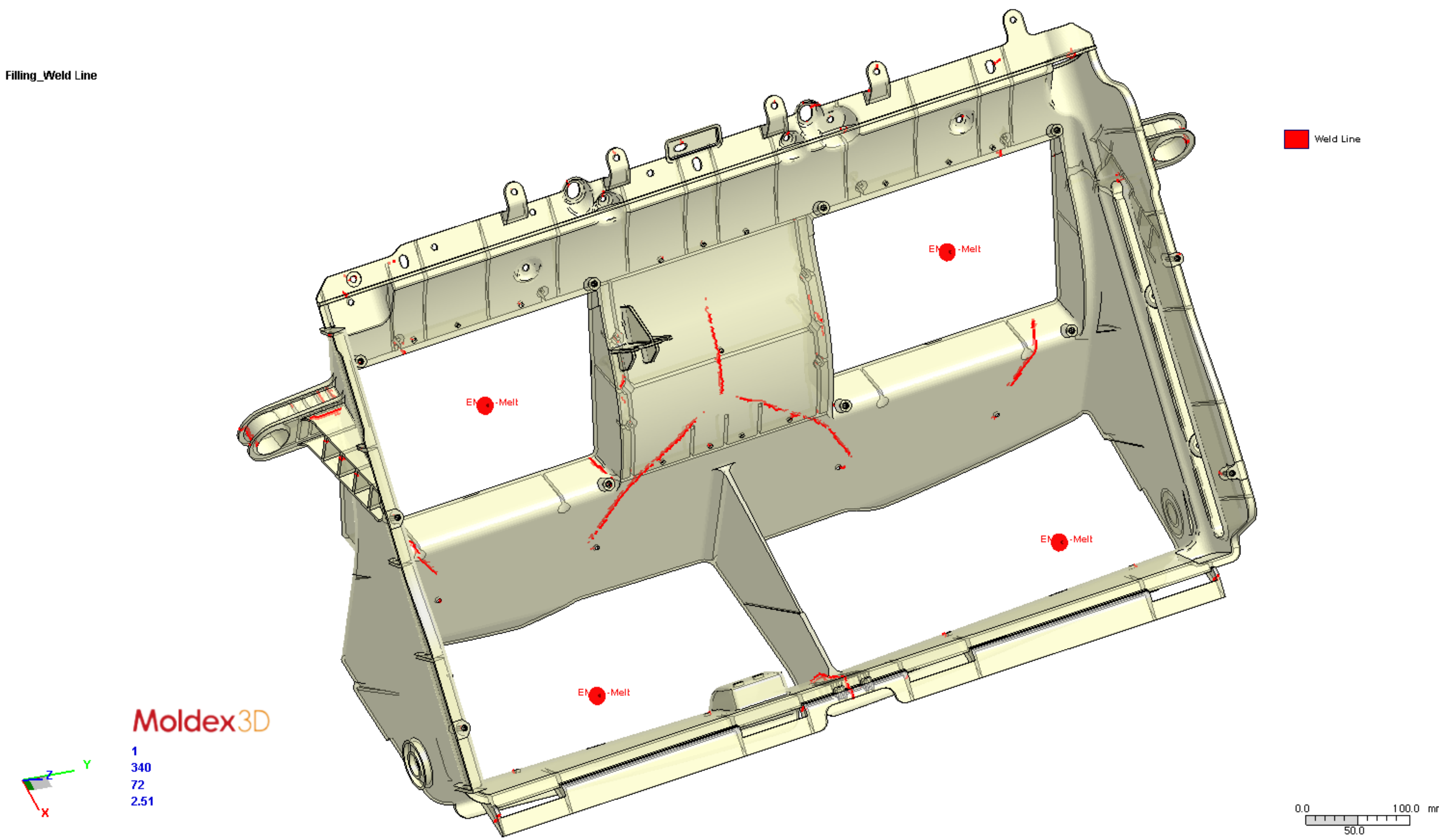
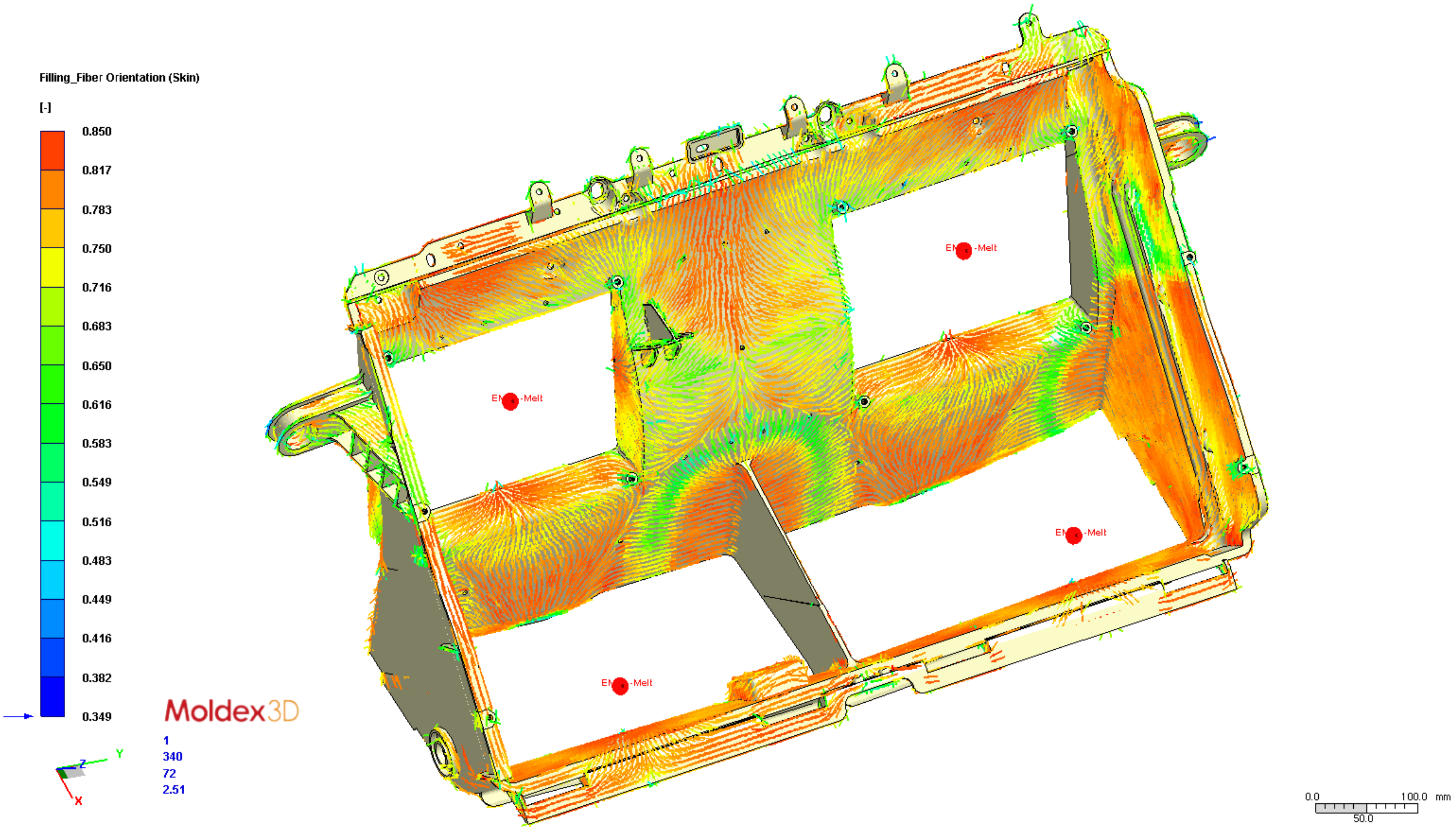
Engine air conveyor – Gate Contribution



