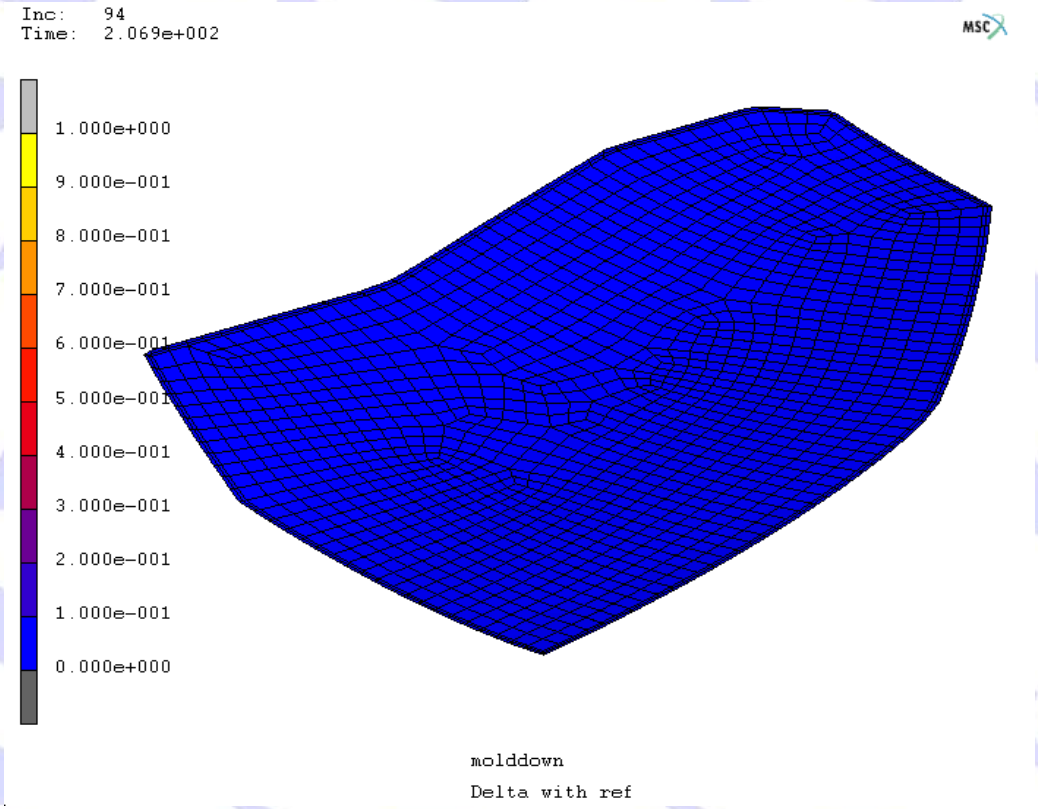
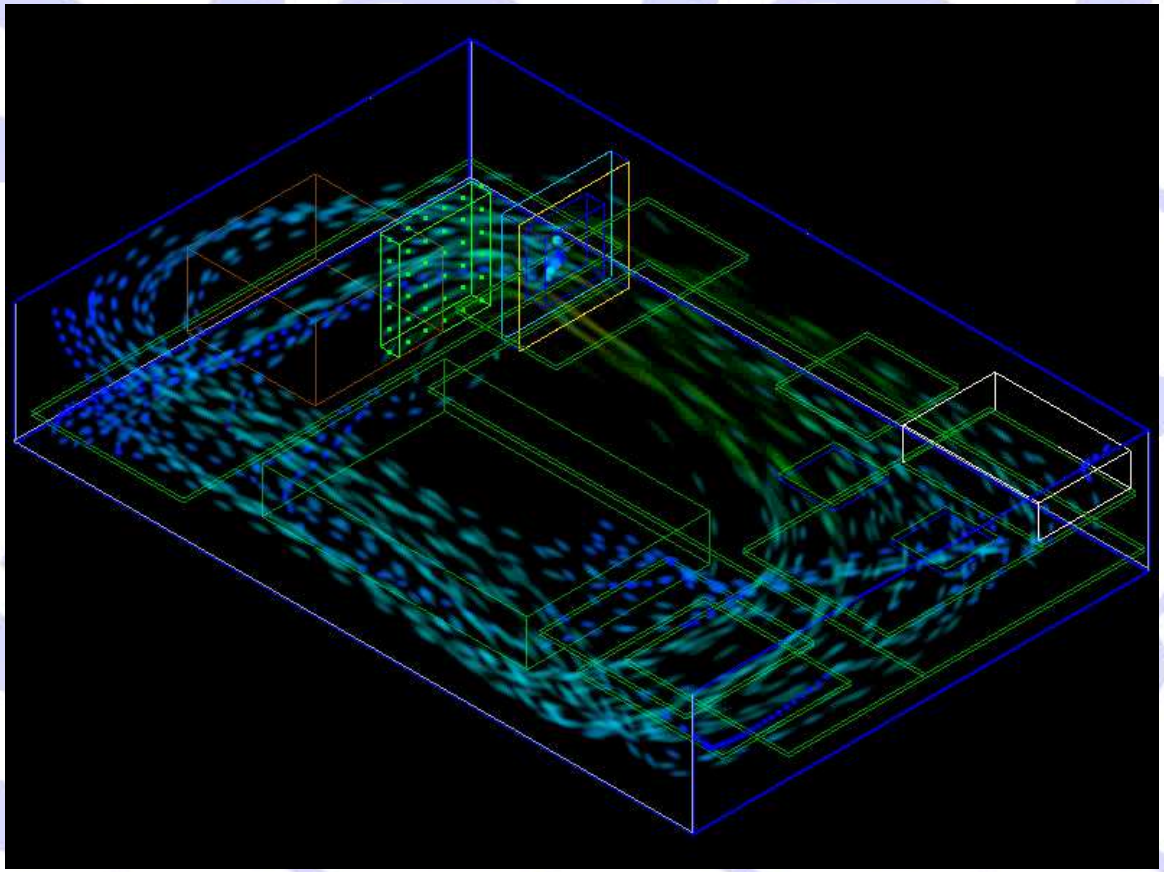
Thermo-mechanical projects

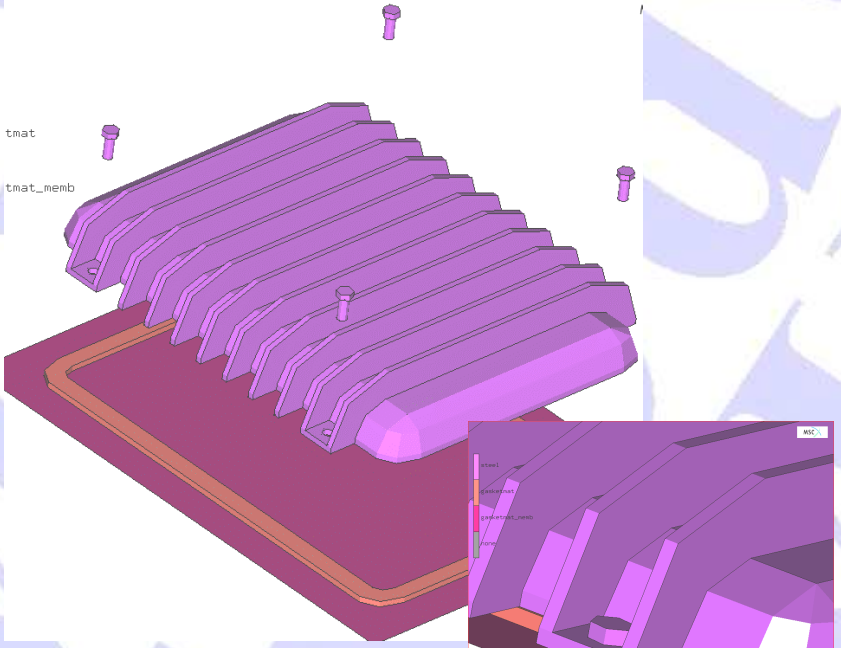


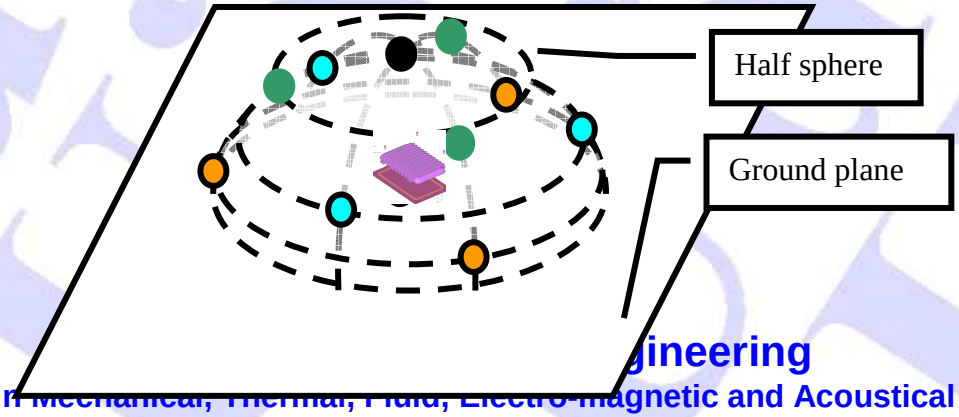
UDY Computational Engineering
Consulting in Mechanical, Thermal, Fluid, Electro-magnetic and Acoustical Engineering
Kapellestraat 64 B-9220 Hamme +32 052 472733 www.udy.be

Fluids

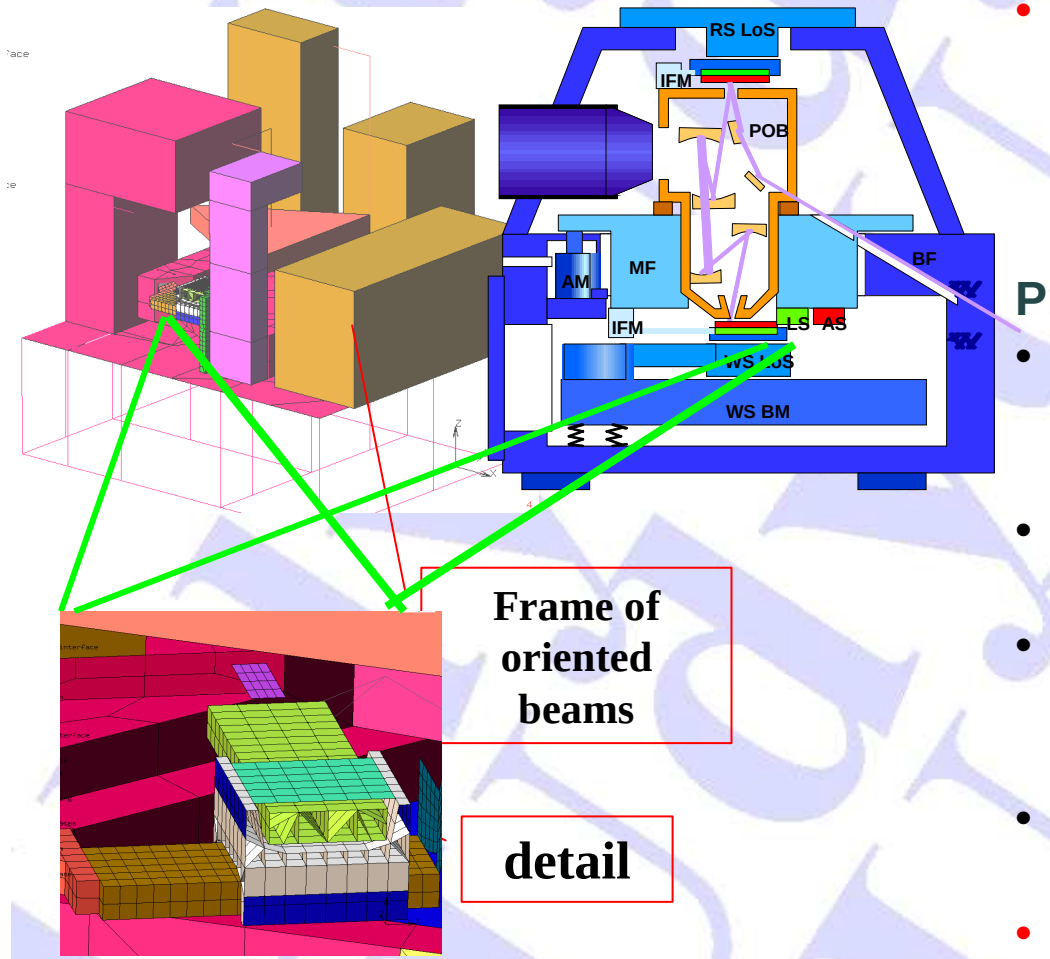


Acoustic projects





Large combined shell/beam/solid structures



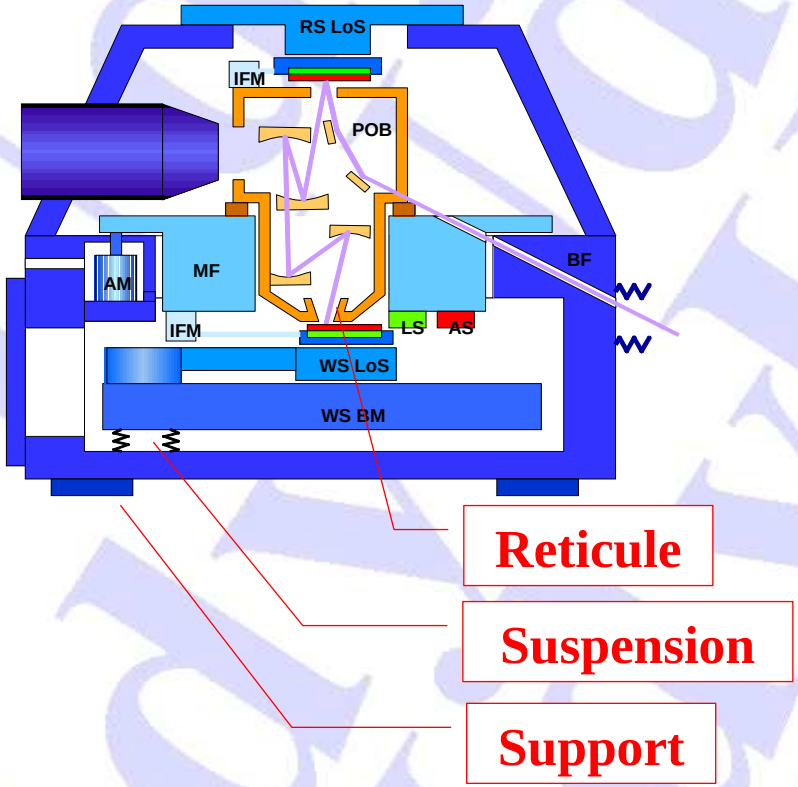
Project description:

- Large structure, consisting of stainless steel plates, beams and solid blocks on top of frame must withstand static and dynamic loads.

Project deliverables:

- Inner structure is very critical for vibration and is modeled in detail for enhanced accuracy.
- Non conforming mesh with tied contact bodies.
- Concentrated masses connected by multiple point constraints (MPC) to reduce number of DOFs.
- Staic, modal, harmonic and transient analysis.
- Sub modeling of critical welds.

Vibration sensitivity of precision equipment



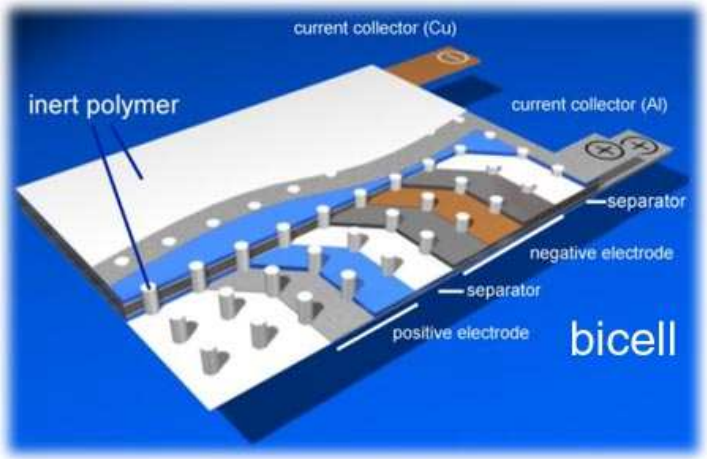
Project description:

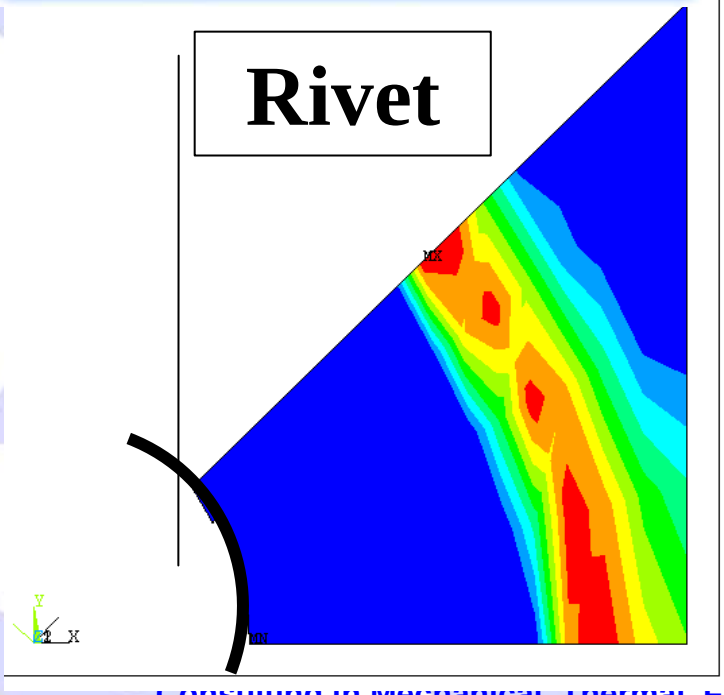
- Precision optical instrument consists of mechanical sledge system which is vulnerable to shock and vibration

Project deliverables:

- Inner structure of instrument modeled in full 3D.
- Realistic loads applied at supports.
- Response at reticule calculated.
- Suspension changed as to lower reticule response.

Riveted structure





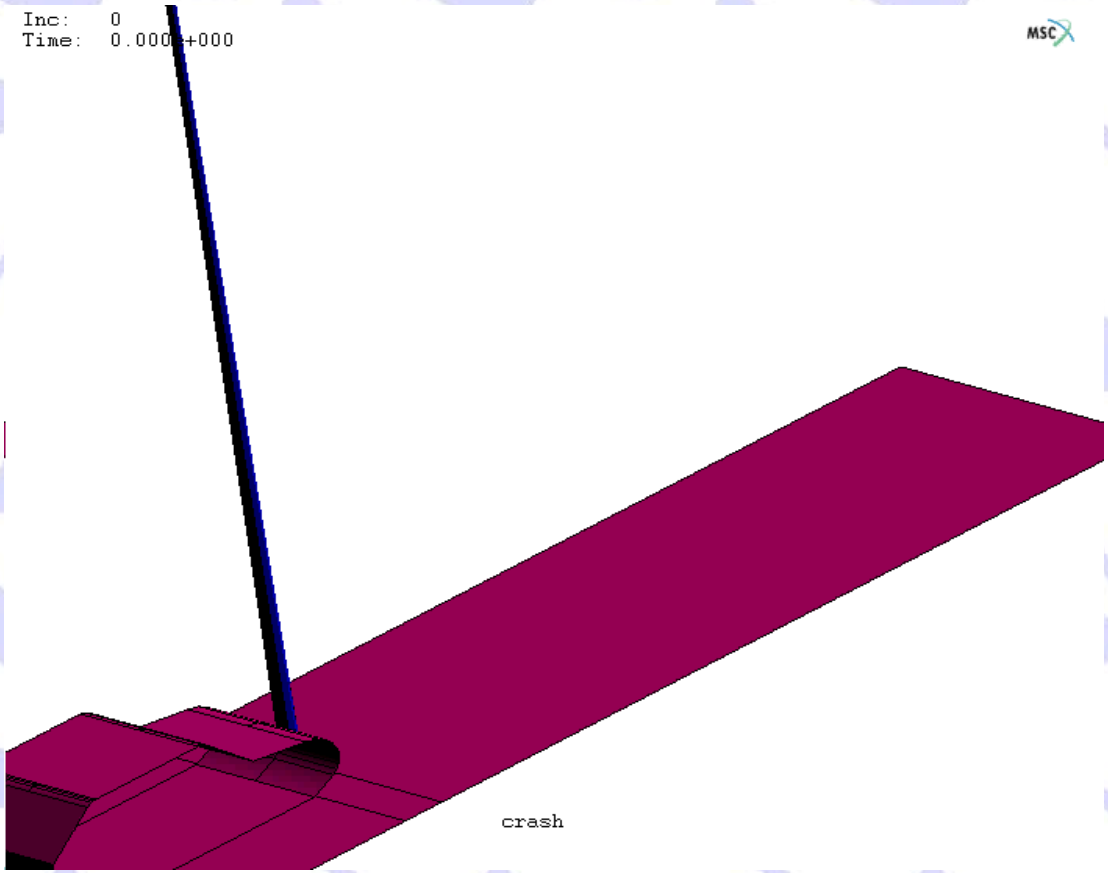
Project description:

- Layers are riveted on each other and contact pressure must be equal during all operating conditions.

Project deliverables:

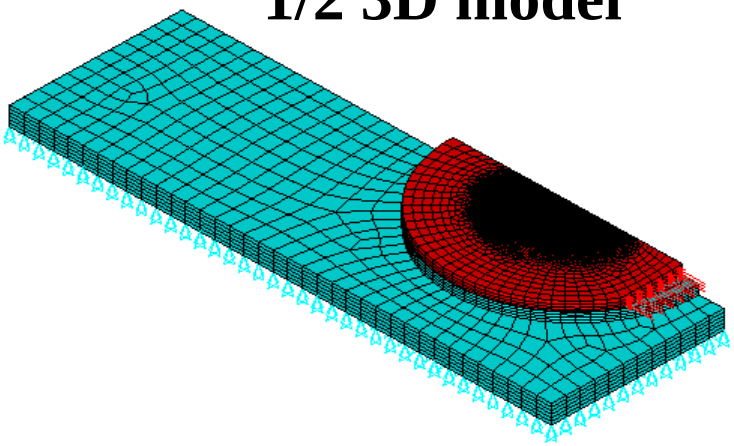
- 1/8 cell modeled with contact bodies
- Contact pressure monitored during change of temperature, lifetime, external pressure etc.
- Design outer case modified to ensure better contact pressure.

Mechanical projects



Lap joint

1/2 3D model



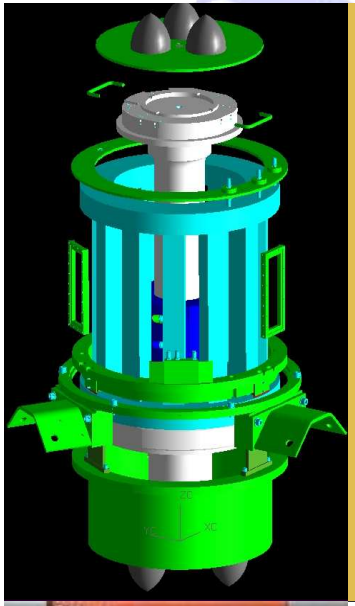
Project description:

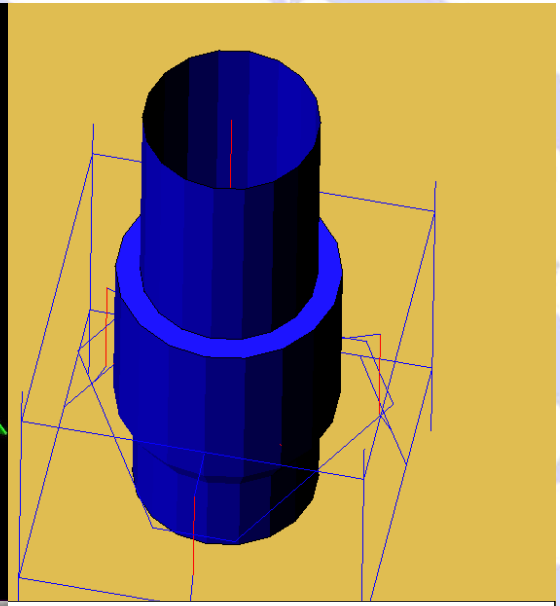
- Ceramic disc lap glued to sub-structure.
- Subjected to external loads and temperature changes.

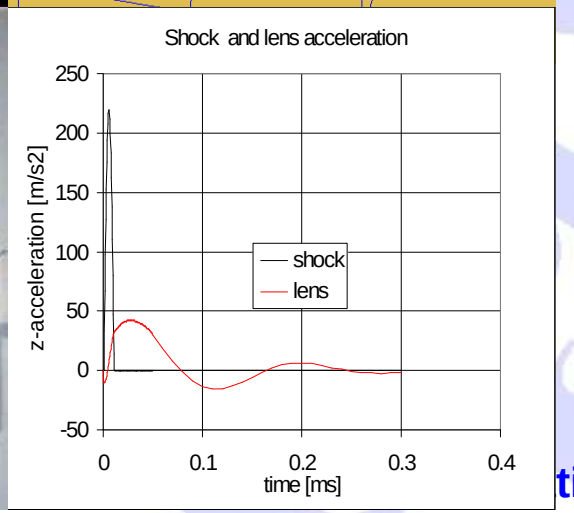
Project deliverables:

- 1/2 3D model.
- Shear stress in adhesive determined.

Transport shock and vibration isolation







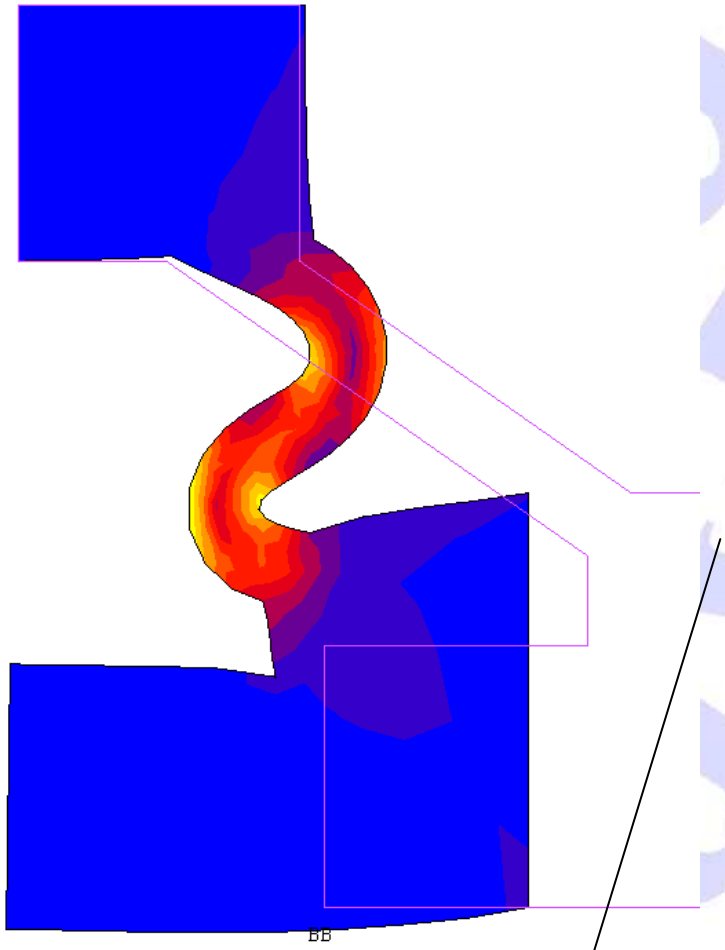
Project description:

- Critical object is mounted in frame and shock-isolated by means of rubber blocks (red lines).
- Non-linear pre-stressed rubber material behavior.

Project deliverables:

- Accelerations on critical object from different drop and vibration conditions according to International Transport Norm IEC 721.
- Analysis in both frequency (including modal and random vibration analysis) and time domain.
- Reduction of shock and vibration level with factor 5.

Vibration isolation



Undeformed

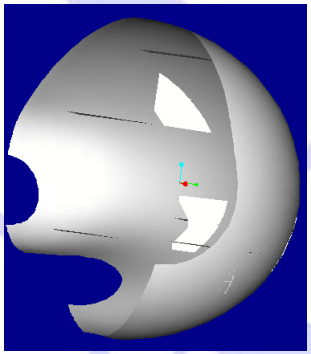
Project description:

- Rubber mount for vibration isolation.
- Undergoes large static pre-stress followed by vibration load.
- Conical part highly stressed and early damage.

Project deliverables:

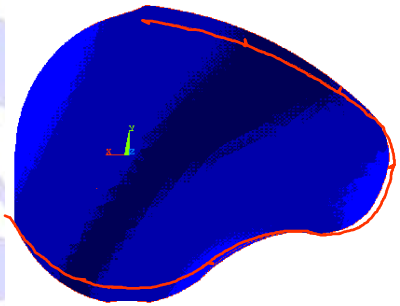
- Material model: Mooney or Ogden incompressible rubber parameters identified.
- Static pre-load applied.
- Dynamic load superimposed (frequency and time domain).
- In case of time domain analysis, friction between rubber surface and steel armature included.

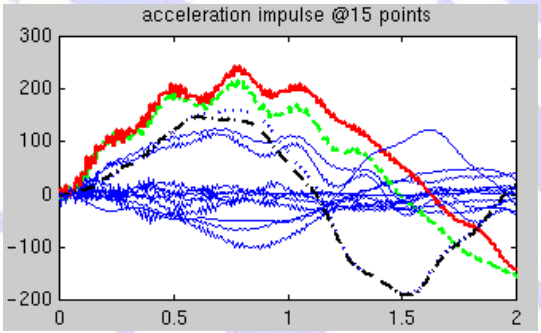
Fragility: PC camera



< Pro-Engineer
Right part

vibration
mode: 290 Hz >





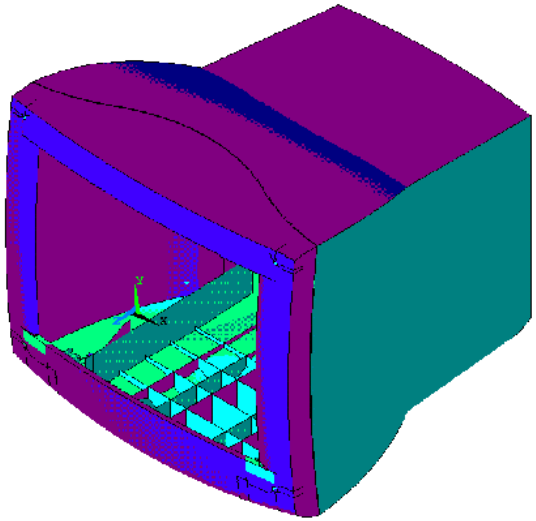
Project description:

- Outer casing of PC camera must be drop resistant up to 1 meter.
- Geometry: imported from CAD program.

Project deliverable:

- Parametric model of assembly stiffness
- 15 drops
  - internal force response
  - relative displacements
- Design of integral casing with flexibility to absorb shock

Drop resistance: PC monitor



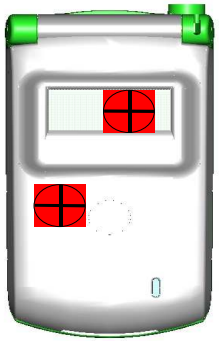
Project description:

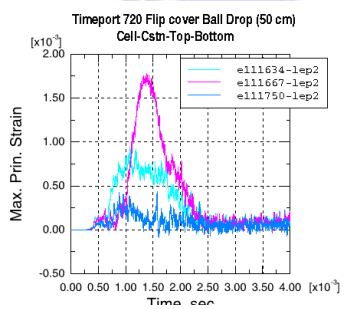
- Determine influence of reducing the wall thickness on drop behavior of monitor plastic enclosure concepts.

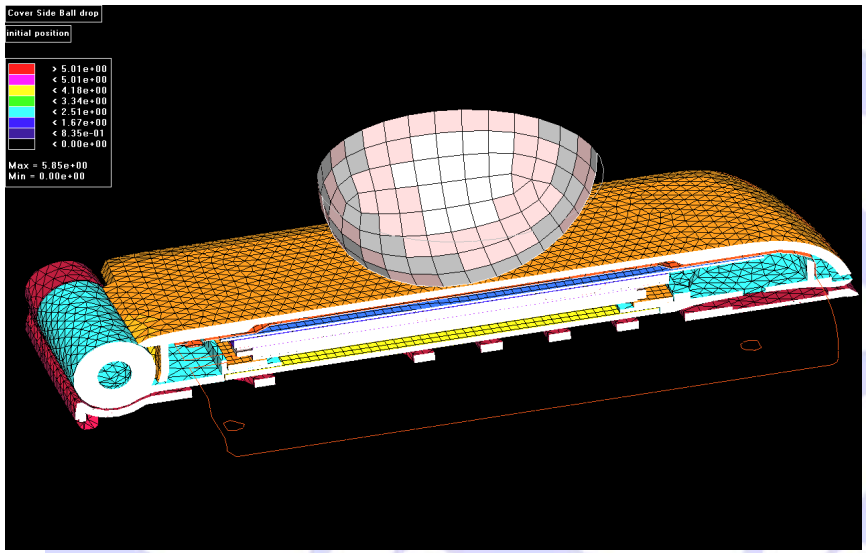
Project deliverable:

- Testing: validation & model input of current monitor.
- Determine influence of thickness.
- Design new monitor concepts.
- Extensive parameter study: thickness, ribs, curvature modifications, etc by Design of Experiments (DOE) methods.

Drop test simulation







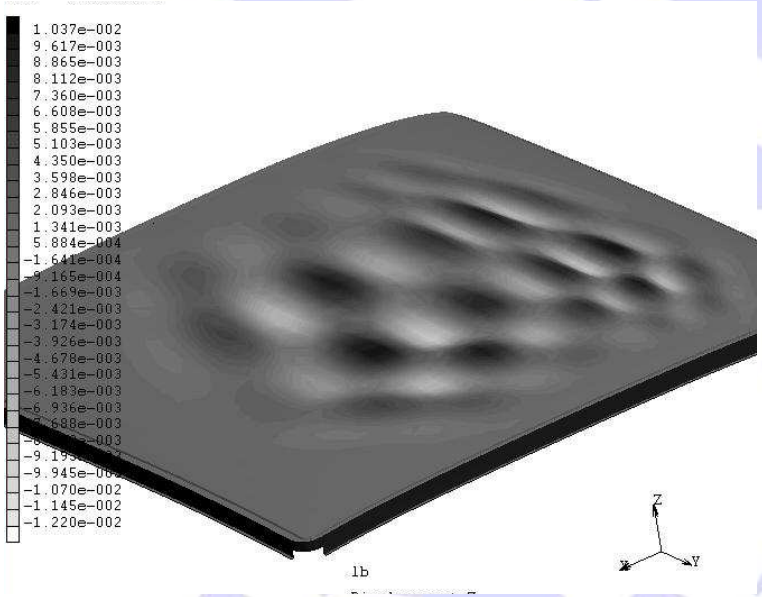
Project description:

- Drop test (1.5 m) and ball drop test on 3rd generation mobile phone set.
- Optimize clamping of LCD glass screen as to withstand the tests.

Project deliverables:

- Complete interior modeling with about 40 contact bodies.
- Time domain simulation (0 to 0.3 ms) with non-linear material behavior.
- New LCD clamping proposed, simulated, verified and implemented.

Buckling of shallow plate



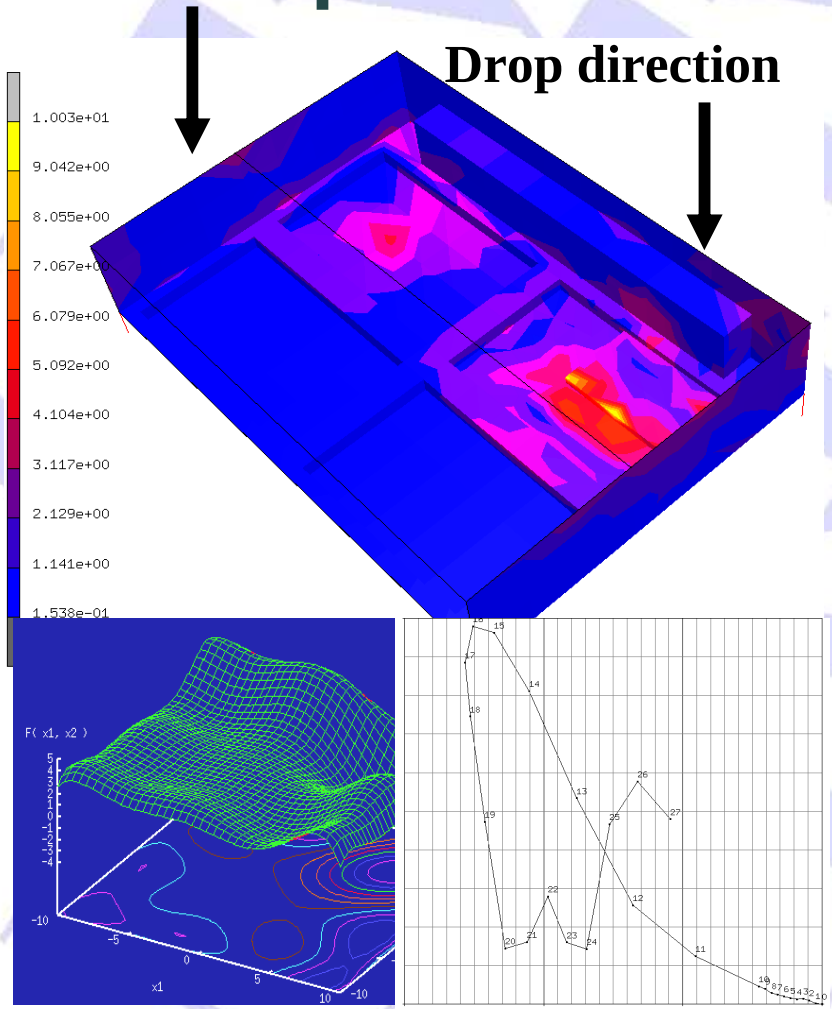
Project description:

- Thin shallow plate is loaded in normal direction
- Collapse can occurs if load is too high
- Development of reliable buckling and post-buckled assessment for structure, subjected to a number of environmental (pressure, vibration) loads

Project deliverables:

- Buckling model developed, including effect of possible metal yield plasticity
- Study the effect of geometrical imperfections, which are very important here due to shallowness
- Limits of curvature and boundary conditions at edges determined

Drop resistance of plastic housing



Project description:

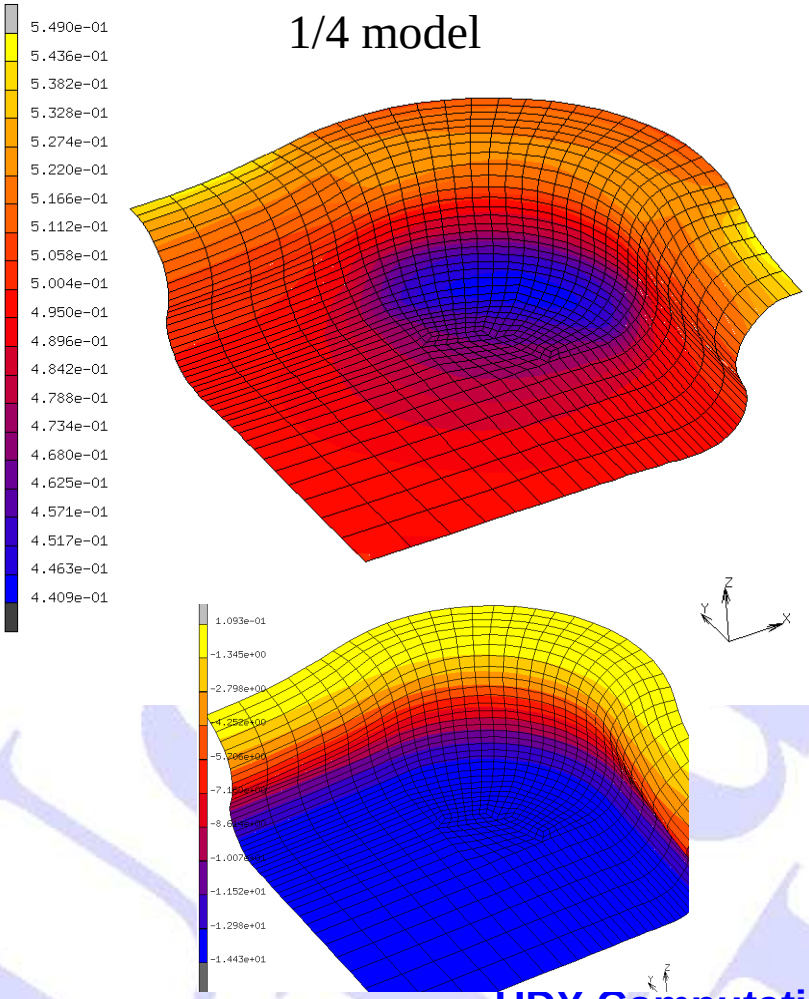
- Development of combined
  - •plastic housing of electronic apparatus
  - •PS buffers and carton box

  to withstand drop test and minimize transport costs.
- Nonlinear characteristics of PS buffers must be taken into account.

Project deliverable:

- PS buffers modeled by nonlinear springs.
- Critical locus (transformer mount) identified.
- Bottom plate structural modifications proposed.
- Minimization of buffer volumes
- Response surface to arrive at minimum transport cost for maximum drop resistance.

Metal stamping, deep drawing, sheet forming, blow forming



Project description:

- Metal blank is pressed between upper and lower die or plastic is blown against die.
- For metals: plasticity and hardening behavior. For plastic foil: super-plasticity behavior.
- Fissures can develop in corners.