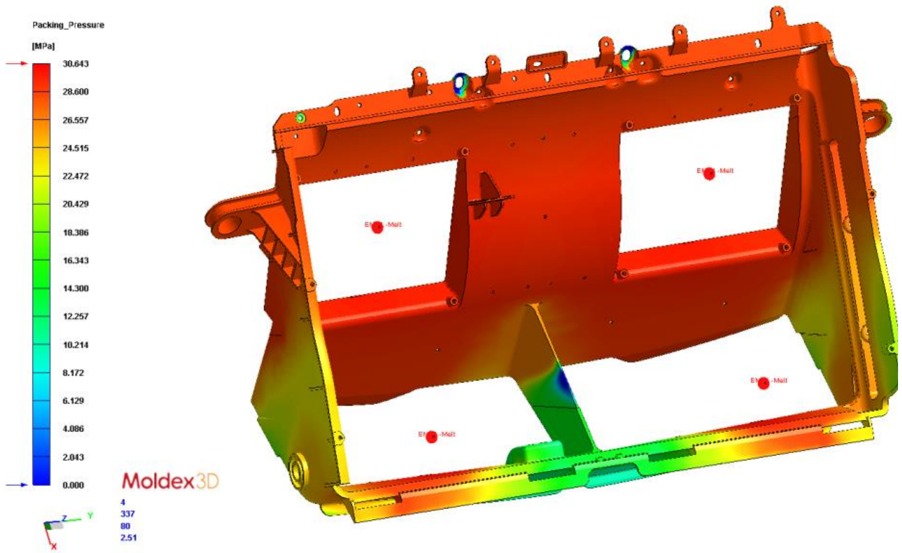
Engine air conveyor – Weldlines



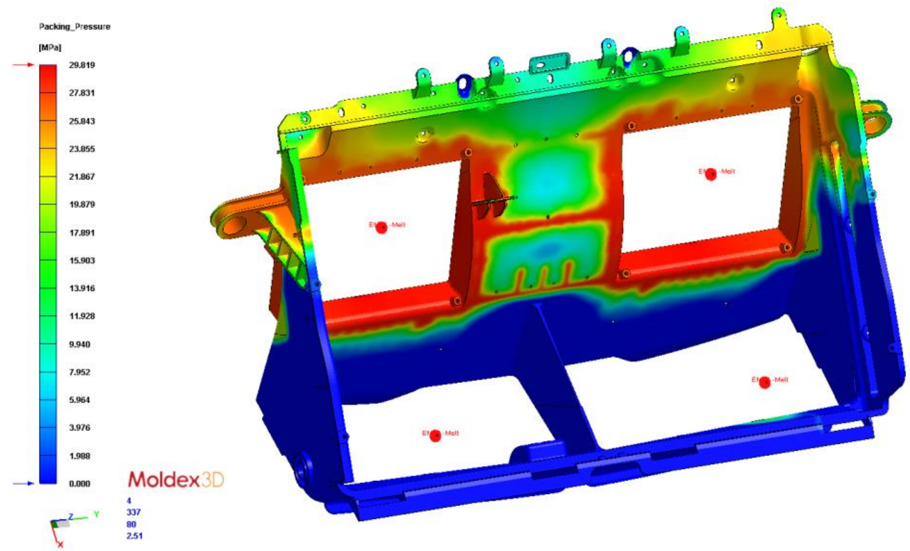
Engine air conveyor – Fiber Orientation



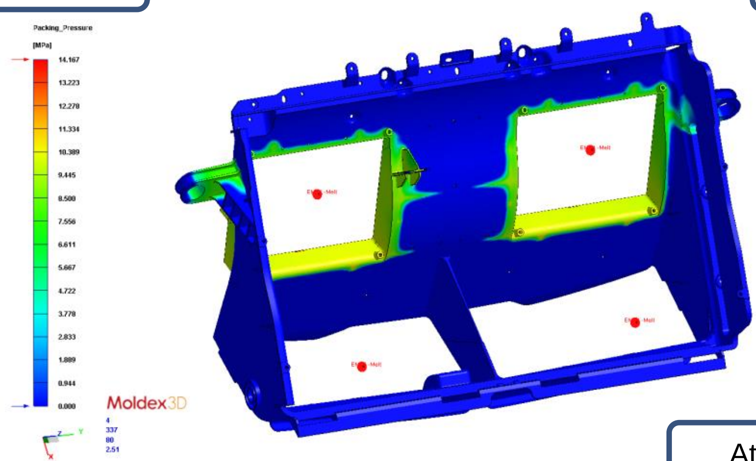
Engine air conveyor – Packing pressure distribution