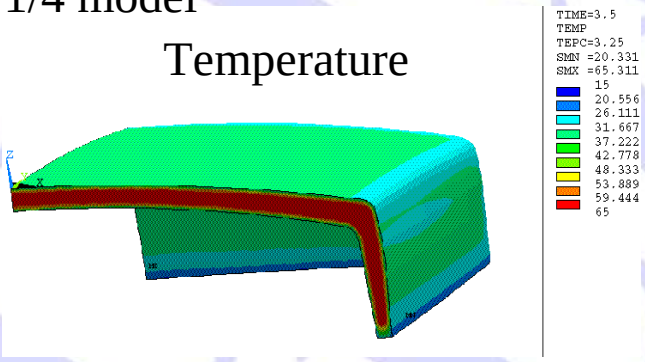
Project deliverables:

- Radius of dies adapted to ensure correct product radius.
- Stamping or forming process optimized by monitoring strain and thickness distribution of blank during process.
- Exact radius for perfect closure if required in end product, e.g. for electro-magnetic compatibility (EMC.)

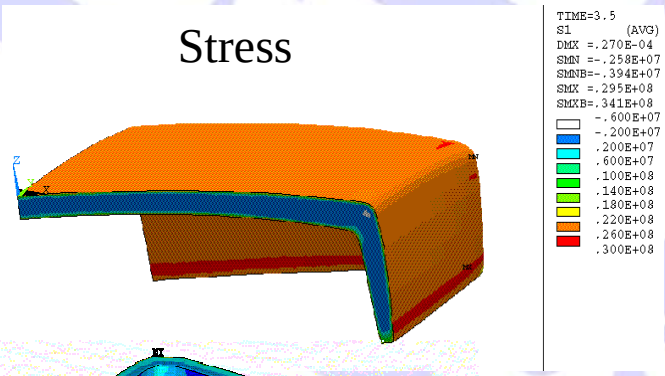
Thermo-mechanical analysis for process optimization

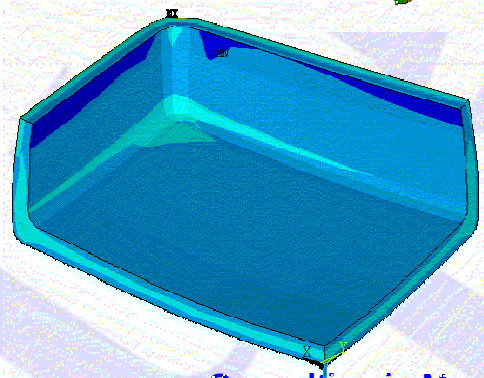
1/4 model

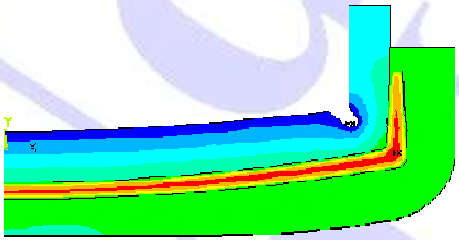
Temperature



Stress







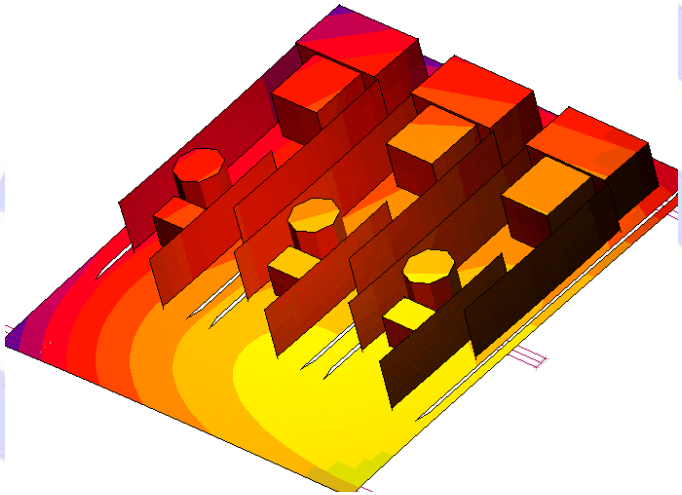
Project description:

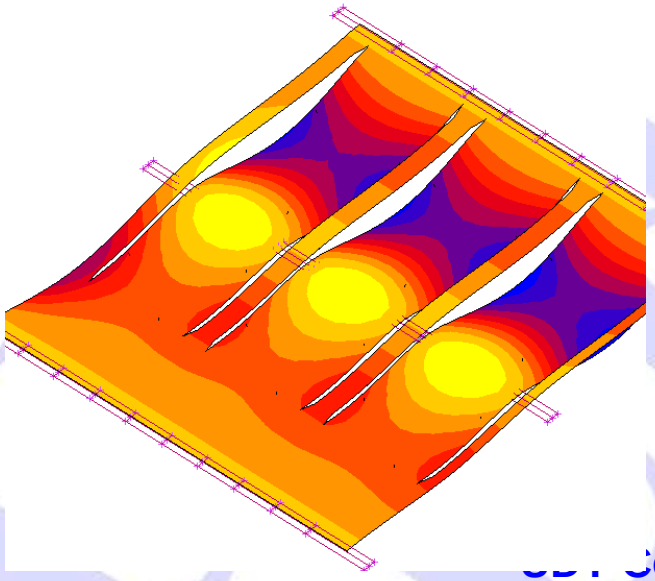
- Object passes through furnace while coating is applied.
- Stress develops which can cause cracks in the object.

Project deliverable:

- Optimization of temperature profile of furnace such that cracks are avoided AND energy consumption is minimal.
- High surface compression stress
- Control charts delivered in Excel format which can be used easily by factory personnel.

Manufacturing process optimization





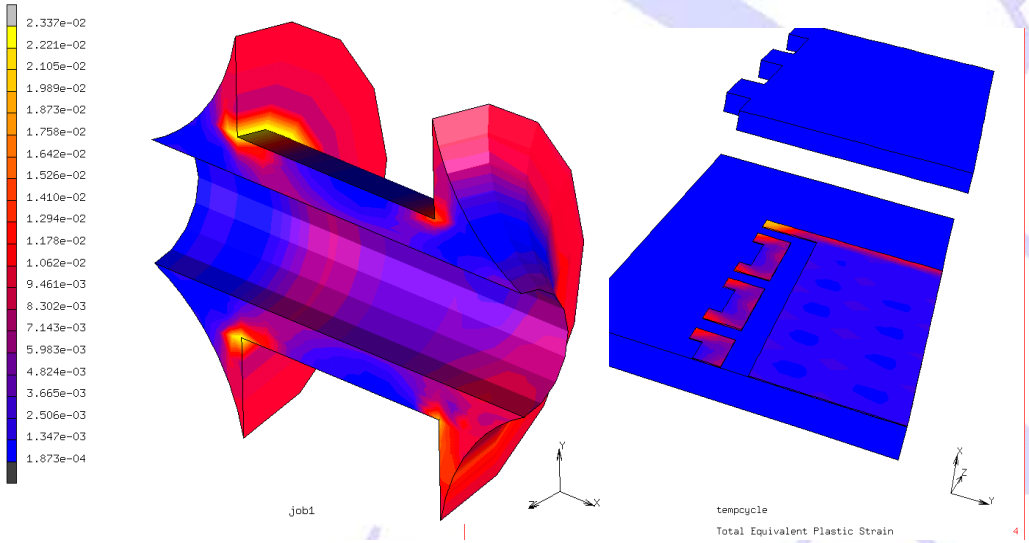
Project description:

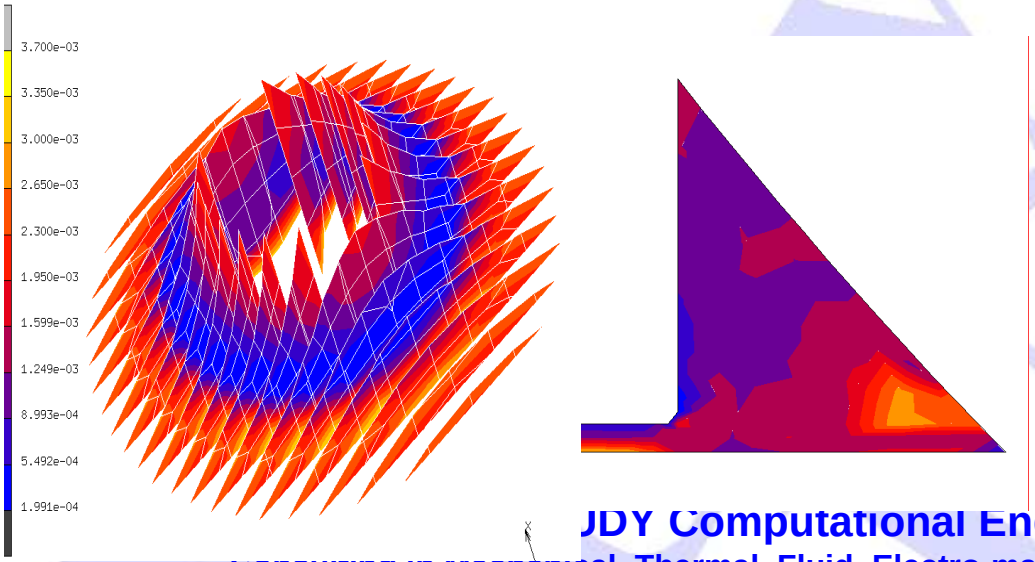
- Printed board with loose components passes through wave soldering equipment and is not wetted at some regions.
- Reduction of vibration level if in use.

Project deliverables:

- Thermal behavior.
- Modal analysis.

Thermal low cycling fatigue





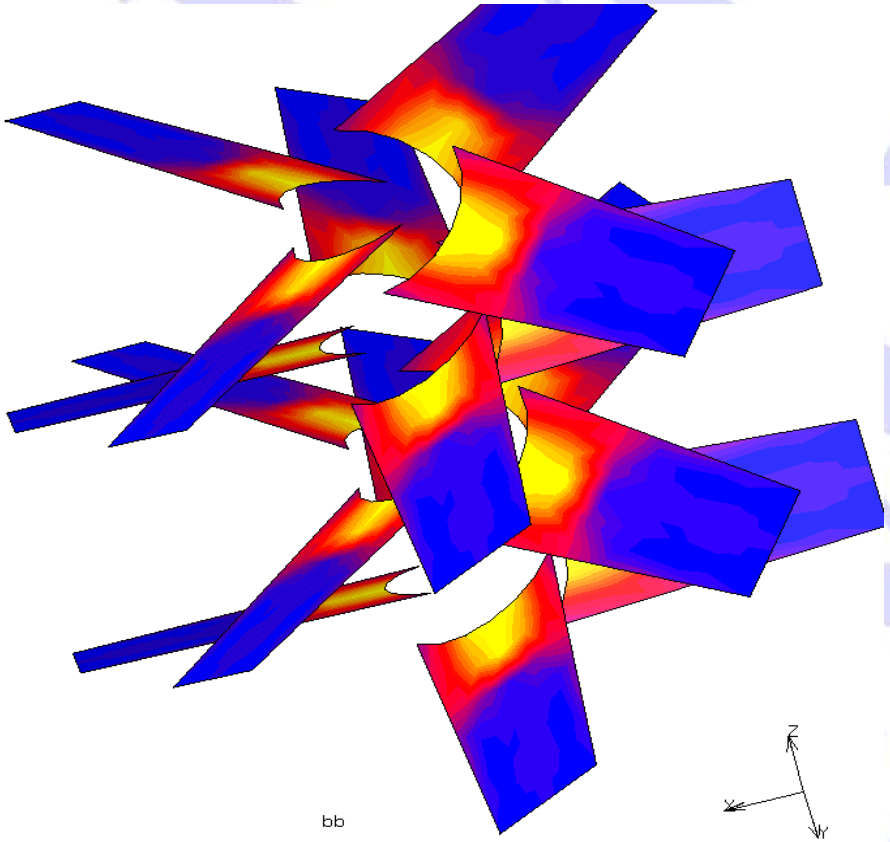
Project description:

- Metal piece or layer is subjected to external load combined with temperature cycling.
- Because of differences in thermal expansion coefficients, plastic straining causes fatigue and premature failing of service.
- Lifetime calculated according to Coffin-Manson relation.

Project deliverables:

- Geometry and material choice optimized as to reach required service lifetime.
- Inspection of development of damage inside the material.

Mixer thermo-mechanical analysis



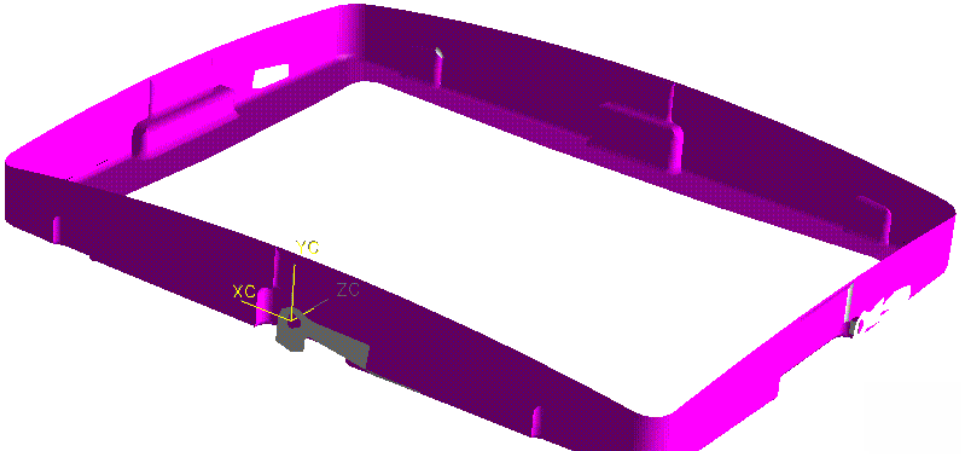
Project description:

- Mixer is made of steel core with platinum skin.
- Operates at 1000+ deg C in highly viscous fluid
- Small cracks develop in skin giving rise to blade breakage.

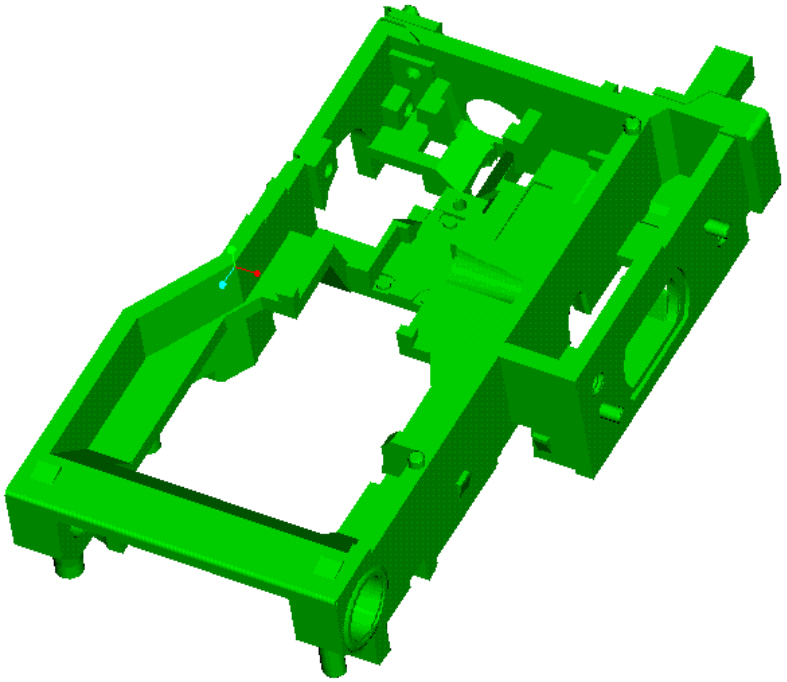
Project deliverables:

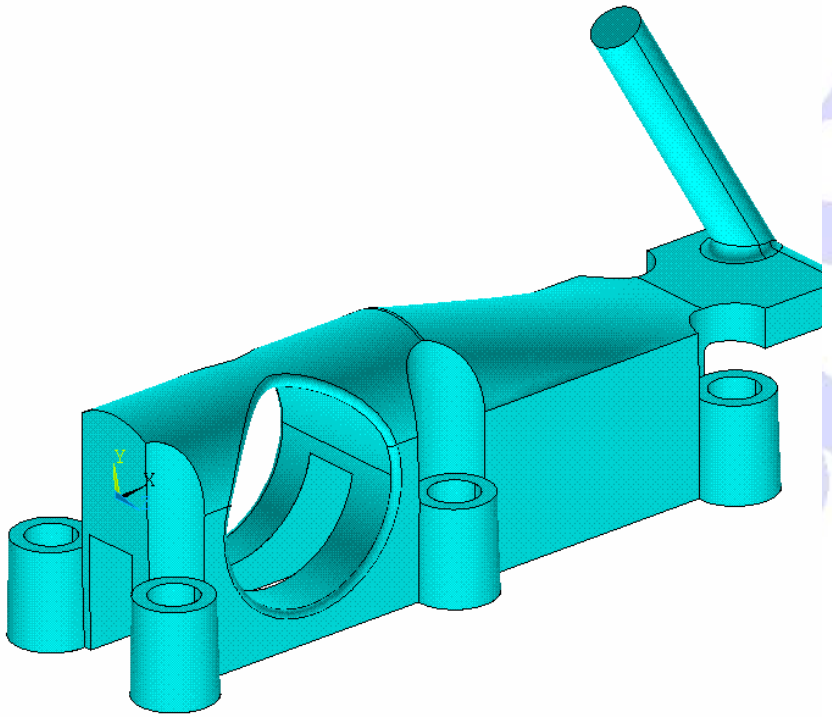
- Viscous load implemented via user subroutine
- Thickness distribution of platinum skin optimized (thicker at central hub region).
- Lower platinum weight combined with higher lifetime.

CAD interfacing

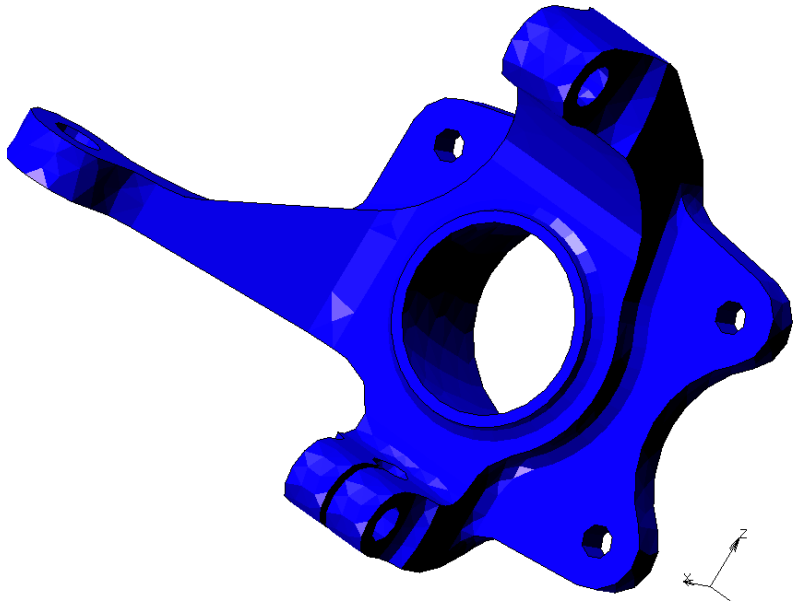


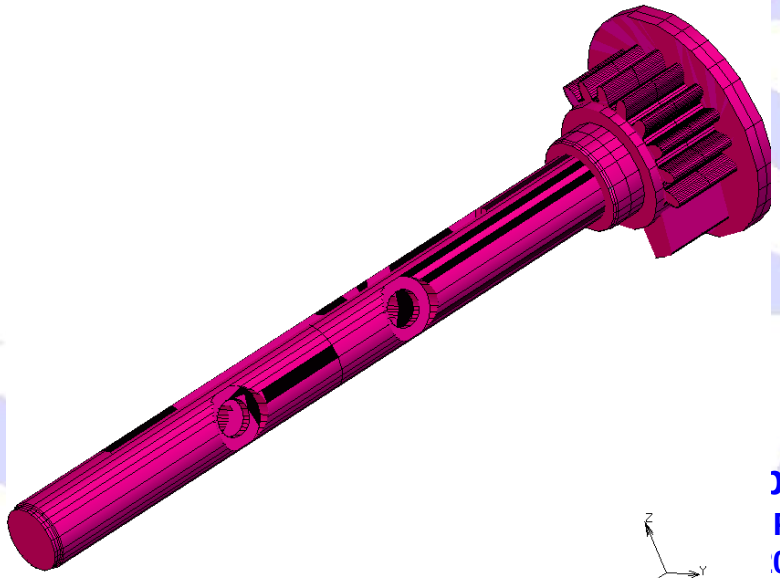
Possibility to interface with most CAD programs directly or via industry standards



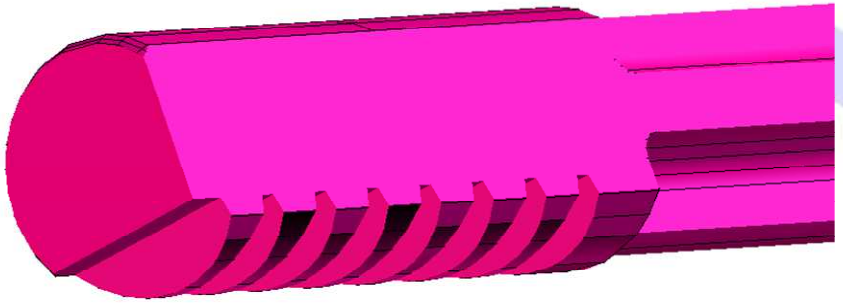


CAD interfacing

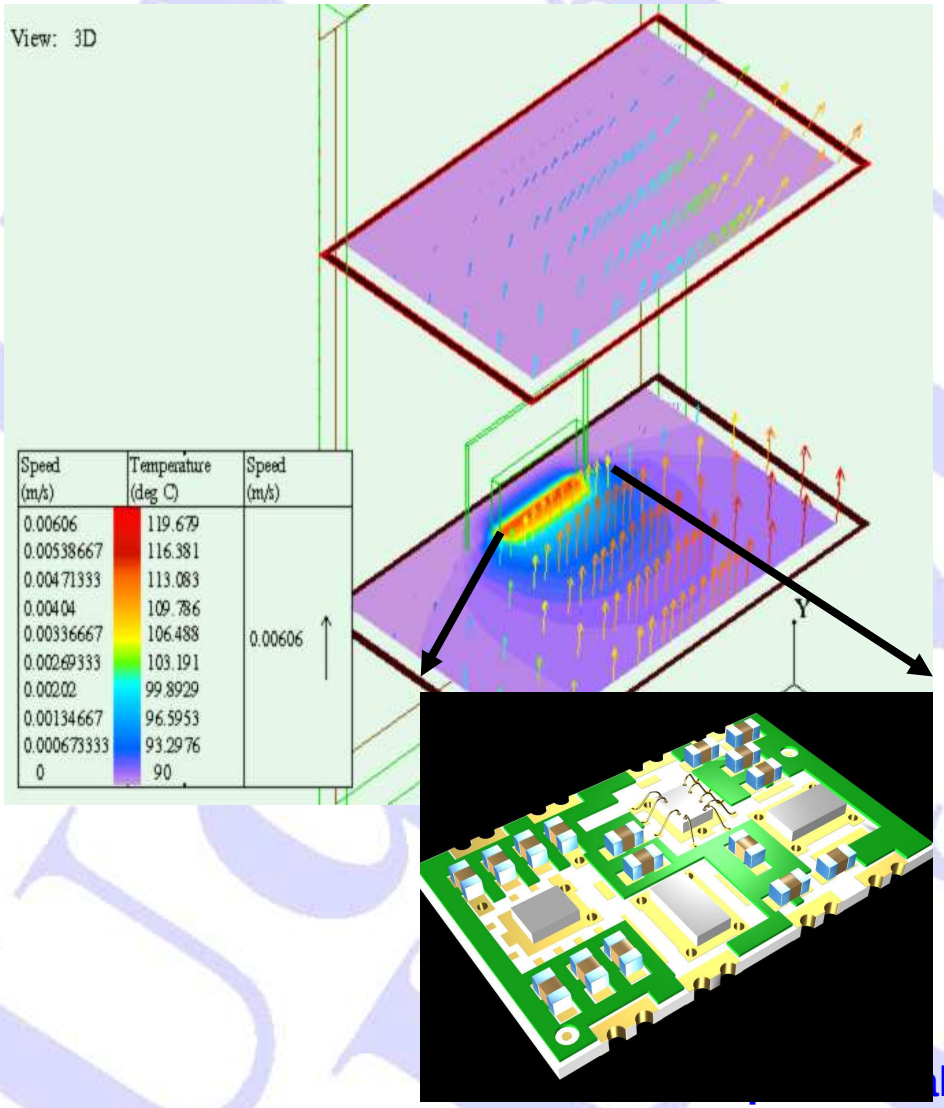




Possibility to interface with most CAD programs directly or via industry standards



Cooling of electronics



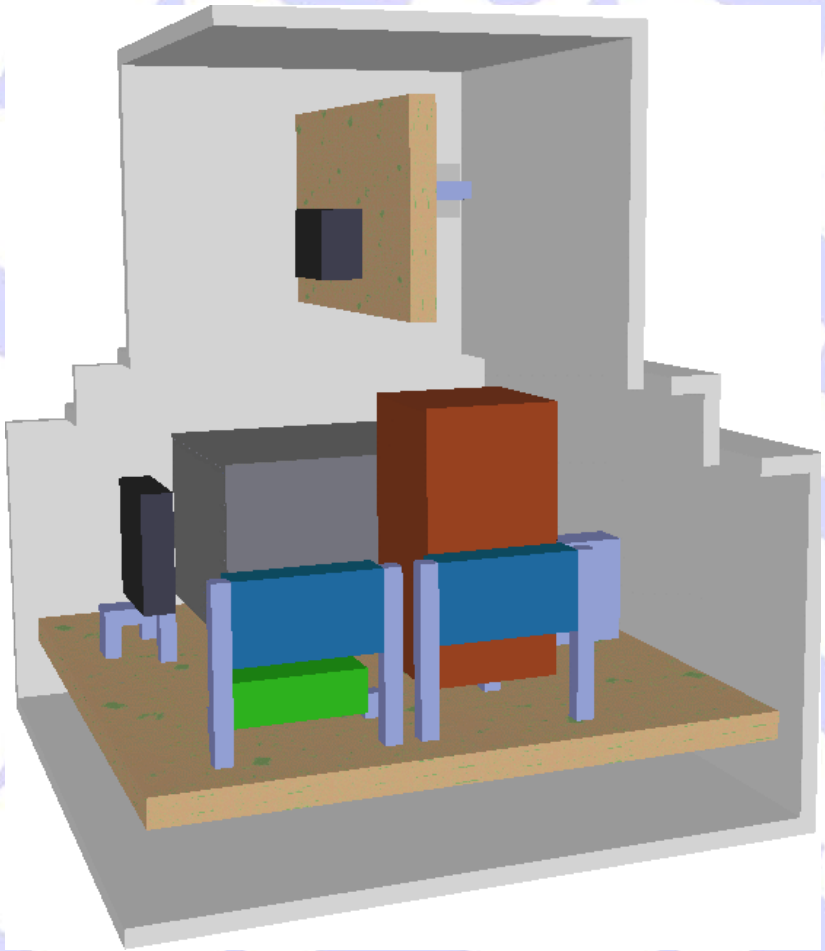
Project description:

- RF amplifier in mobile telephone dissipates power which causes hot air flow to start (chimney effect), which affects performance of neighboring components.

Project deliverables:

- The temperature, the direction and speed of airflow is calculated as function of different operating conditions.
- The location is optimized as to keep the temperature of adjacent components below critical limit.

Fluid structure interaction



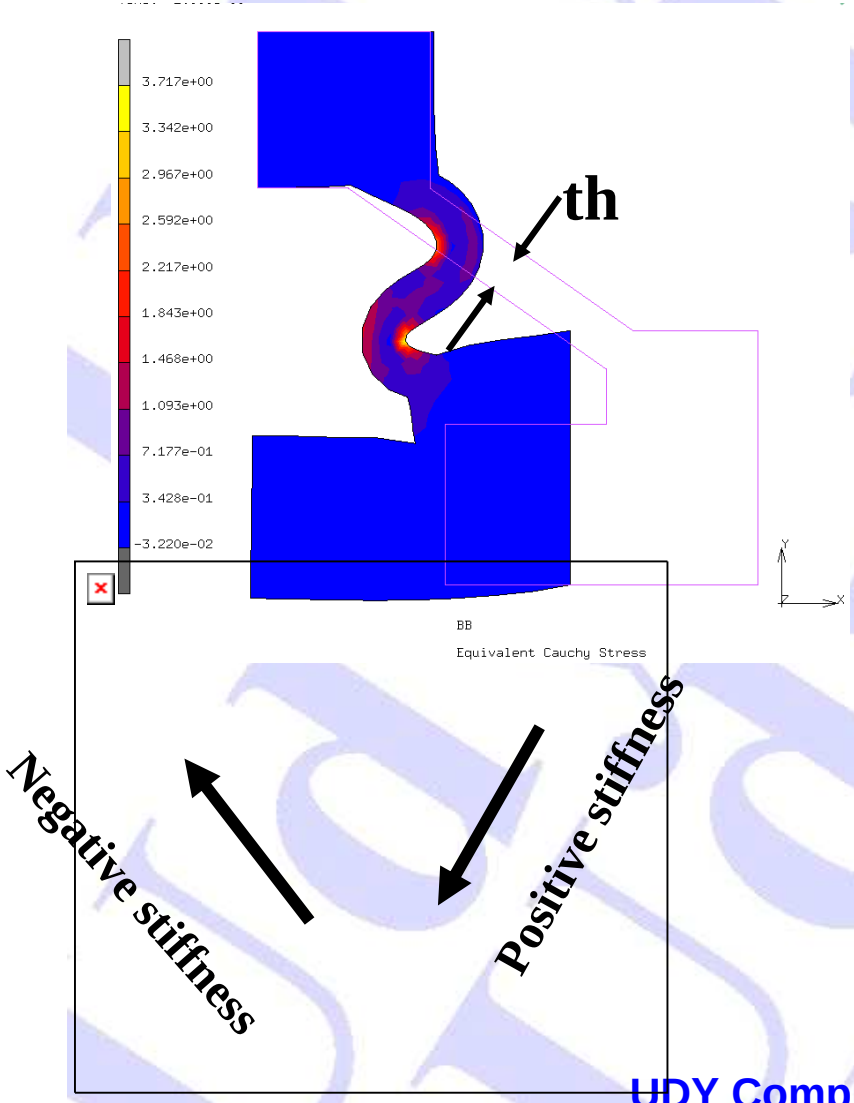
Project description:

- Forced air flows through ducts and cabinet.
- Causes components and panels to vibrate.
- Noise emission.

Project deliverables:

- Air flow (also turbulent) is calculated in CFD.
- Alternating pressure is imported in FEM and vibration on structure is determined.
- Can be transient or random vibration.

Snap through analysis of rubber knob



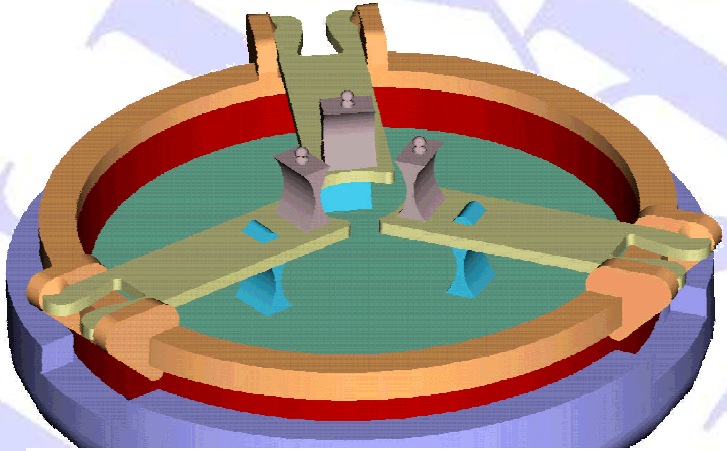
Project description:

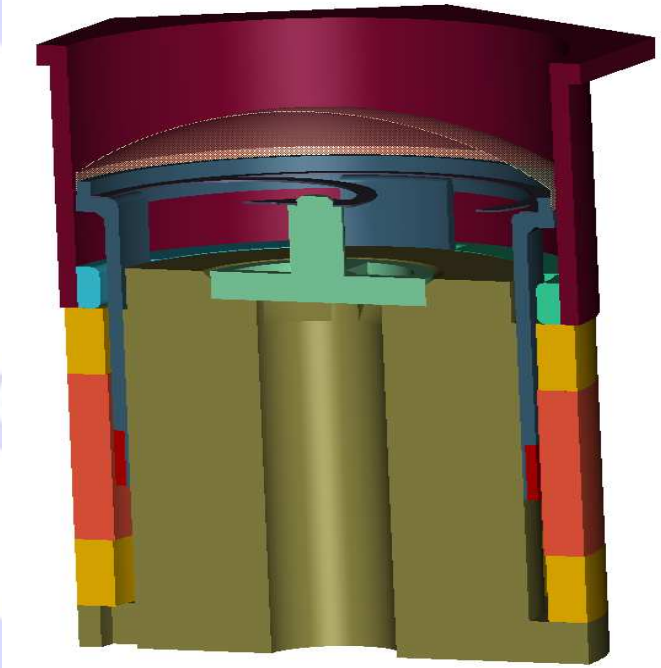
- Rubber knob for keyboard application.
- Knob material is silicone rubber.
- Must give tactile feedback (snap feeling) to operator.

Project deliverable:

- Large displacement pre- and post-buckling analysis with incompressible material.
- Ogden material model implemented.
- Rubber material Shore hardness specified.
- Thickness th determined to obtain wanted force at which negative stiffness starts.
- Cauchy (true) stress below certain level to guarantee lifetime of 10^6 cycles.

Kinematics of actuator





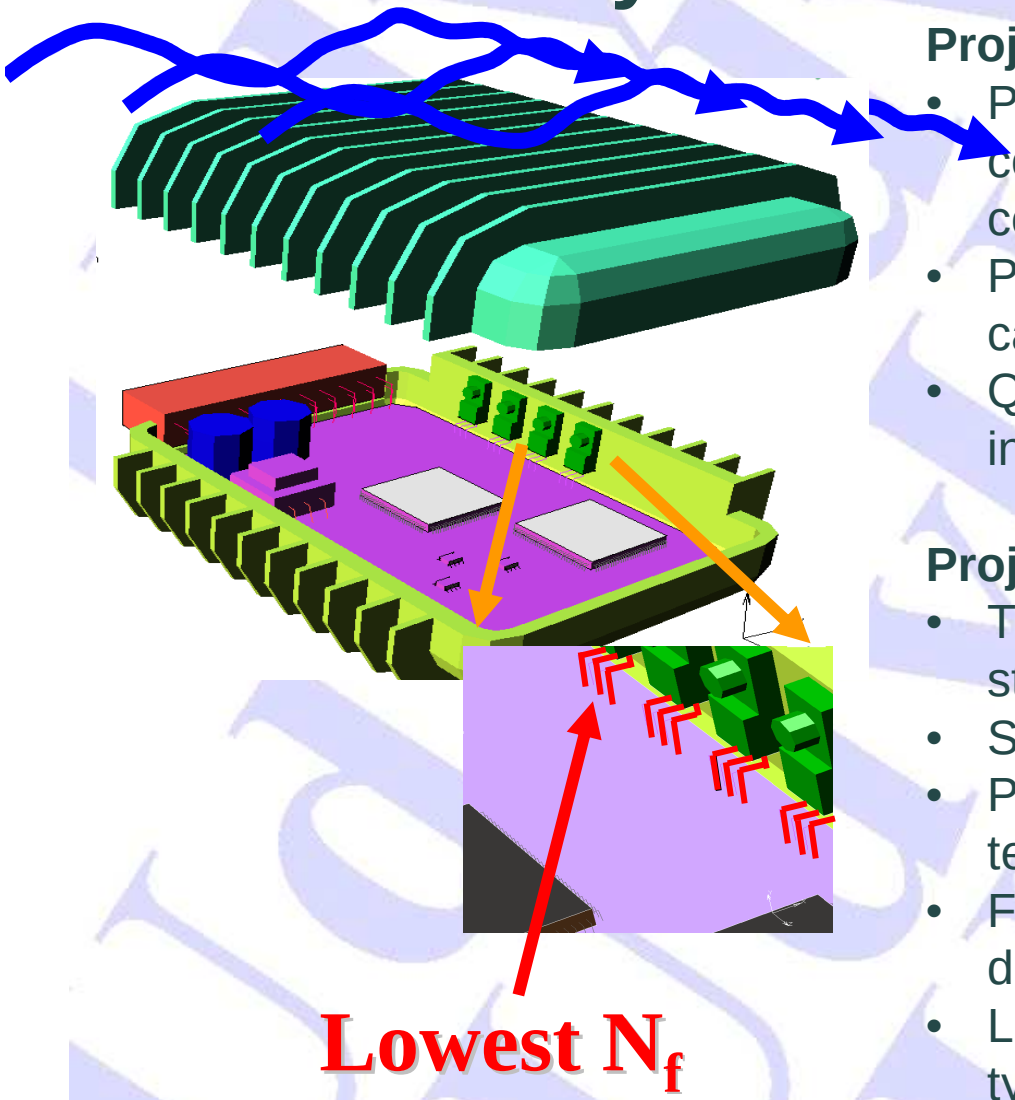
Project description:

- Moving mechanisms (actuator), driven electro-dynamically.
- Imported from IGES.
- Fully 3D.

Project deliverables:

- Analysis in frequency and time domain.
- Magnetic field imported from other software. This field can vary as function of coil position.
- Friction between moving and fixed surfaces included.
- Sound radiation to half infinite space calculated.

Reliability of PCB interconnections



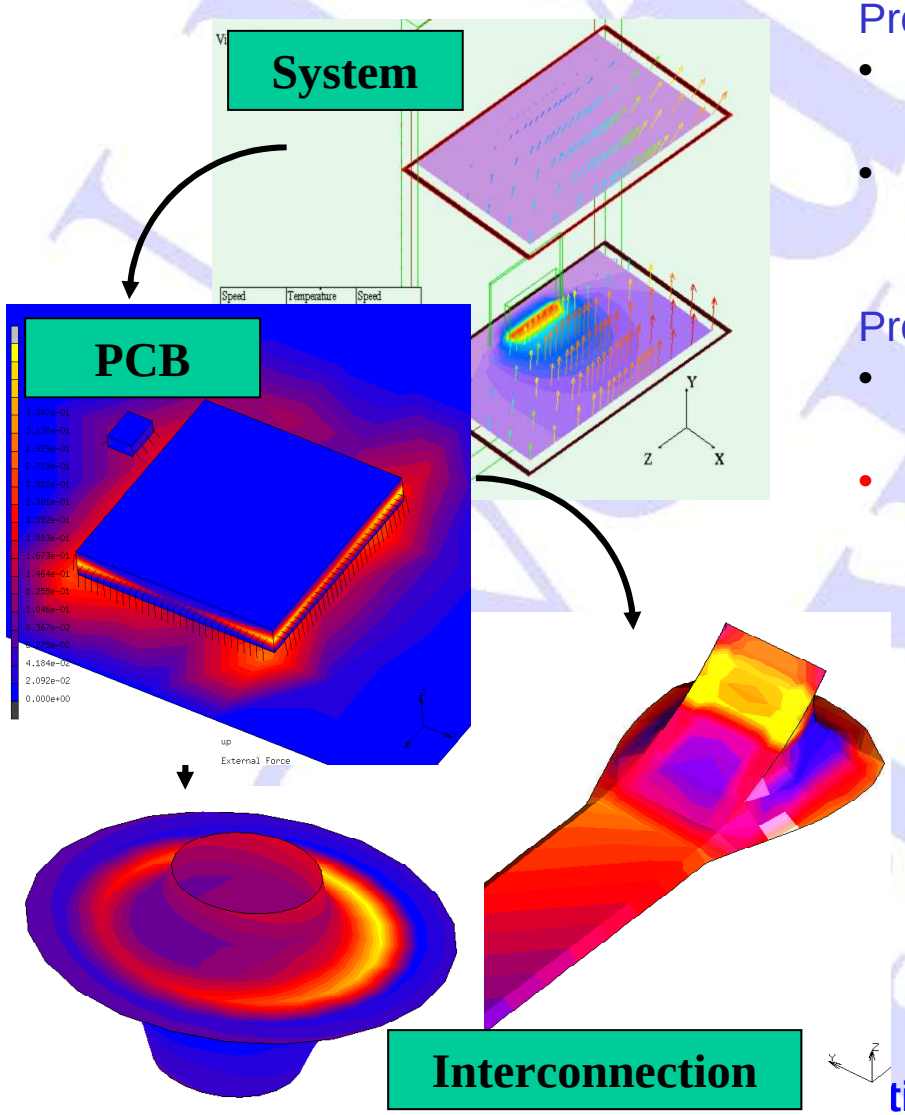
Project description:

- Printed circuit board (PCB) is subjected to combined stressors such as environmental cooling and vibration
- PCB is mounted in die cast aluminum casing which acts also as heat sink.
- Question: what is lifetime of weakest interconnection?

Project deliverables:

- Temperature field from CFD imported in structural model
- Solder temp. dep. properties and creep.
- PCB orthotropic material properties, temperature dependent.
- FET's screwed or spring loaded (see detail).
- Lifetime determined per interconnection type.