At 3.15 s after EOF

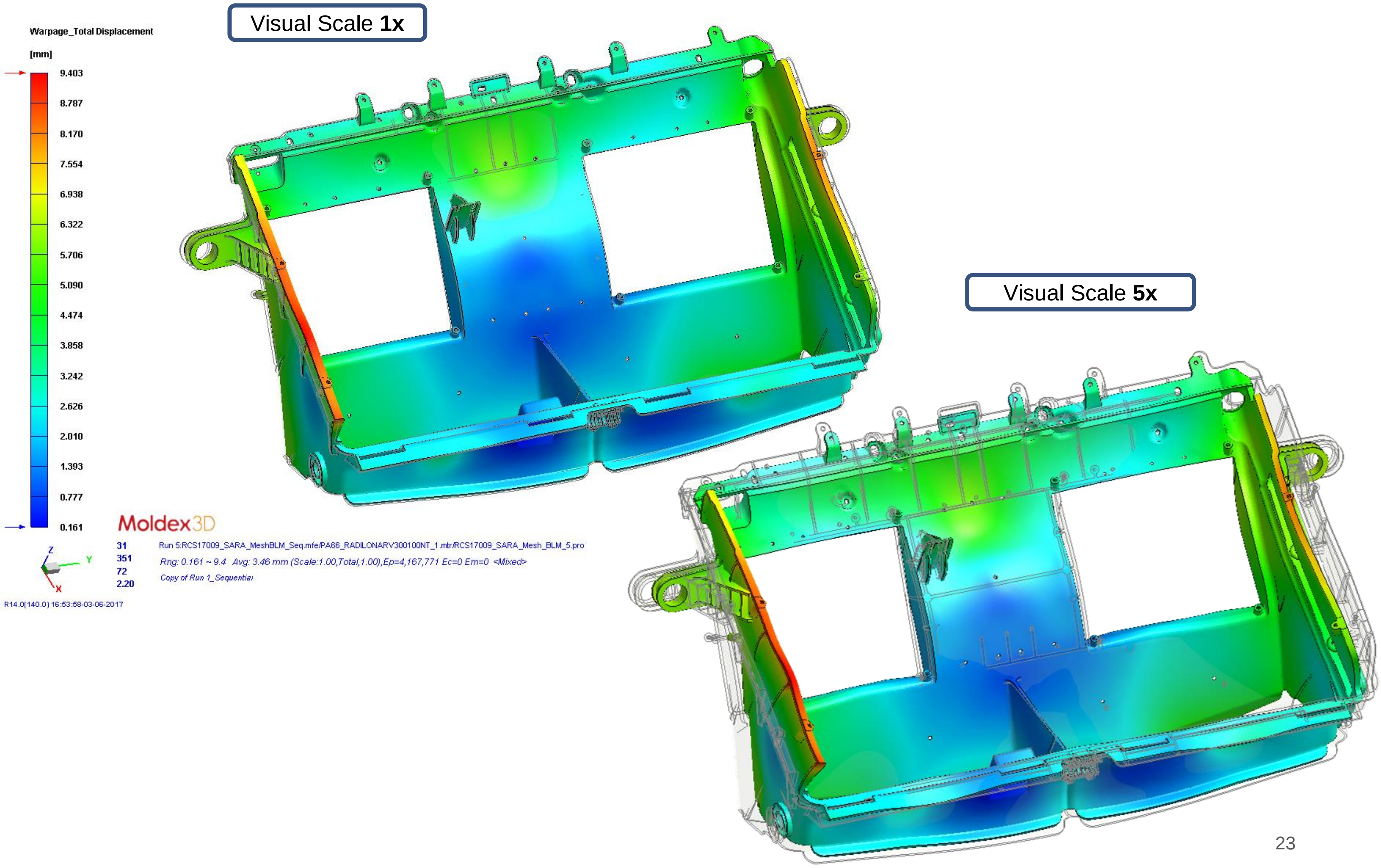


At 6.15 s after EOF

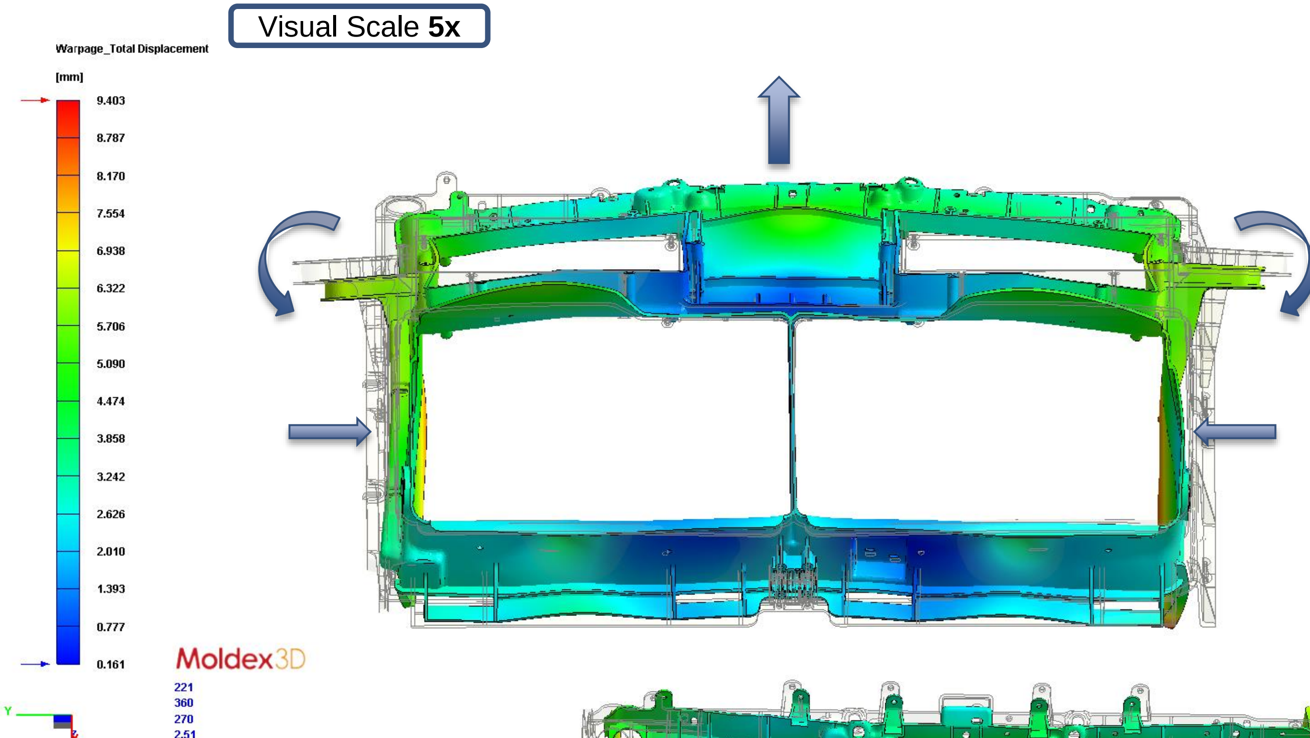


At 9.27 s after EOF

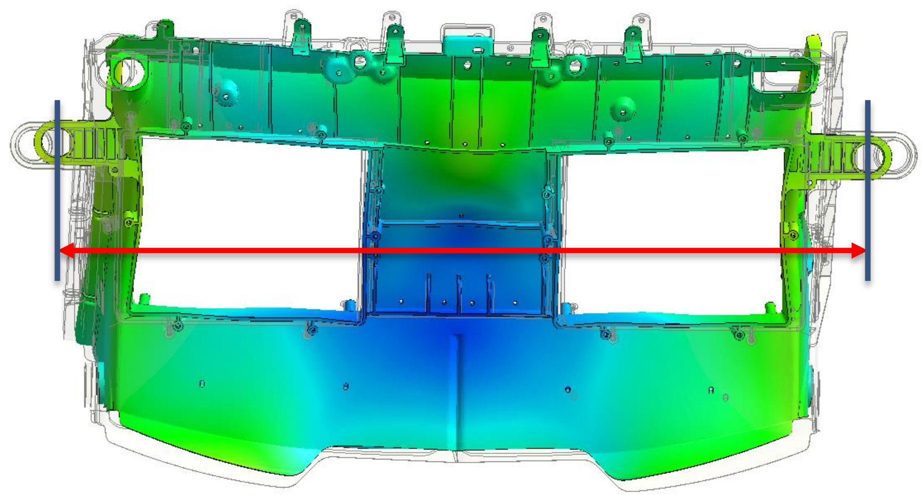