Printed circuit board (PCB) lifetime analysis



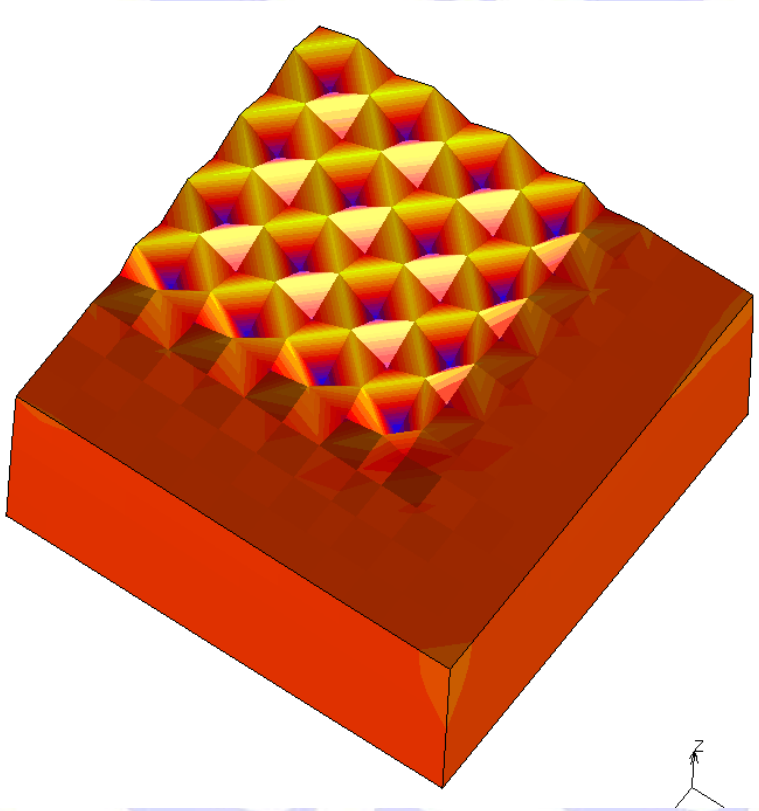
Project description:

- PCB is subjected to power and ambient temperature cycling, shock and vibration.
- Causes fatigue (plasticity, creep) in solder interconnections.

Project deliverables:

- Fatigue lifetime of complete PCB under realistic operating conditions is determined.
- Three "tier" sub-modeling approach:
  - System: air flow (forced/natural) in cabinet gives steady state or transient temperature field.
  - PCB: this field, together with the mechanical boundary conditions and loads (e.g. shock) are applied to the PCB, from which temperature and loads on individual solder joints are determined.
  - Interconnection: finally, fatigue lifetime of interconnection is calculated (from extensive geometric and material library, including Pb-free solders).

Precision die and mould design



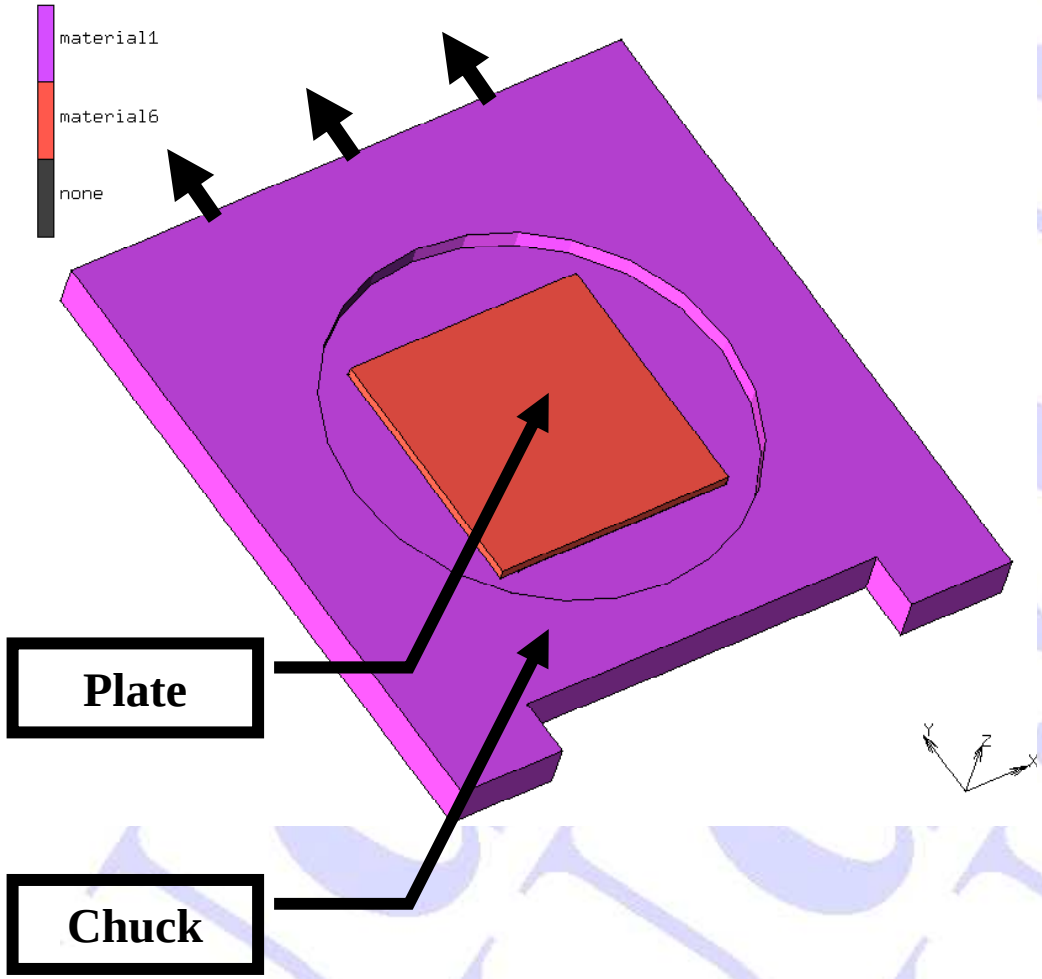
Project description:

- Precision pattern to be pressed in substrate shows spring back, hence inaccurate.

Project deliverables:

- Die and substrate modeled
- Pressing process modeled
- Resulting pattern compared with wanted pattern
- Difference applied as correction on die as to compensate spring back.
- Pattern as designed obtained exactly in substrate.

Dynamic stick-slip contact analysis



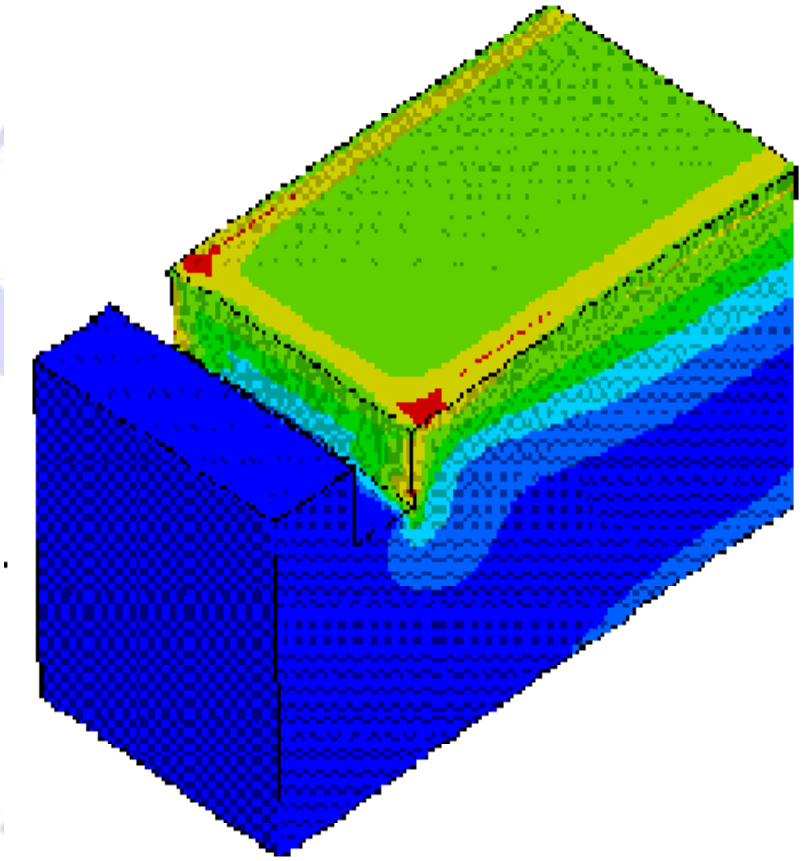
Project description:

- Square plate rests freely on sledge (chuck).
- Sledge is accelerated and decelerated in time.
- Plate is not allowed to slide relative to sledge. What is maximum allowable acceleration?

Project deliverables:

- Advanced dynamic deformable contact body analysis in the time domain, including stick-slip friction.

Stress concentration analysis



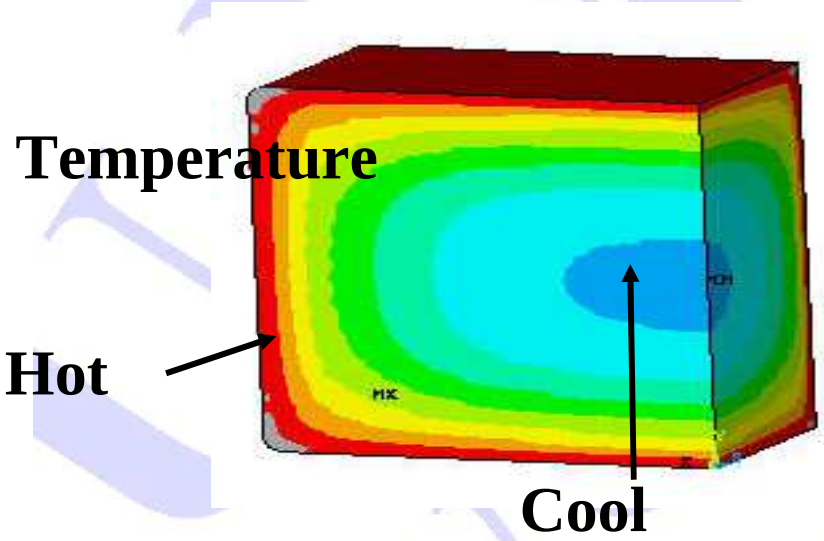
Project description:

- Dissimilar materials bonded or jointed together develop stress if temperature changes due to CTE (coefficient of thermal expansion) mismatch.
- Stress is concentrated at edges.
- Difficult to interpret due to singularity.
- Question is: how much is it really?

Project deliverables:

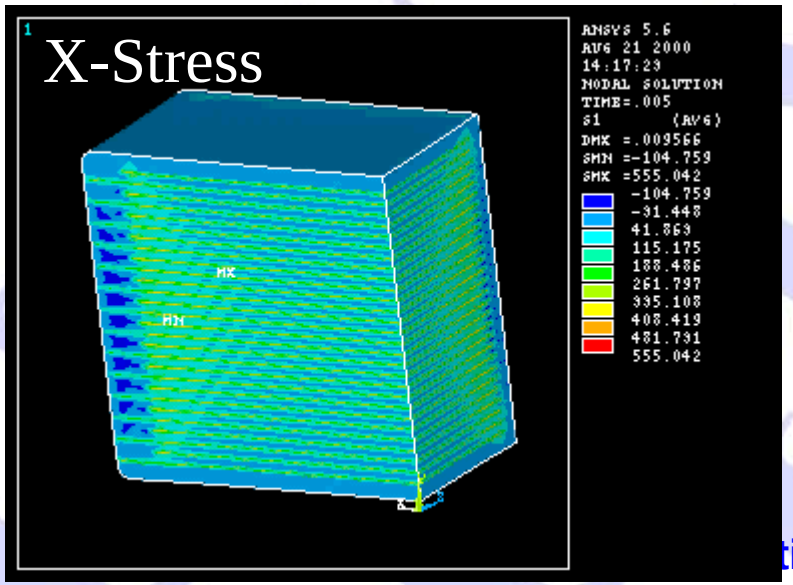
- Stress concentration factors from book of R.E. Peterson (analytical) combined with extrapolated FEM stress calculation results in adequate handling of stress singularities.

Combined thermal /stress analysis



Project description:

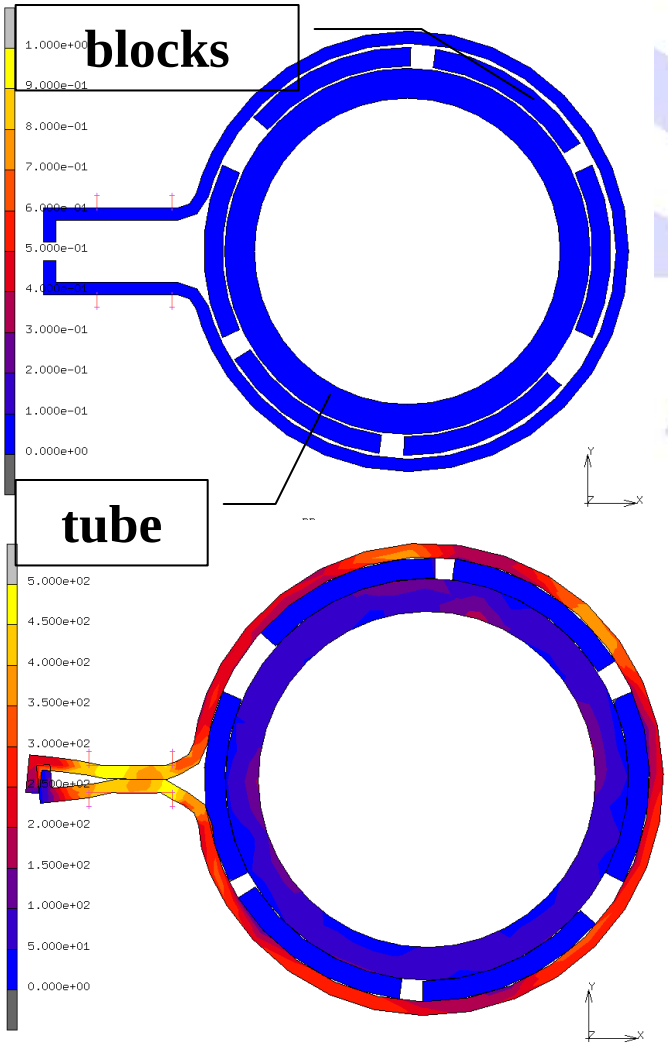
- Block with interior layered structure is subjected to external transient (time dependent) heating process causing stress to occur in layers due to dissimilar CTE (coefficient of thermal expansion).



Project deliverables:

- At each time and each position within the structure, the temperature and stress is evaluated.
- Inter-laminar stress between layers determined.
- Parameter variation.

Clamping band design



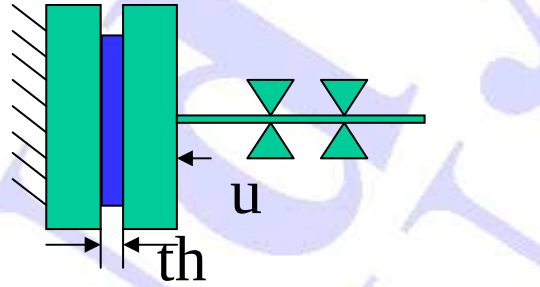
Project description:

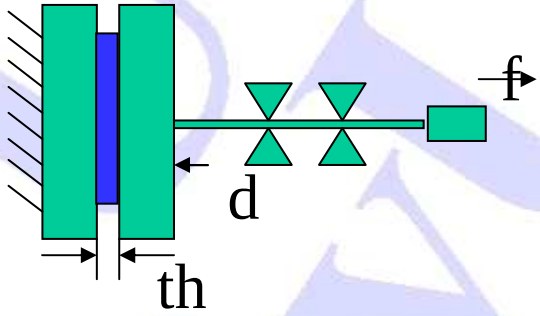
- Steel band must be clamped around glass pipe with blocks between and is subjected to alternating temperature.
- Question: design clamp such that stress in tube is evenly distributed at each temperature and no glass breaking occurs.

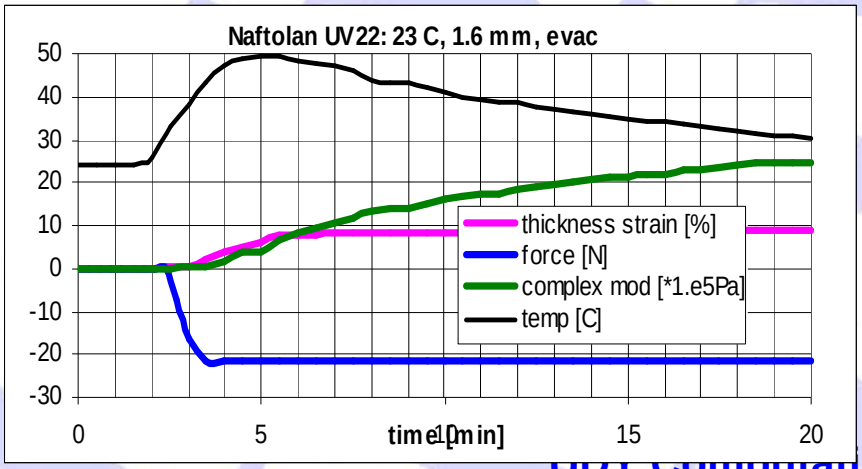
Project deliverable:

- Clamping simulated using contact algorithm
- Temperature varied
- Novel and patented design is such that stress in pipe is quasi-uniform at each working temperature, making adequate use of plasticity and hardening effect of the steel material.

Modeling of curing behavior of glue







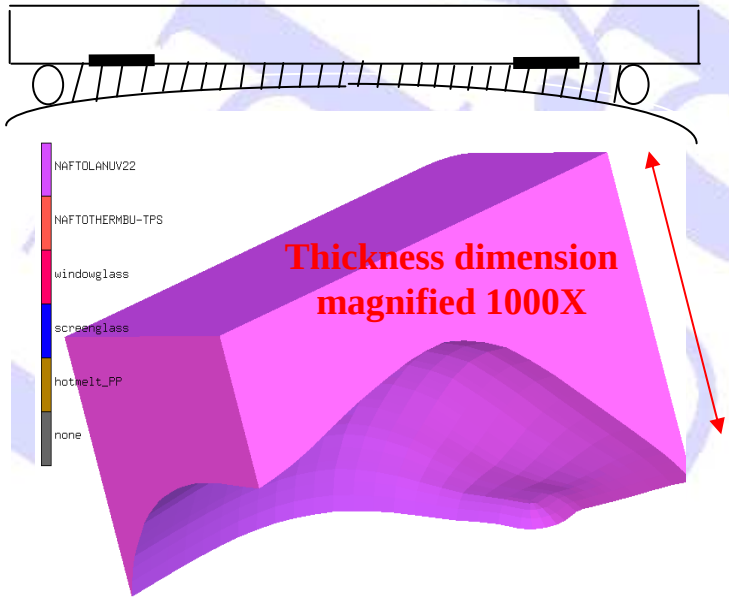
Project description:

- The curing of glue or in general plastics can cause considerable deformations and internal stress.
- Determine curing parameters and general method for FEA analysis of curing systems.

Project deliverables:

- Free and fixed plate experiment to determine strain and stress build-up (plus additional temperature measurement for reaction heat generation).
- Experiments reproduced in FEM model and appropriate material model developed.
- Adoption of global “pilot-curing” parameter, governing all other material parameters

Lamination of resin



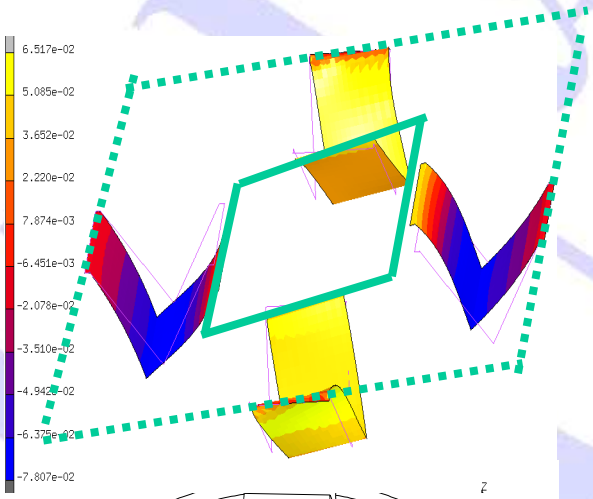
Project description:

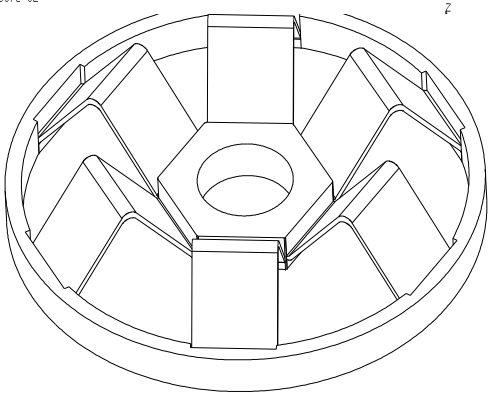
- Flat plate and rigid substrate are connected to each other by pouring liquid lamination resin between them.
- Curing shrink of resin causes plate to deform.
- In some cases, resin delaminates from plate.

Project deliverables:

- Measured substrate geometry imported.
- Curing of lamination resin simulated according to generalized “pilot-curing” parameter.
- Deformation mechanism simulated.
- Criterion for delamination established (Rankine stress).
- Guidelines and design rules to prevent delamination.

Large stroke spring (from FEM to CAD)





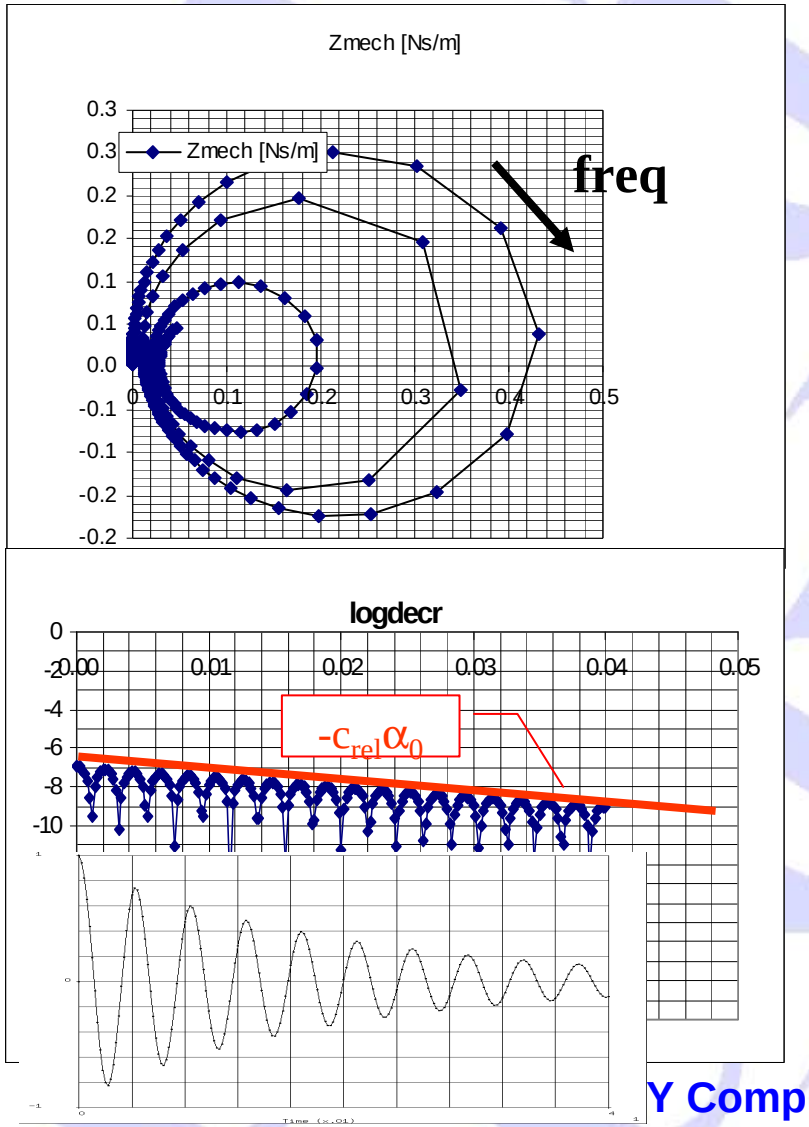
Project description:

- Suspension consists of leaf springs.
- Stiffness must be low and linear in vertical direction over very large stroke. In other directions stiffness must be large, especially against rotation.
- Number of cycles to fatigue > 10^9

Project deliverables:

- Linear stiffness characteristic over large stroke realized by tapered (patented) thickness.
- Rotational stiffness very large. Rotation modeled with rigid ties to save computation time.
- Material choice as to fulfil high cycle fatigue requirement.
- Over 100 model variations done to find the wanted characteristics (impossible experimentally).
- First tool = production tool.

Advanced material characterization



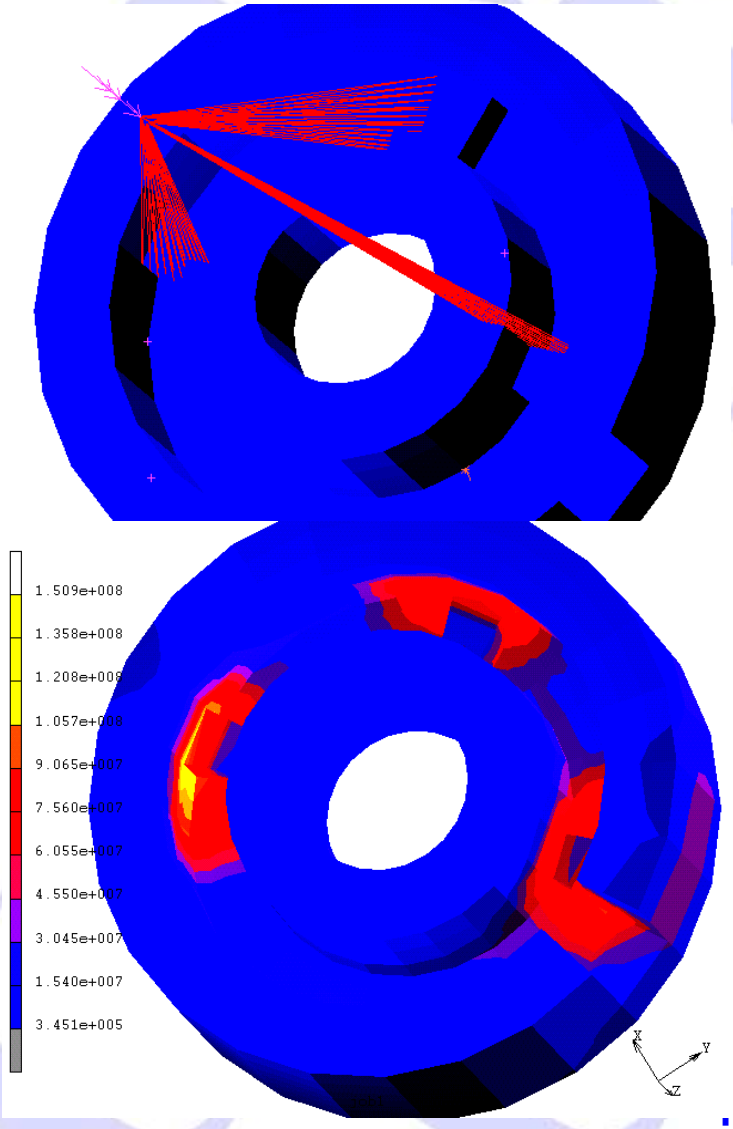
Project description:

- The knowledge of the exact material parameters is one of the key factors for reliable virtual prototyping.
- From many materials, the data are not available from textbook, nor even from the suppliers.

Project deliverables:

- We have a wide network of institutions for the appropriate measurement equipment.
- We developed own measurement equipment for specialized dynamical measurements based on mechanical impedance. Curve fitting in Nyquist space allows accurate determination of modulus and damping as function of frequency and temperature. Small samples can be used.
- Shown is compressed PUR foam.

Pulley with coil spring



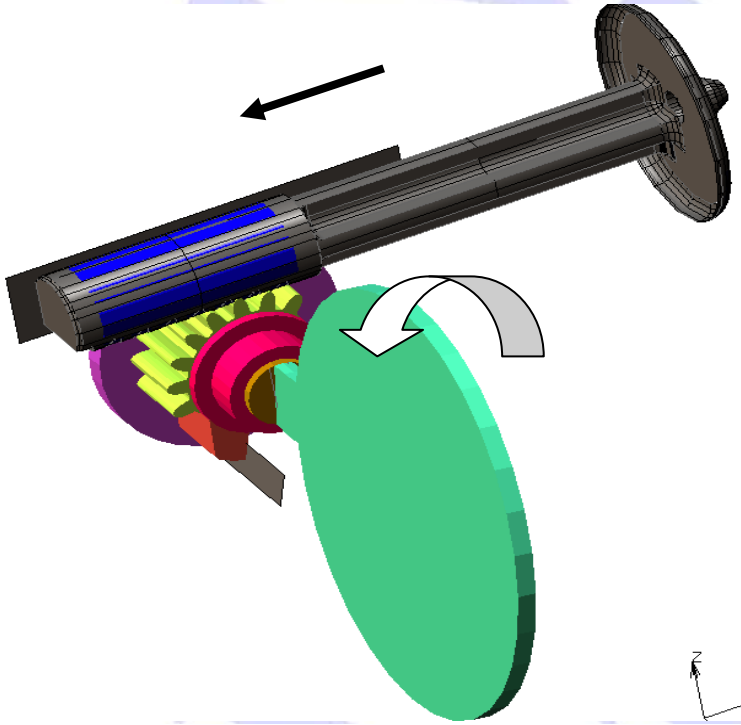
Project description:

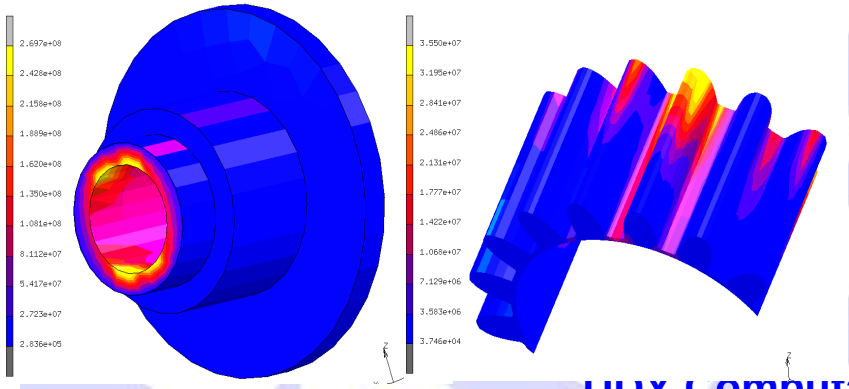
- Rotating plastic pulley is tensioned by coil spring which grips pulley at protruding radial ribs.
- Spring is suddenly unwinded, pulley hits stop.
- Ribs break.

Project deliverables:

- 3D model imported from IGES.
- Coil spring modeled by discrete rotating spring.
- Rotation simulated by tyings.
- Stresses in ribs calculated.
- New ribs designed to decrease stress to 30% of allowed maximum.

Gear analysis





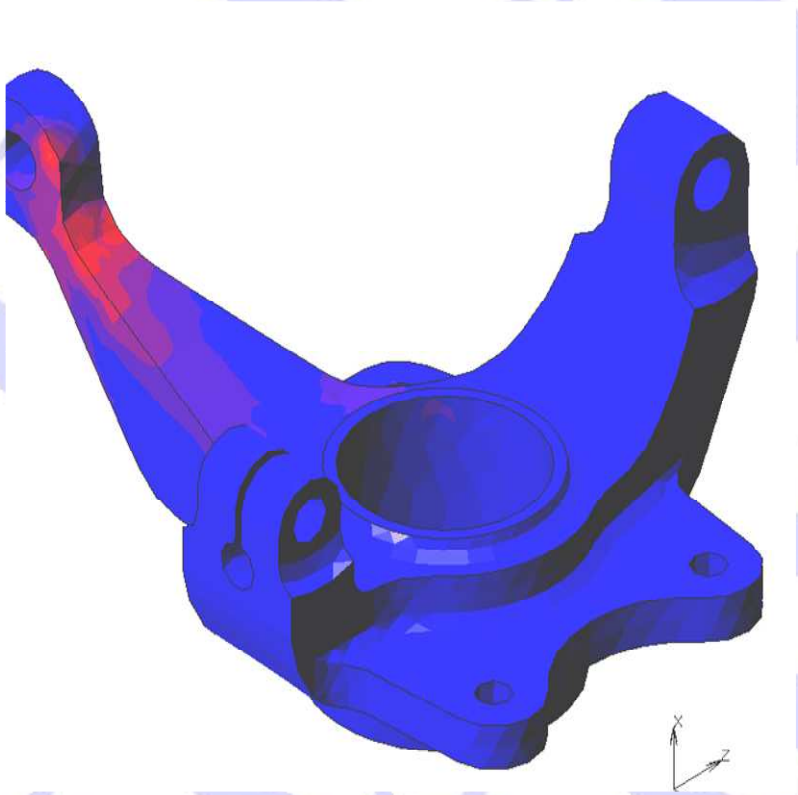
Project description:

- Fully 3D rack-and-pinion mechanism, imported and meshed from CAD.
- Time domain dynamic impact (actual impact time, no estimation).
- Linear and rotating parts.
- Pre-stressed central hole due to overmold.
- Multi-body deformable contact.
- Combined plastic/metal parts

Project deliverables:

- Impact force calculated a.f.o. time.
- Stresses in critical parts investigated.
- Proposals to minimize damage at shaft / overmold interface.

High Cycle Fatigue analysis



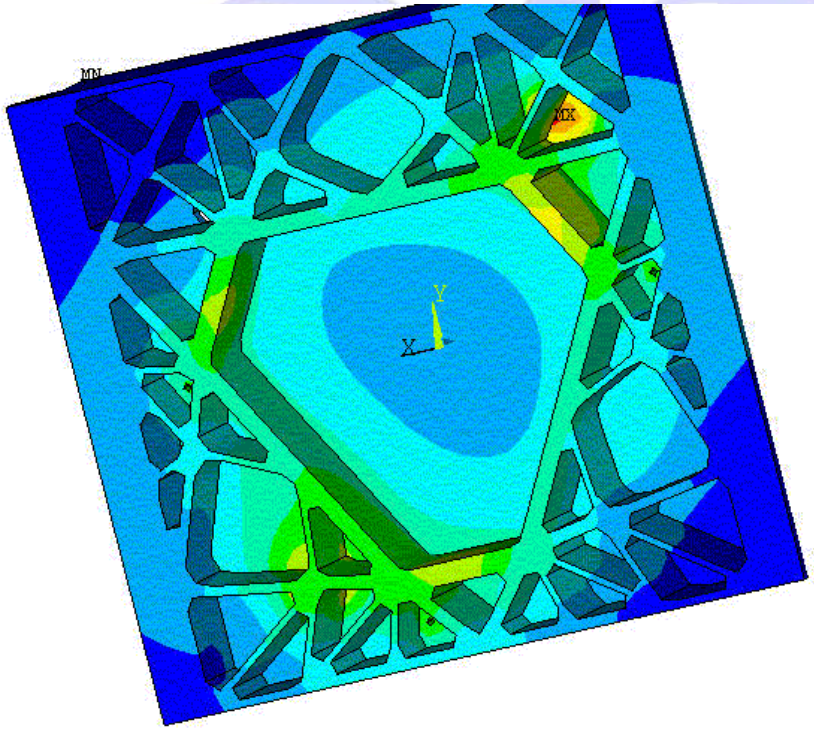
Project description:

- Automotive part with intricate geometry imported from CAD.
- Stress and vibration High Cycle Fatigue (HC) analysis required for measured load history input.

Project deliverables:

- Power Spectral Density (PSD) of vibration stress determined from given time history.
- Critical stress location identified and HC fatigue lifetime calculated.
- Redesign of part as to increase this lifetime for more reliable and safer product.

Thermal deformation of machined part



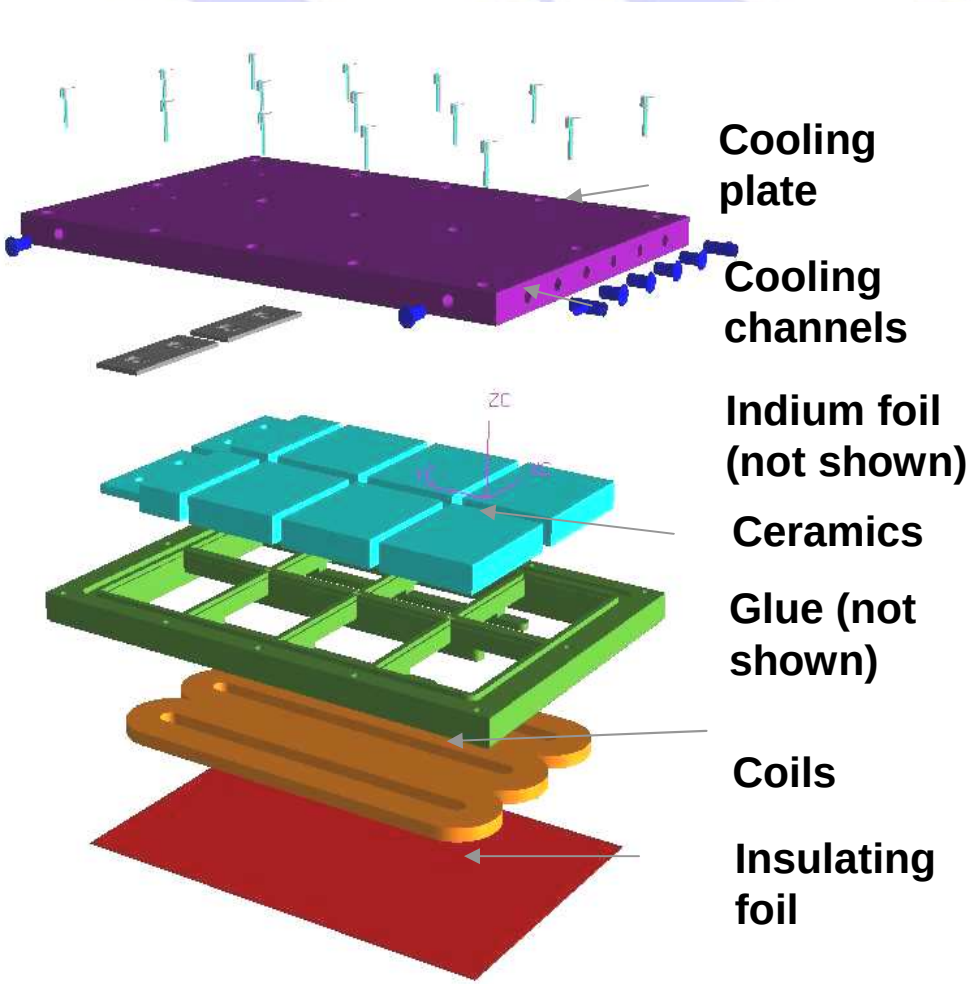
Project description:

- Machined part serves as carrier for electrical equipment which generates heat.
- Maximum allowed warp-age of carrier must be in the nanometers region

Project deliverables:

- Thermo-mechanical model built starting from initial CAD model.
- Thermal deformations calculated.
- Warp-age determined
- Reinforcing ribs at backside optimized as to minimize the warp-age at the required level.