Engine air conveyor – Warpage



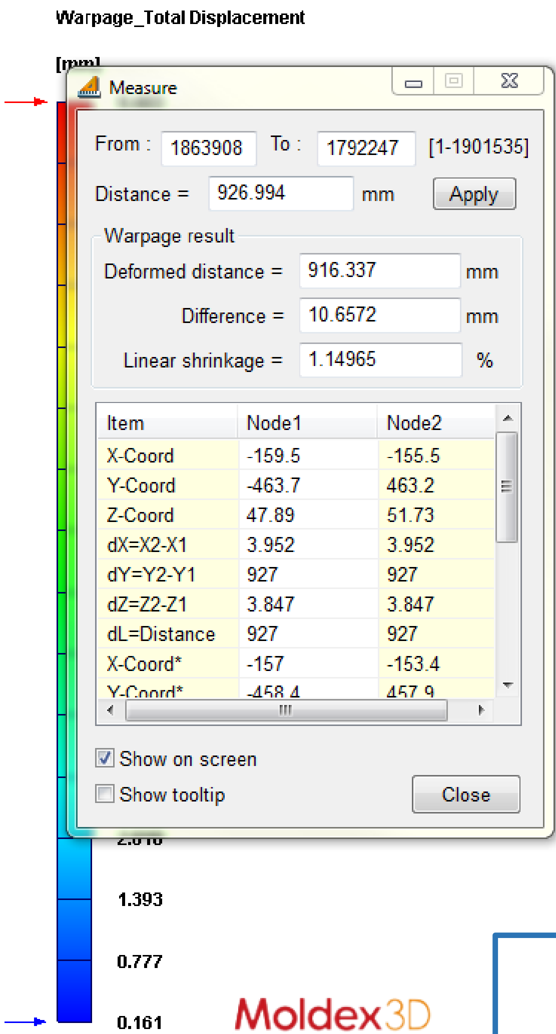
Engine air conveyor – Warpage

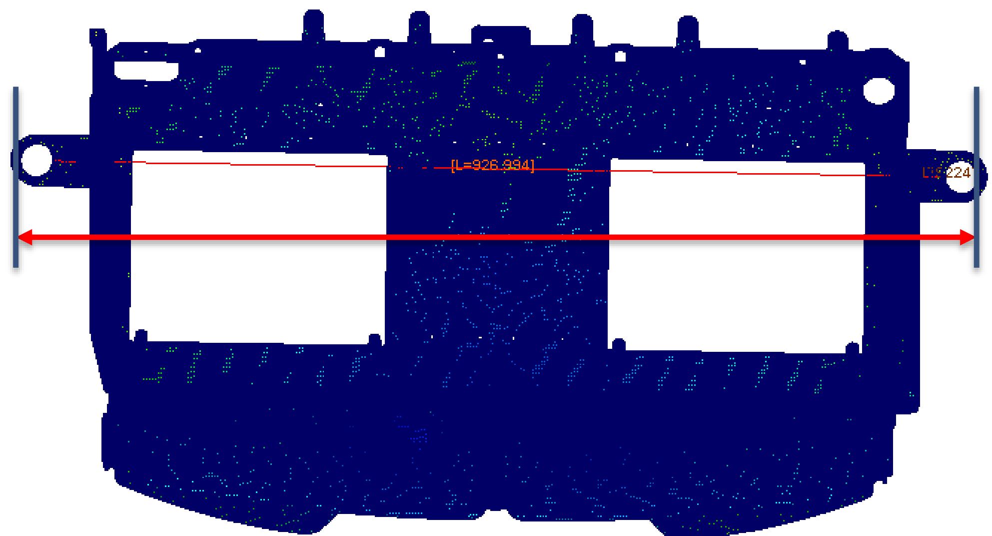


Critical dimension to control (assembly with frame)



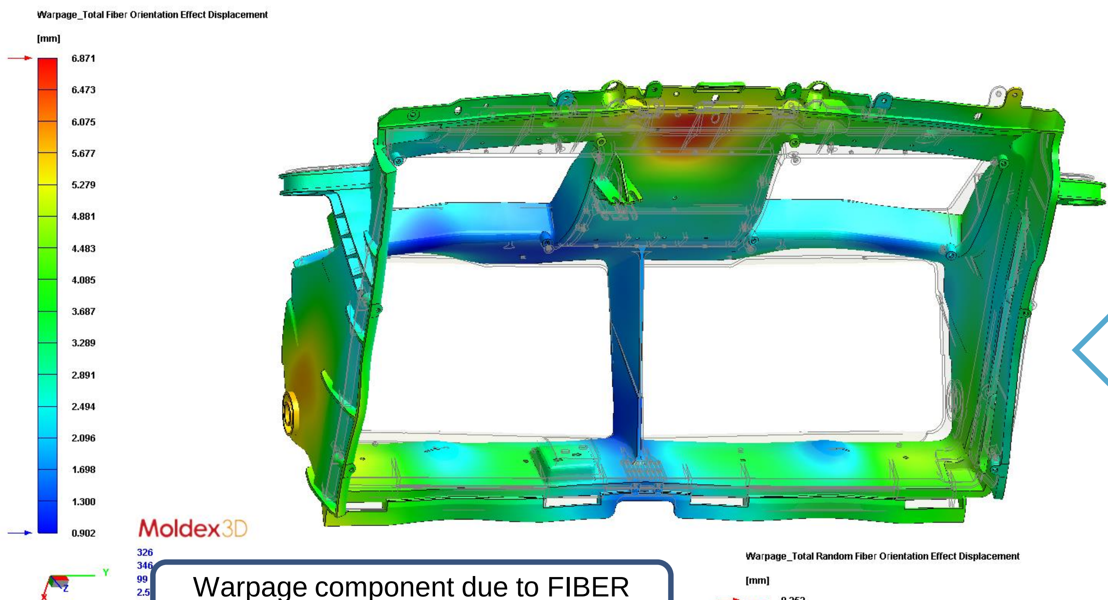
Engine air conveyor – Shrinkage compensation





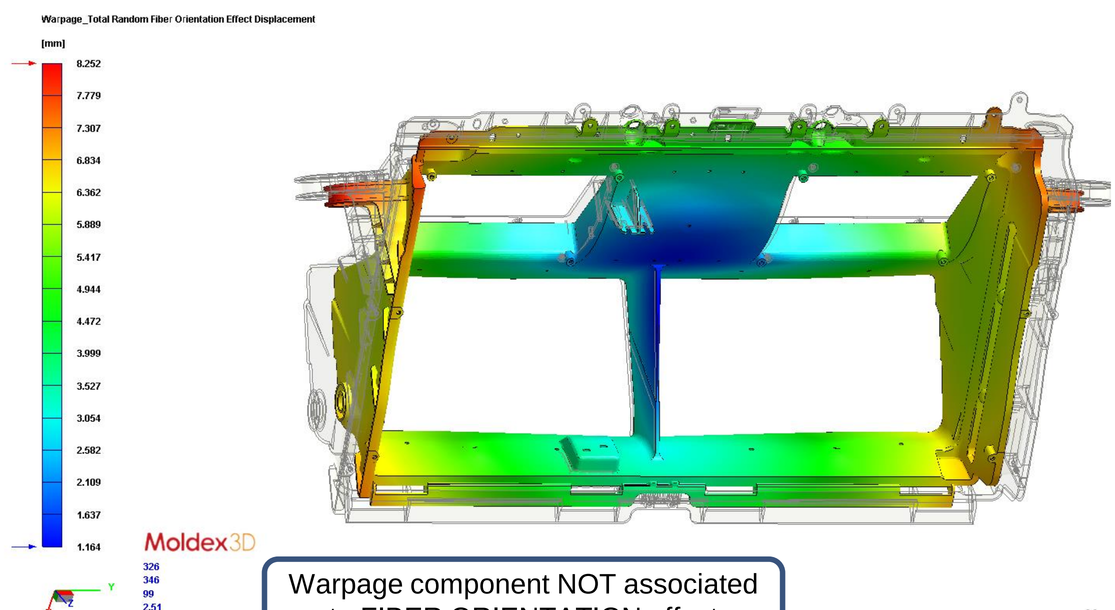
The analysis predicts the actual loss of dimension in the critical distance between the mounting holes, being HIGHER than the maximum expected shrinkage (in reality it is due to a superimposition of shrinkage and warpage effect).

Engine air conveyor – Warpage effects



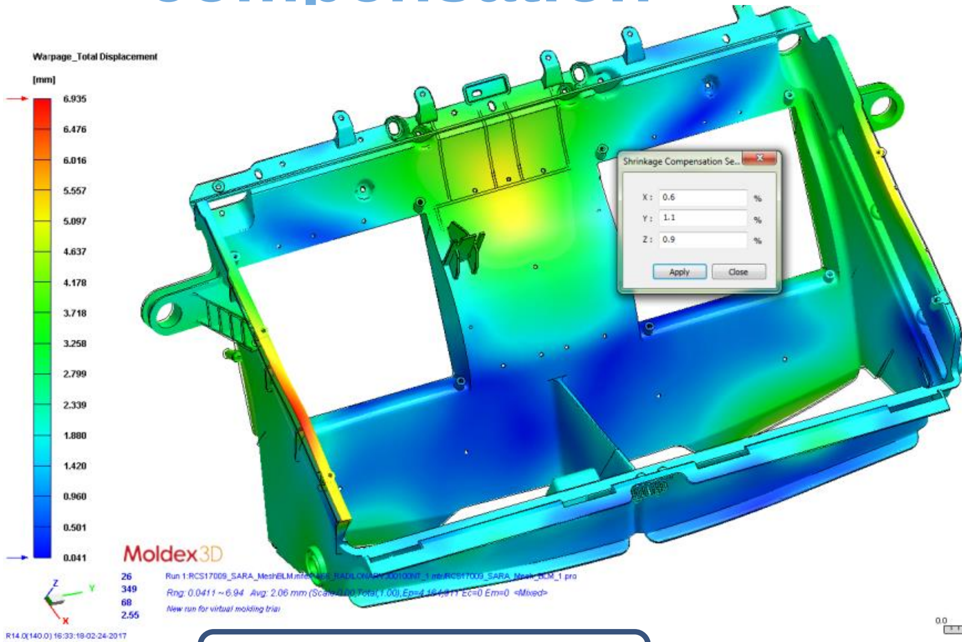
Warpage component due to FIBER ORIENTATION effect