Design of constant temperature plate



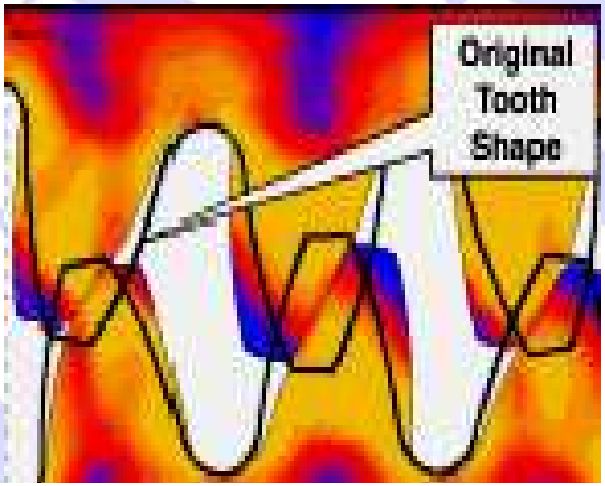
Project description:

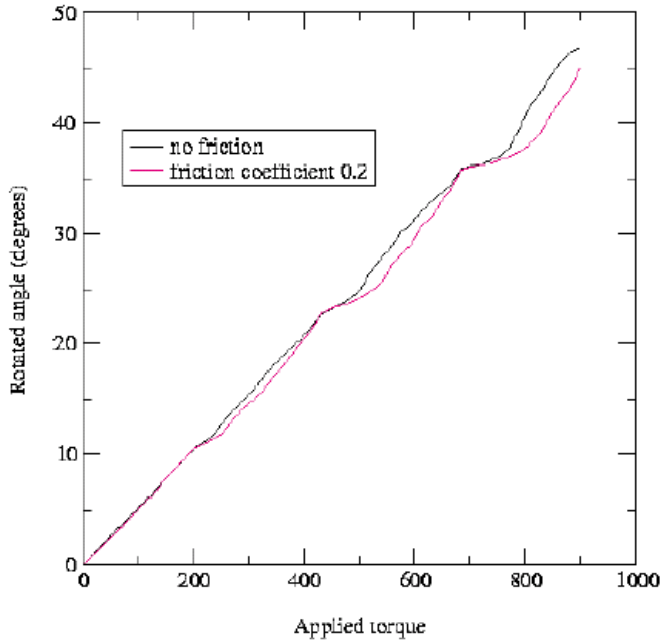
- Plate with cooling channels and heating coils must maintain constant temperature during operation with different environmental conditions.
- Plate stack consists of different exotic material including ceramics, glue and foils

Project deliverables:

- Complete stack modeled
- Resistive heating applied, taking care of changing resistivity at high temperature
- Environmental load histories applied
- Complete virtual prototyping

Gear Analysis





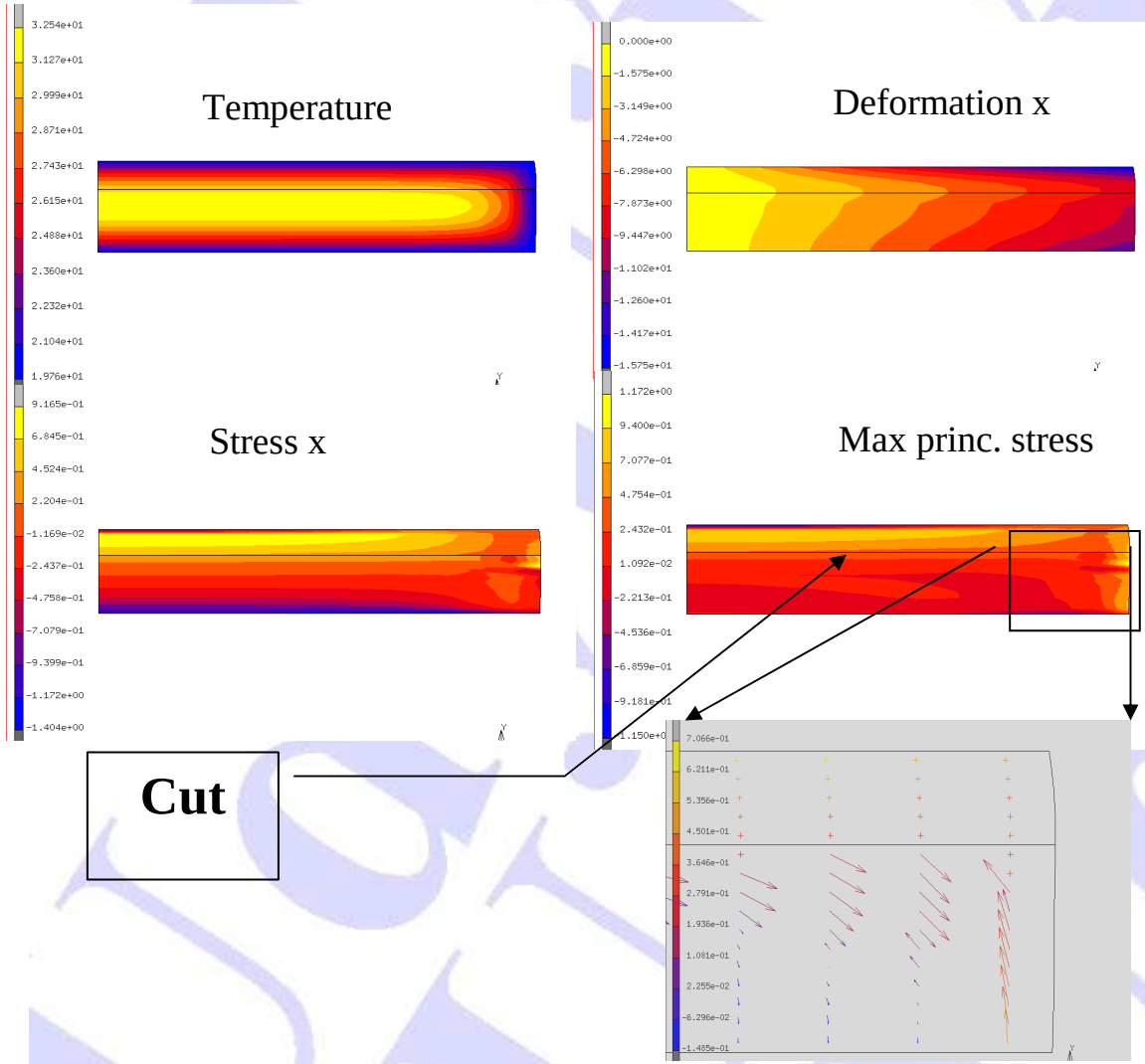
Project description:

- Determine gear deformation and stress during rotation with given load.
- Compare with undeformed but rotated shape for detailed analysis
- Influence of friction

Project deliverables:

- Deformation of involute profile under load calculated.
- Detailed rotating tooth stress and deformation analysis, including break-off.
- Influence of friction and lubrication.
- Transmission error and jitter from tooth flex reduced.

Continuous process simulation



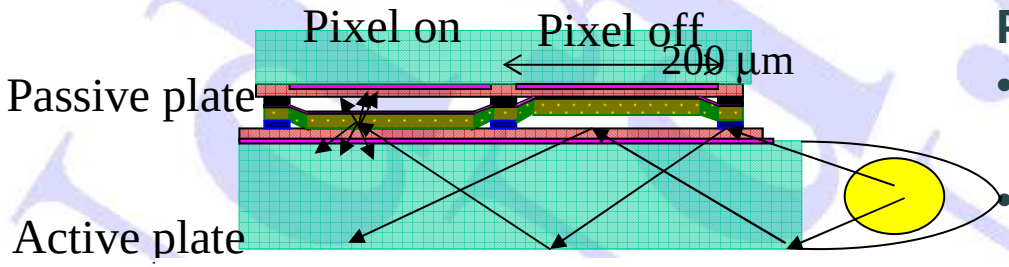
Project description:

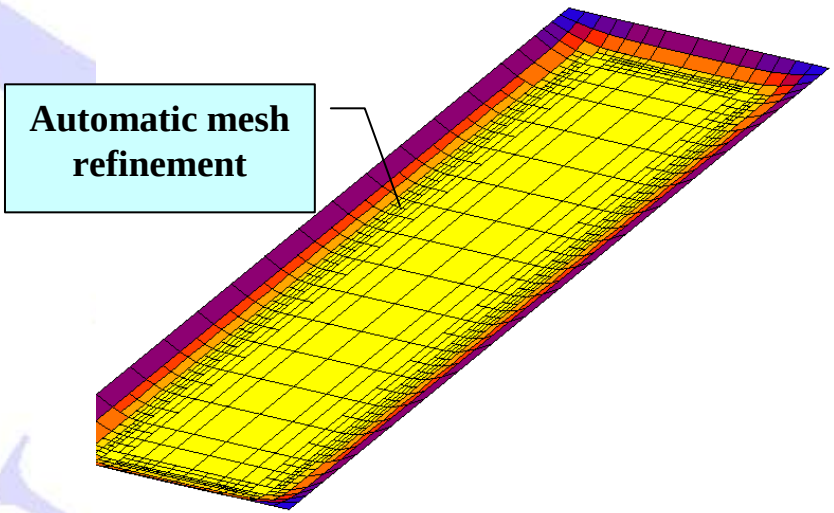
- Continuous slab passes trough oven in z-direction.
- During annealing, slab is cut, causing large stress redistribution and possible breakage.

Project deliverables:

- Complete off-line virtual prototyping of process.
- Process conditions optimized as to avoid breakage, resulting in considerable cost reduction on annual basis.

Electrostatic MEMS





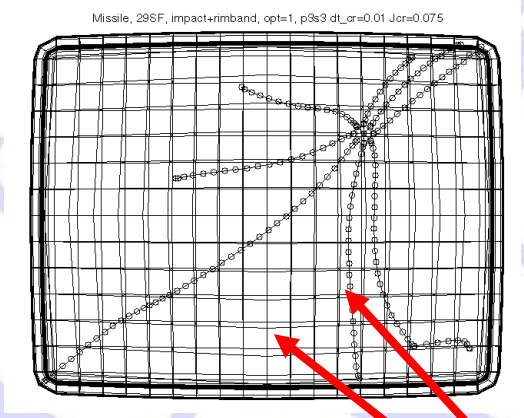
Project description:

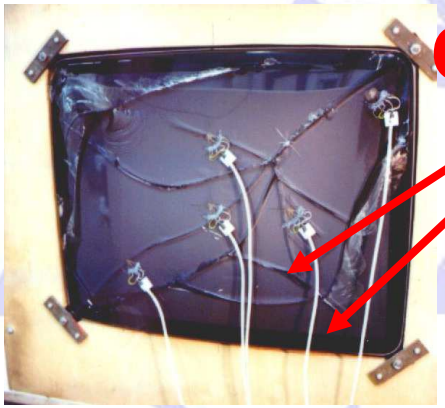
- Thin foil flips between 2 plates, via electrostatic force.
- Premature wear of foil due to repeated contact.

Project deliverables:

- Complete virtual prototype, including electrostatic actuation.
- All design variables can be changed to study influence.
- Methods devised to lower contact stress at “landing”.
- Mesh refinement at contact zone for enhanced accuracy.

Crack analysis





Cracks

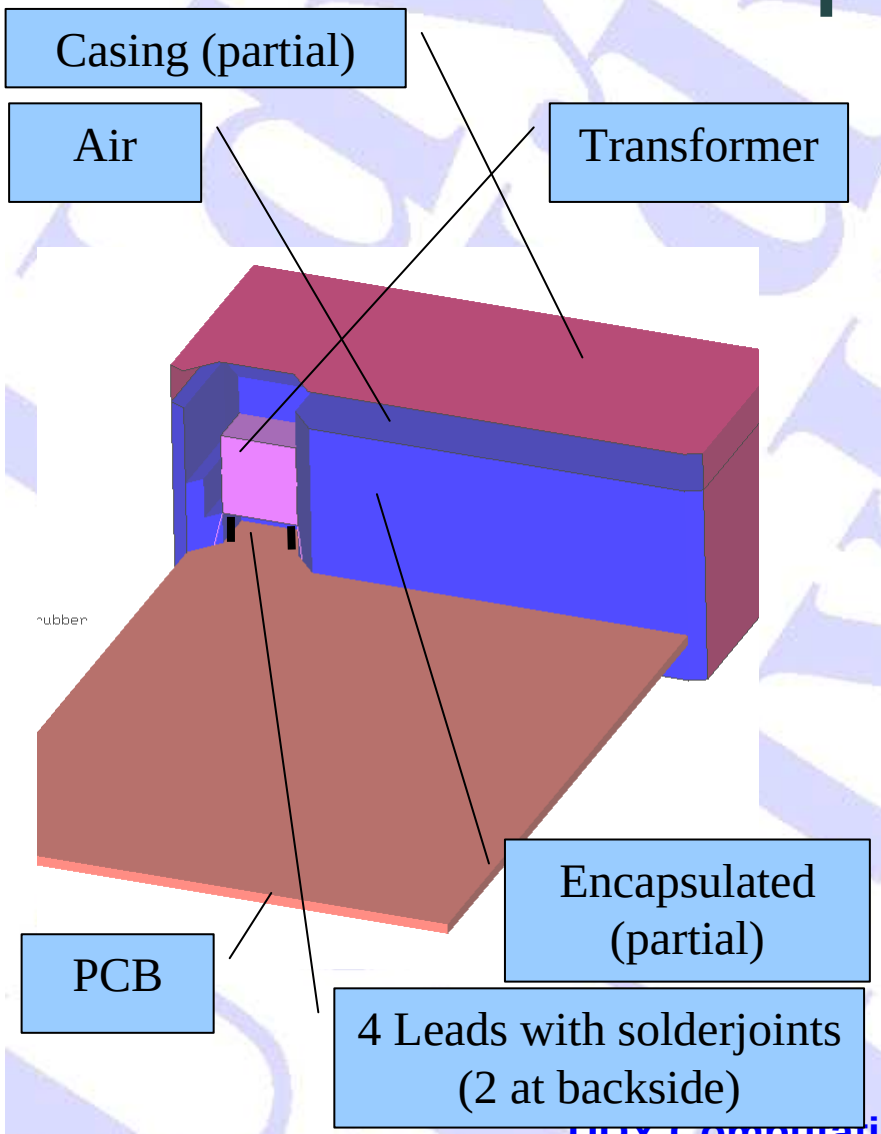
Project description:

- Ball impact on glass plate to test its resistance to cracking
- Influence of geometrical parameters and residual stress on crack behaviour

Project deliverables:

- 3D CAD model imported, meshed and residual stress imported
- Impact of ball simulated using Hertz contact
- Dynamic stress distribution calculated a.f.o. time
- Energy release rate calculated at impact point
- Compared with experiments.

Encapsulation



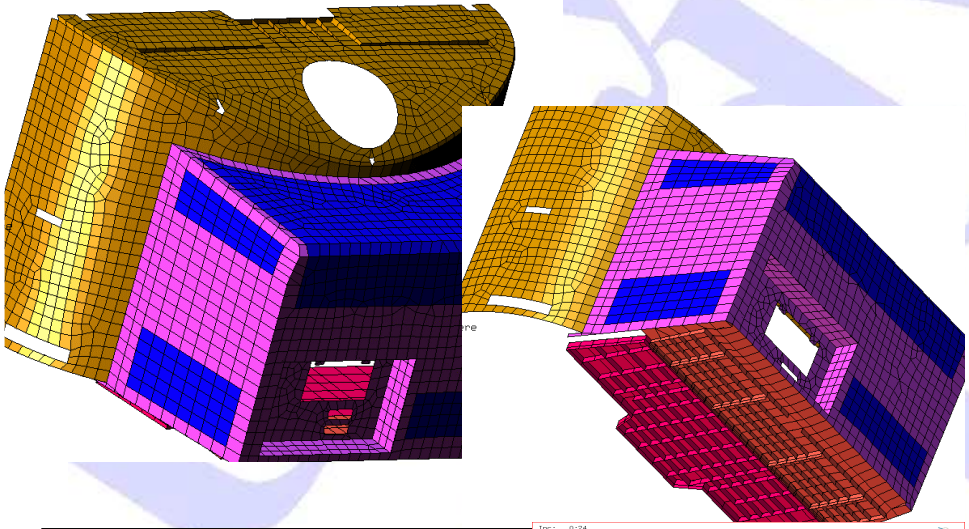
Project description:

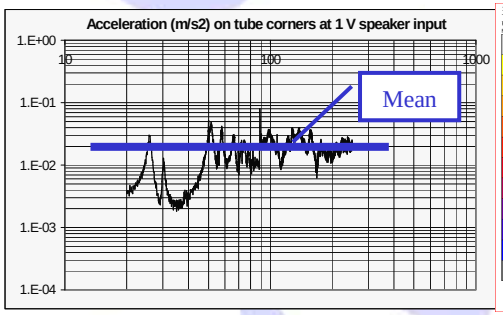
- PCB with transformer soldered with its 4 leads to the PCB, partially or completely encapsulated in outer ballast casing.
- Question: what are forces on solder joints during temperature cycling (-40/125 deg C) with different encapsulation materials if there is (not) release coating and if filling is partial?
- Picture shows Finite Element Analysis model. For visibility, the casing, and the encapsulation are partly omitted.

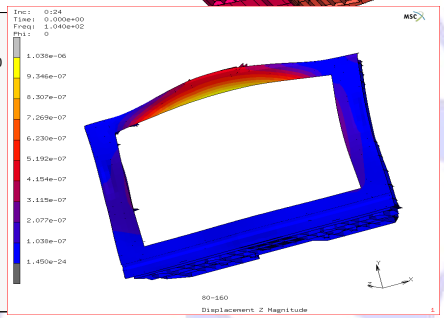
Project deliverables:

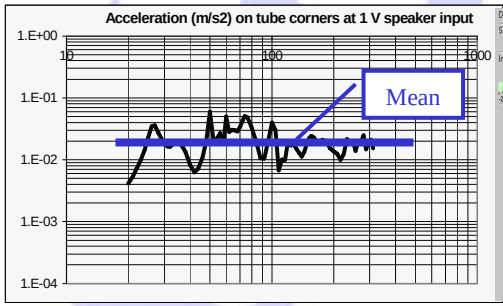
- The encapsulation is cured at 60 deg C. No stress nor forces at this temperature.
- The program calculates the forces at the 4 solder joints at 3 temperatures: 125, -40 and 20 deg C.

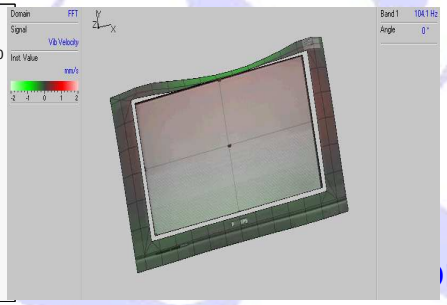
Noise, Vibration and Hiss (NVH) analysis











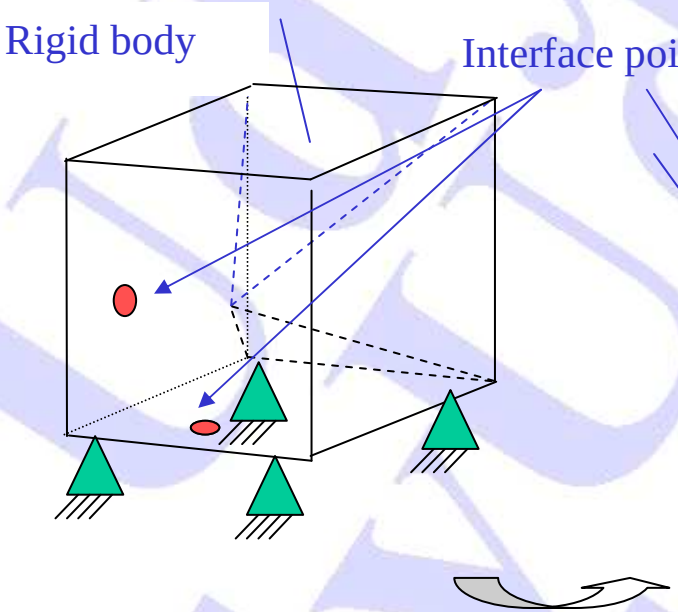
Project description:

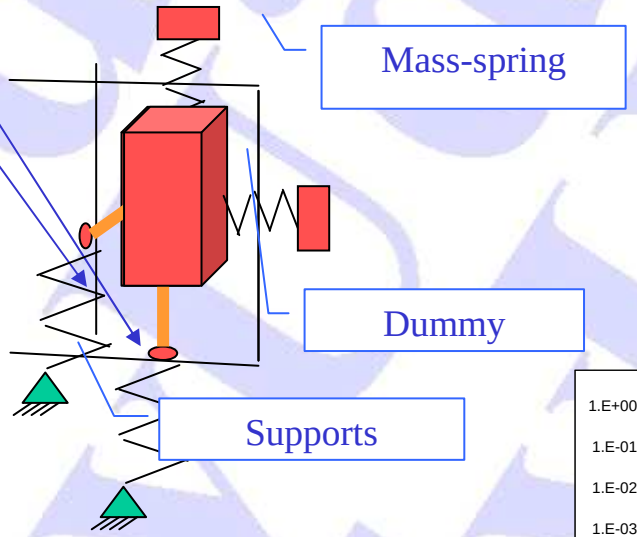
- Assembly consisting of multiple parts contains vibrating source causing NVH.
- How to reduce NVH level?

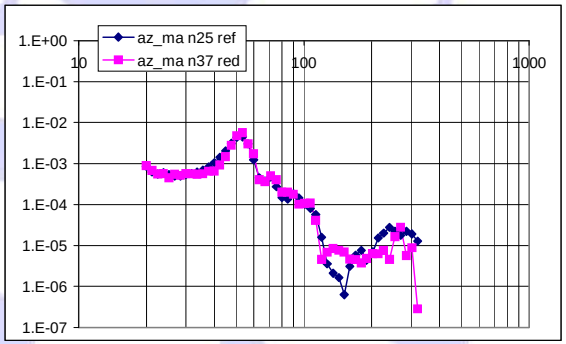
Project deliverables:

- Large model meshed in Pro-E using Pro Mechanica quad/tri mesher.
- Imported using NASTRAN format.
- Frequency domain analysis with real and imaginary part (damping).
- Transfer function obtained from electrical input of vibrating source to acceleration output (m/s^2V), see left bottom.
- Comparison with laser vibrometer measurement very good.

Model reduction for dynamic simulations







Constant part of model (large)

with interface points

Variable part of model (small)

with complex springs

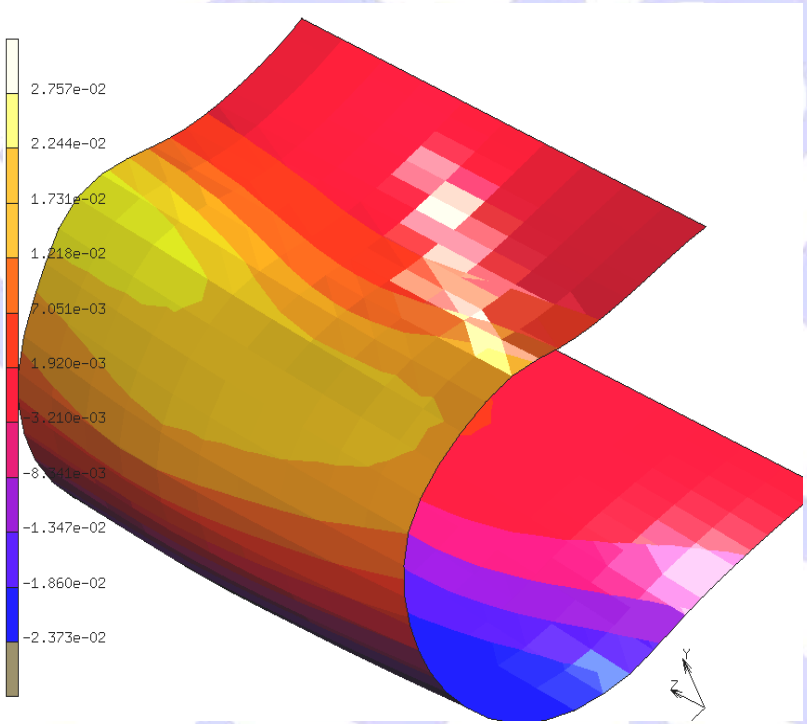
Project description:

- Dynamic simulation of large structure of which only small part, e.g. engine with mounts, can be modified.