GF orientation is the main responsible of the anisotropy and distortion effects induced in warpage

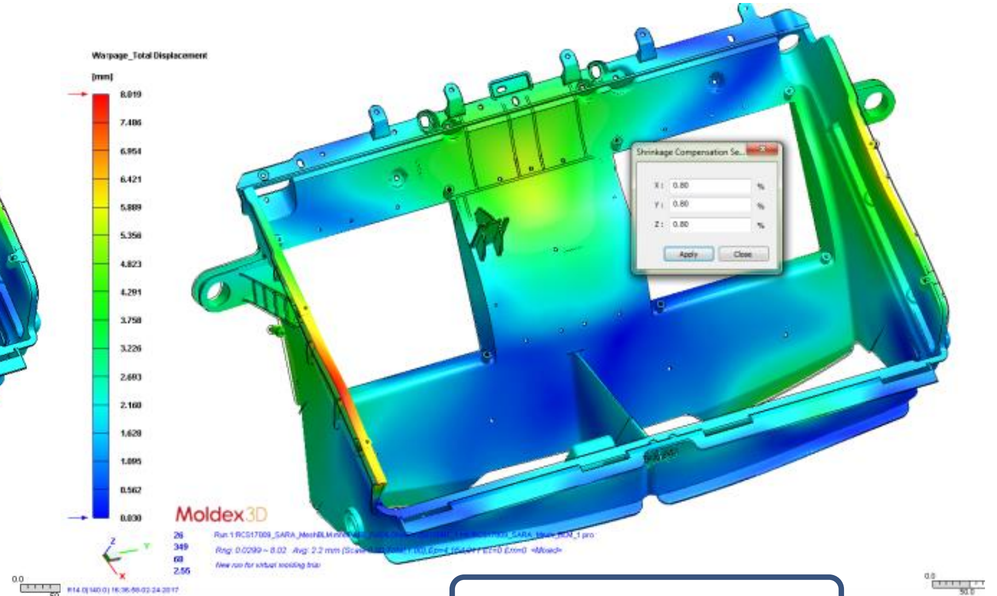


Warpage component NOT associated to FIBER ORIENTATION effect

Engine air conveyor – Shrinkage compensation



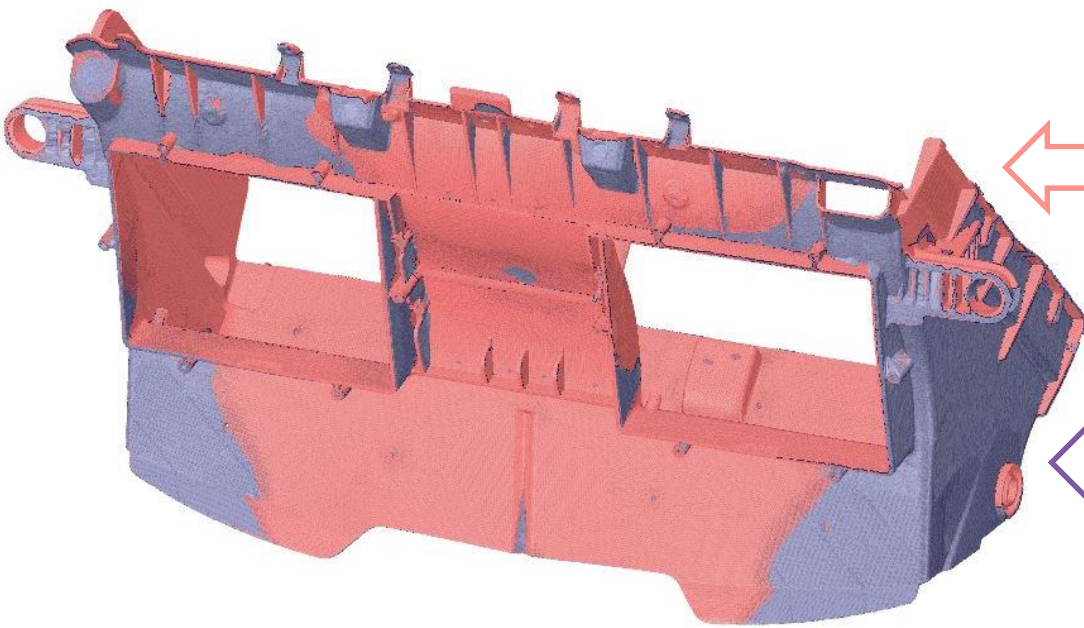
Different shrinkage along X-Y-Z
(0.6% – 1.1% – 0.9%)



Uniform shrinkage (0.8%)

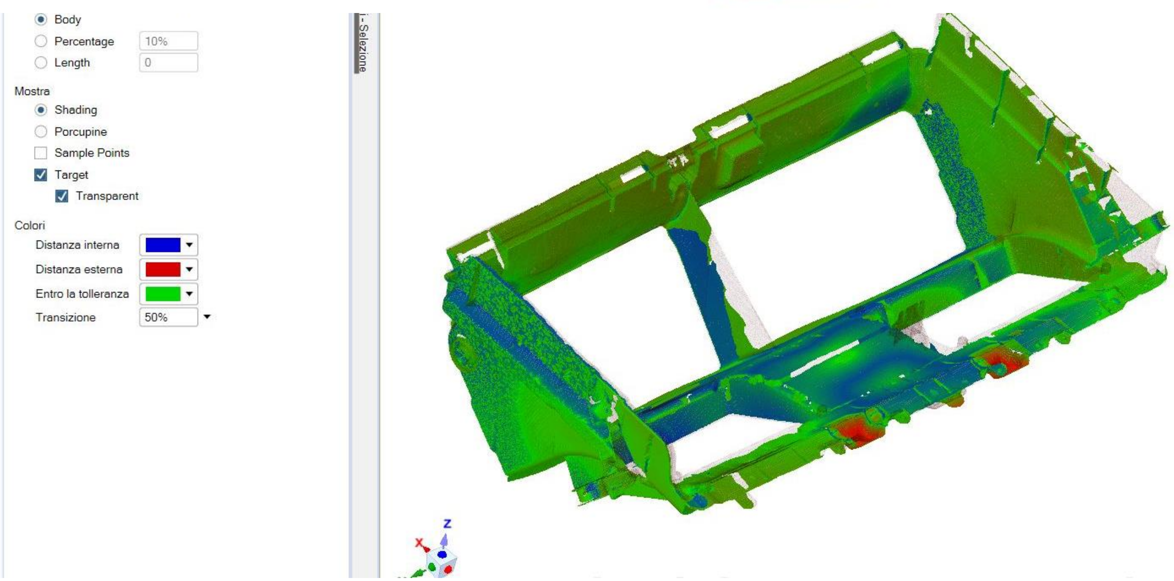
Tentative to find out the **optimal value** of nominal linear shrinkage to apply in toolmaking.
MOLDEX allows to **compensate warpage from shrinkage effect by setting a custom X,Y,Z % value**.
In this analysis, the more "blue" is the model, the more the nodal deviation with respect to nominal shape of the item is low, so the more the "overall shrinkage" value chosen is able to copy the desired one.

Engine air conveyor – Real prototype molding vs predicted shape



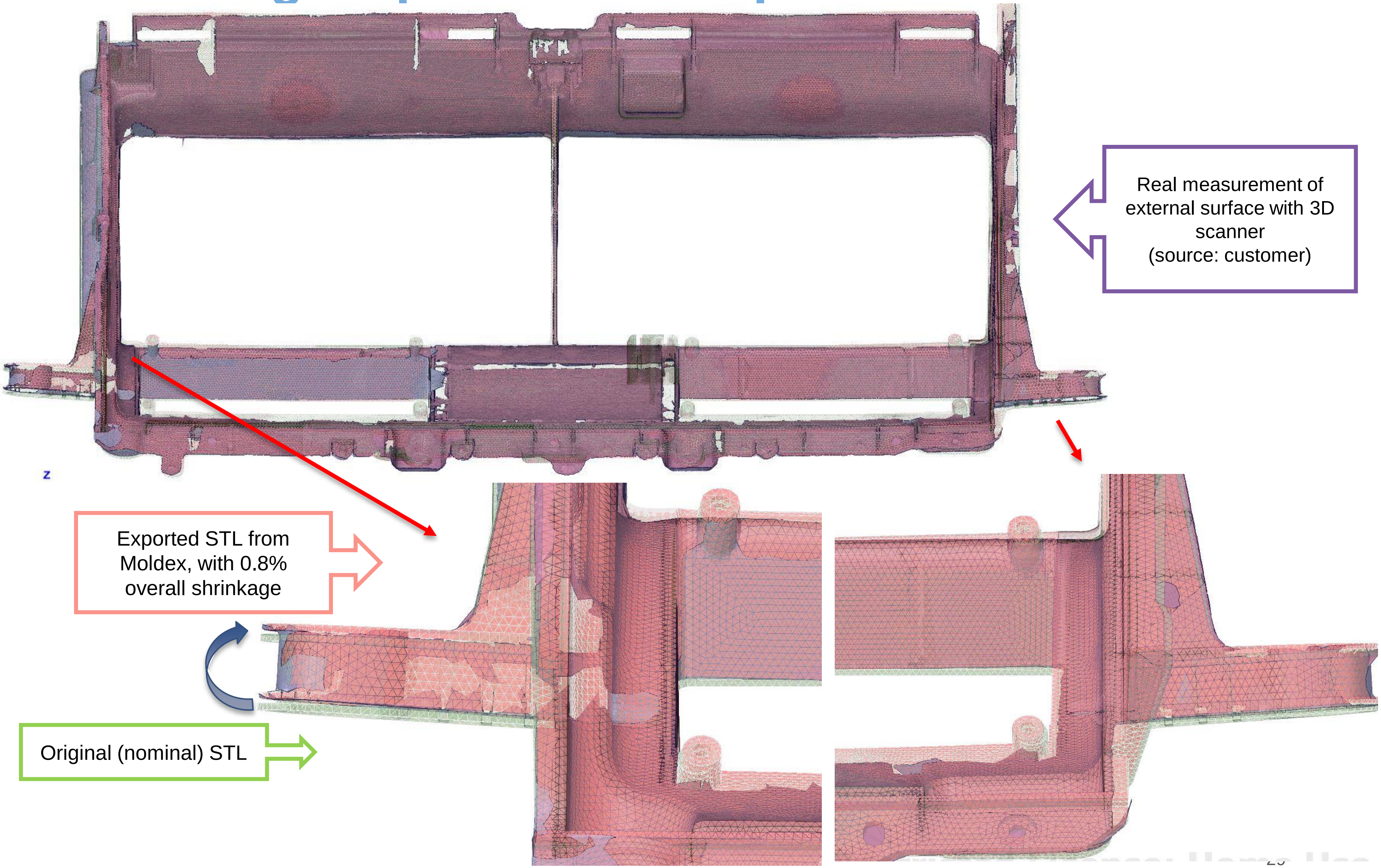
Exported STL from Moldex, with 0.8% overall shrinkage

Real measurement of external surface with 3D scanner (source: customer)



Fairly good agreement between real prototype molds and CAE predictions

Engine air conveyor – Real prototype molding vs predicted shape



Engine air conveyor – Prototype

Future improvements in warpage prediction

Evaluating Moldex3D Enhanced Warpage module

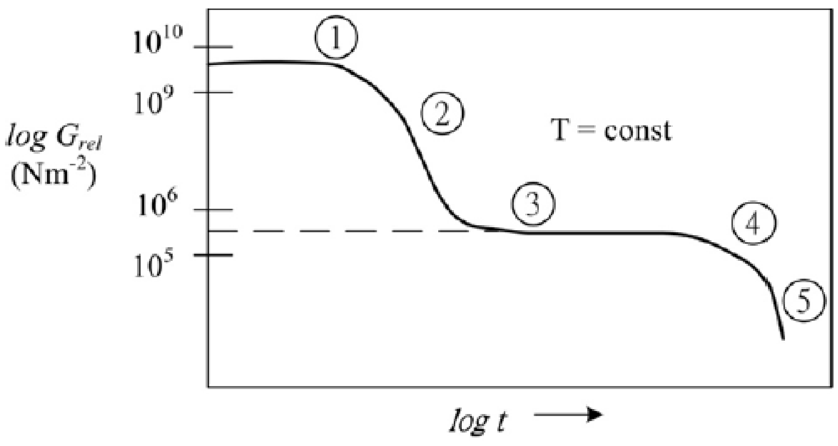
Moldex3D

Moldex3D Enhanced Warpage module and Structural viscoelastic data

Moldex3D

- New **Enhanced Warp** module of Moldex3D allows to take into account the mechanical properties of the polymer, during cooling (transient) in order to account for shrinkage and distortion, at the specific time/temperature they occur
- **RadiciGroup Performance Plastics CAE group**, together with **R&D laboratory** and **CoreTech** support, is investigating how to characterize properly GF reinforced and unreinforced PA materials in order to investigate how to take advantage of this approach to obtain more accurate and reliable warpage results

Relaxation modulus $G(t) = \frac{\sigma(t)}{\lambda_0}$



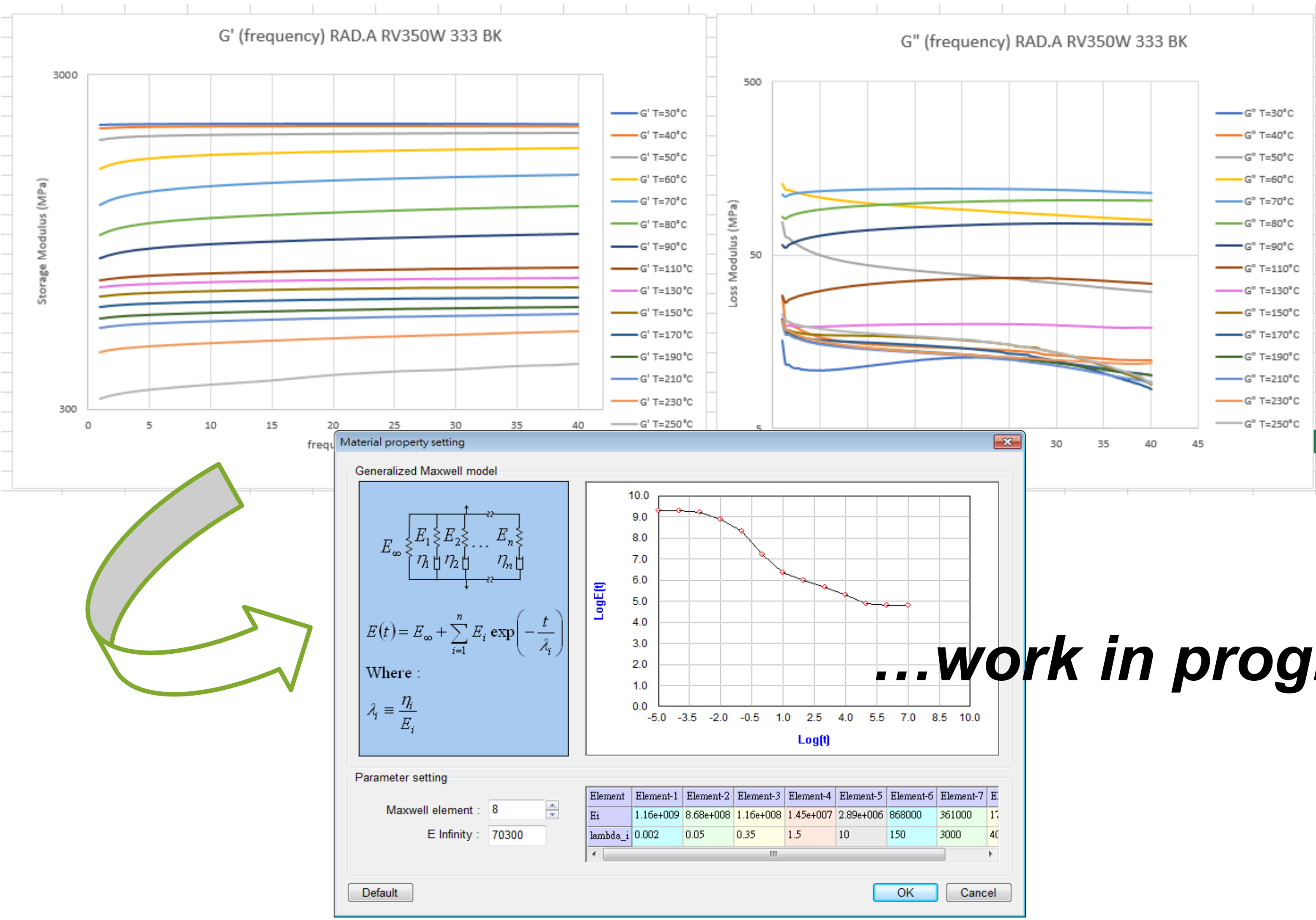
(1) Glassy region
(2) Glass transition
(3) Rubbery region
(4) Viscoelastic flow
(5) Viscous flow

the modulus of polymer is changing dramatically during injection molding cooling process

From liquid, rubber, to solid phase

Moldex3D Enhanced Warpage module and Structural viscoelastic data

Moldex3D



Element	Element-1	Element-2	Element-3	Element-4	Element-5	Element-6	Element-7	E
Ei	1.16e+009	8.68e+008	1.16e+008	1.45e+007	2.89e+006	868000	361000	17
lambda_i	0.002	0.05	0.35	1.5	10	150	3000	40

...work in progress!

Thank You

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