Project deliverables:

- Large part is calculated only once, modification on reduced model with springs, practically no loss of accuracy.

Sheet wrapping and folding



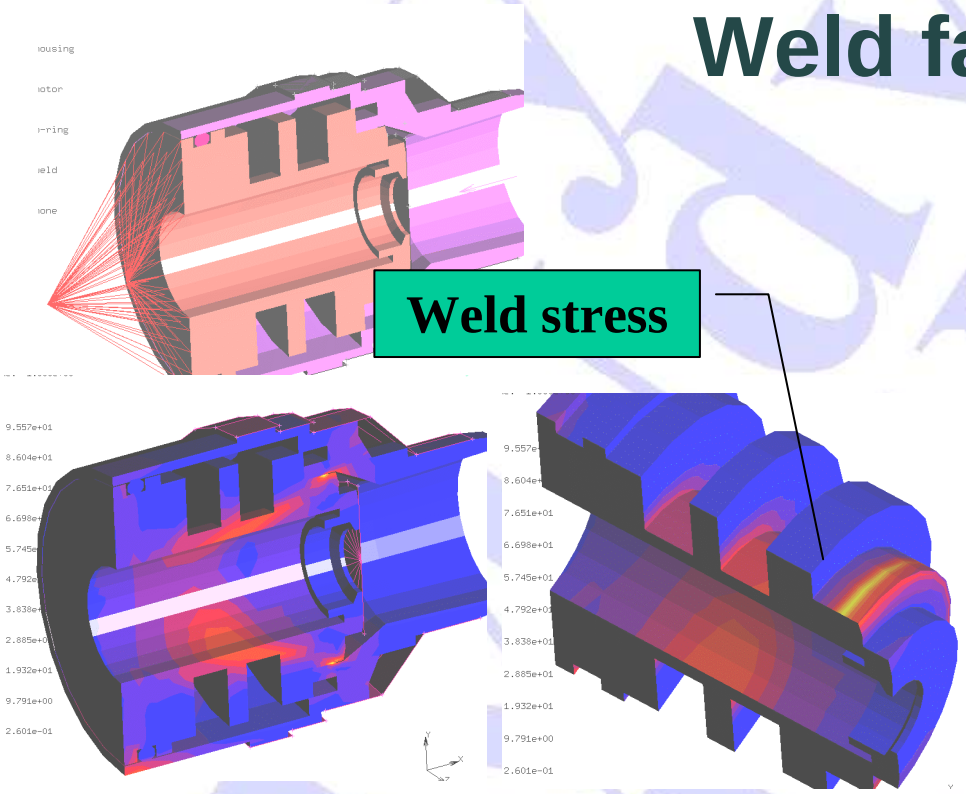
Project description:

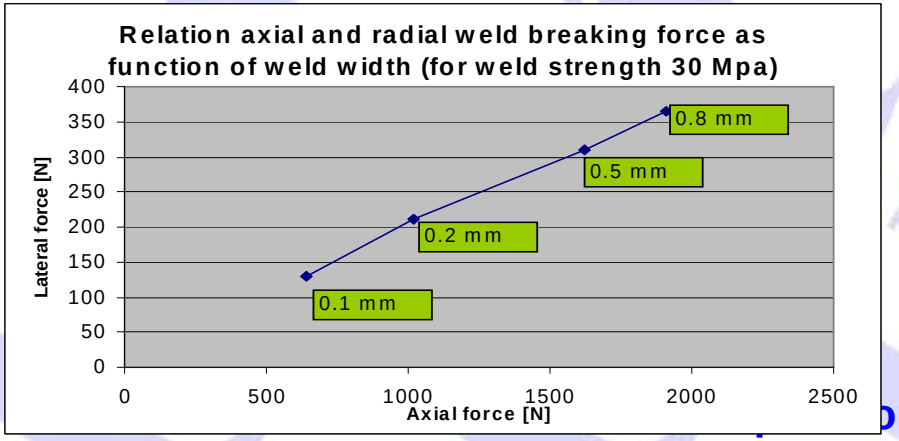
- Investigate critical factors influencing smooth (thin) sheet wrapping and folding.
- How to avoid wrinkles.

Project deliverables:

- Numerical model built, including all manipulations done during the wrapping and folding. Very demanding analysis due to ill-conditioned problem.
- Effect of gravity and disturbing factors included, e.g. air movement.
- Robust production process excluding occurrence of wrinkles, resulting in improved production yield.

Weld failure





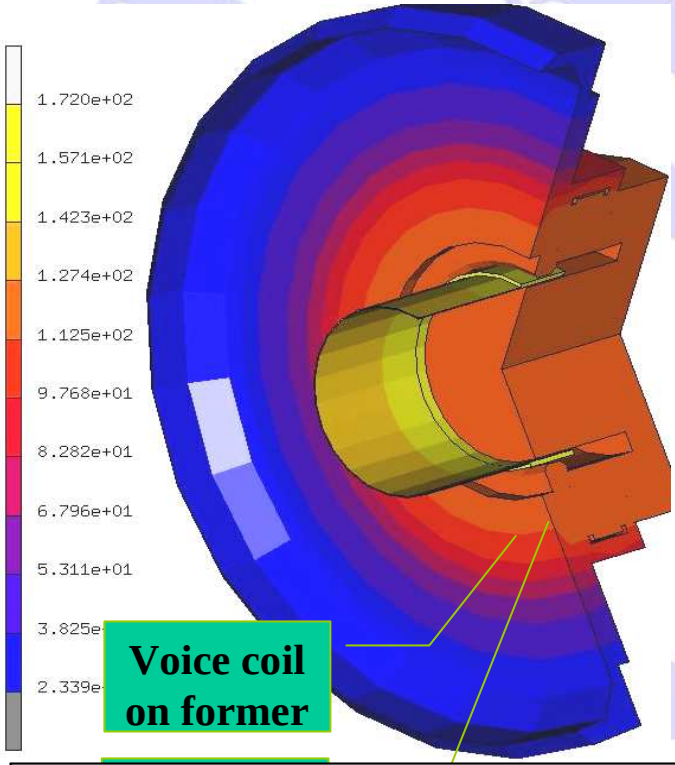
Project description:

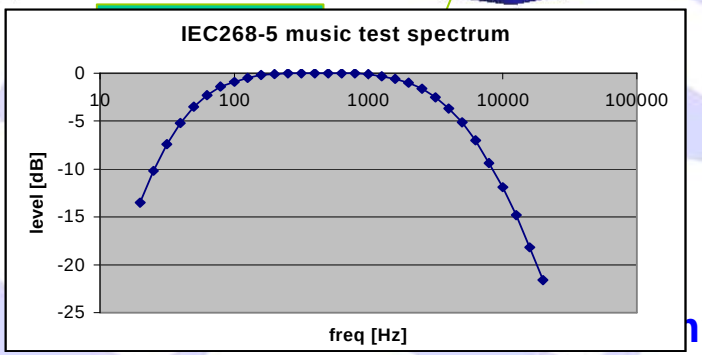
- Two plastic components, are ultrasonically welded to each other at right side.
- O-ring at left side.
- Lateral vertical load causes breakage during factory assembling, unless fact that axial strength is very high.

Project deliverables:

- ½ 3D model with contact bodies.
- Ultrasonic weld width (“engagement”) varied.
- Relation between axial and lateral strength as function of weld engagement established.

Thermal management electro-magnetic coil





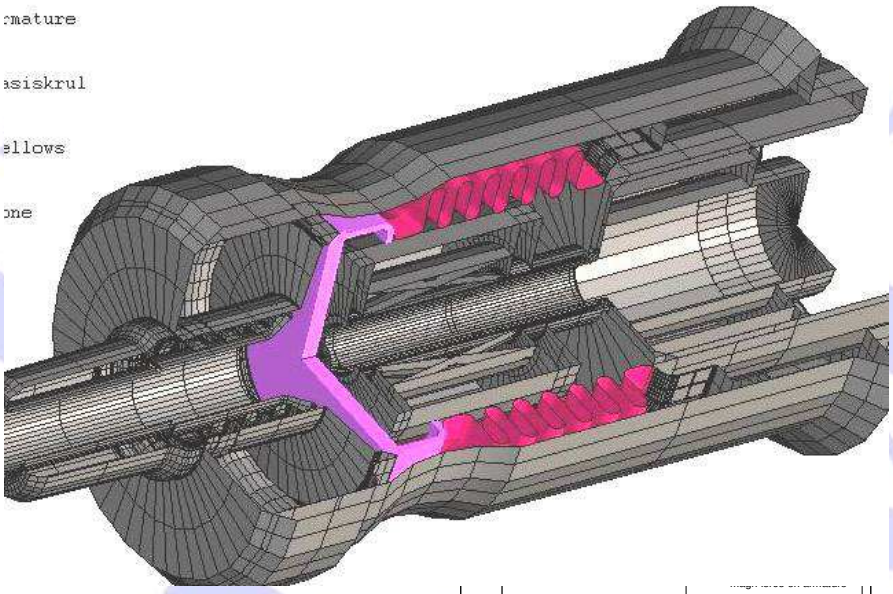
Project description:

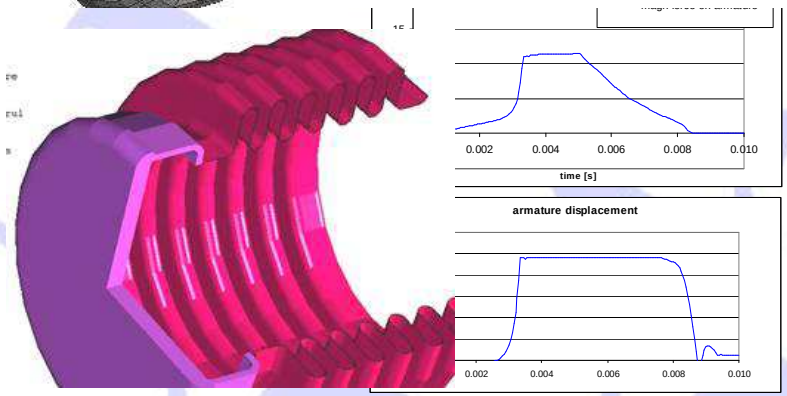
- Vibrating electro-magnetic coil and magnet system heats up during operation, causing possible failure.
- Provide means to decrease coil temperature.

Project deliverables:

- Magnet, pole plates, coil with its former and surrounding air modeled.
- Heating up treated in real time domain for test spectrum.
- Cooling effect of moving coil and temperature dependent heat radiation taken into account.
- Updated automatically within each increment: power and coil velocity decrease due to increased coil resistance.
- Due to detailed insight in heat flow mechanism, the maximum temperature could be lowered below Tg of adhesives used .

Valve design





Project description:

- Gas inlet valve must open and close accurately within 1 ms under varying internal and external pressure and with minimal "chattering".
- Careful balancing of differential pressure over bellows required.

Project deliverables:

- Position dependent flow characteristics programmed in user subroutine
- Dynamic transient and contact analysis.
- On and off electromagnetic force, calculated by other program, imported such that force is continuously adapted to varying position of armature.
- Completely Virtual Prototyped.

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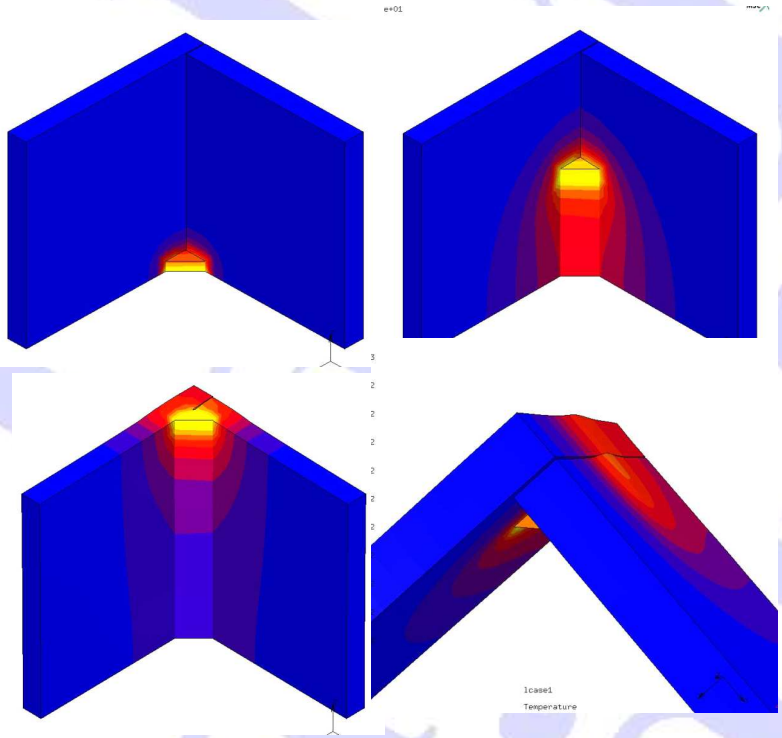
Simulation of precision welding



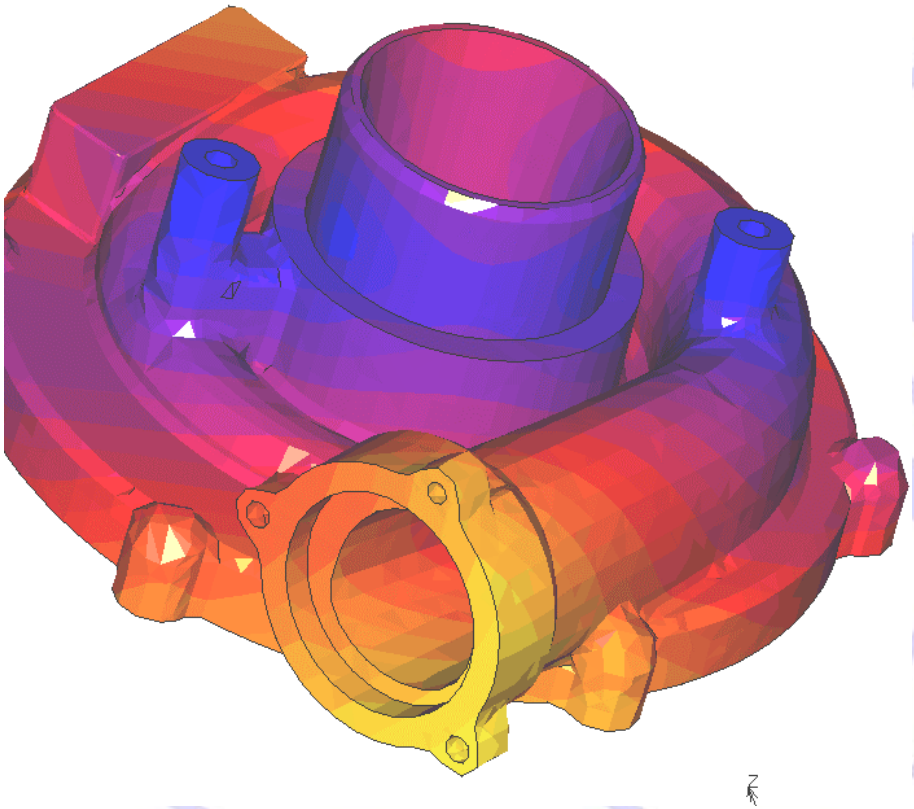
Project description:

- Two separate metal (aluminum or titanium) plates are welded together.
- What are temperatures, stresses, spring-back and deformations during and after the welding process.

Project deliverables:

- Coupled thermal and mechanical calculation.
- Welding speed and power adjustable.
- Welding heat radiation included.
- Welding material is added as in reality.
- Temperature dependent material. properties, also “swelling” of weld material.
- Changing contact conditions during welding taken into account.

Turbo compressor



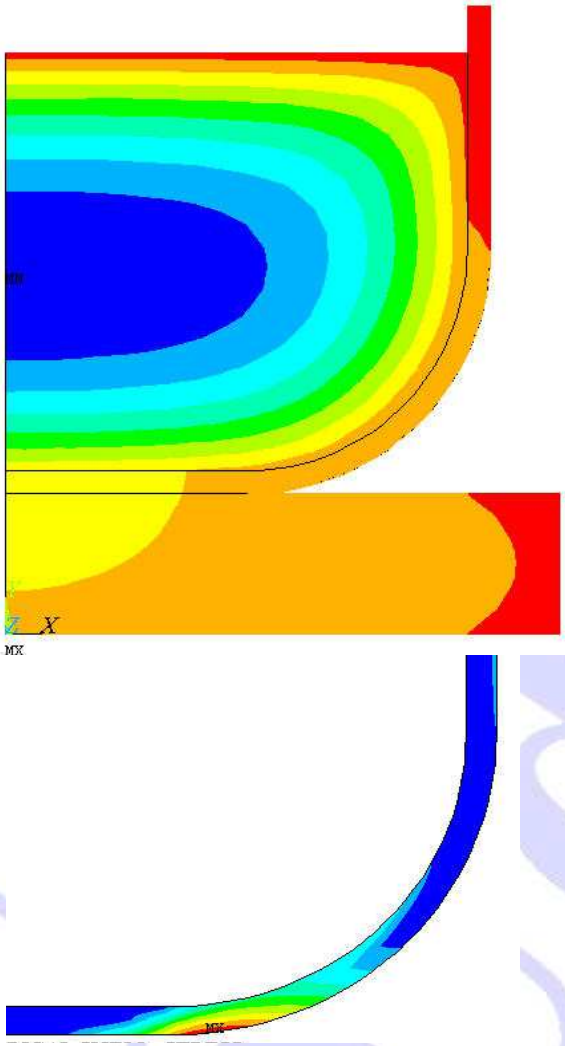
Project description:

- Turbo compressor is subjected to high pressure and temperature.
- Material properties are temperature dependent.
- Determine stress in critical regions.
- Modifications required to lower maximum stress during operation.

Project deliverables:

- Turbo compressor solid model interfaced from CAD directly in full detail.
- Pressure from CFD imported in structural model
- Critical stress regions determined a.f.o. of temperature.
- Design re-iterated to arrive at safer operating conditions.

Failure analysis of sintering crucible



Project description:

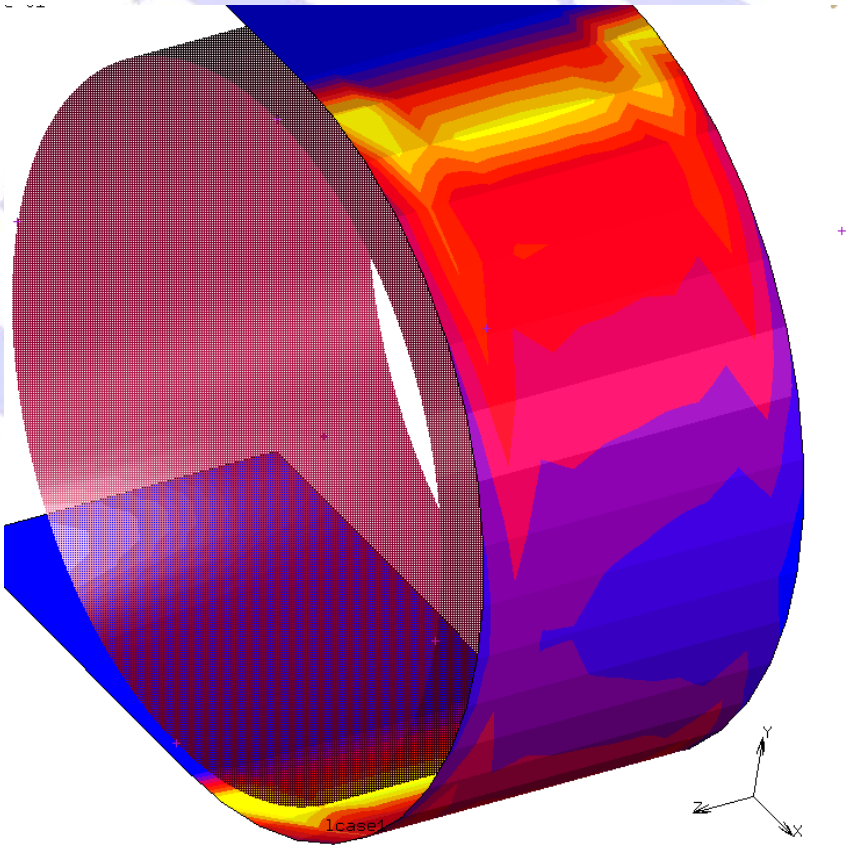
Customer wants more insight in:

- Failure mechanism crucible
- Effect of geometry crucible (diameter, thickness, etc.)
- Parameters for new powder oven design

Project deliverables:

- Numerical model to predict thermal and mechanical behavior of powder crucible
- Definition of length new oven design
- Cost reduction with respect to crucible failure and a shorter new powder oven

Band wear



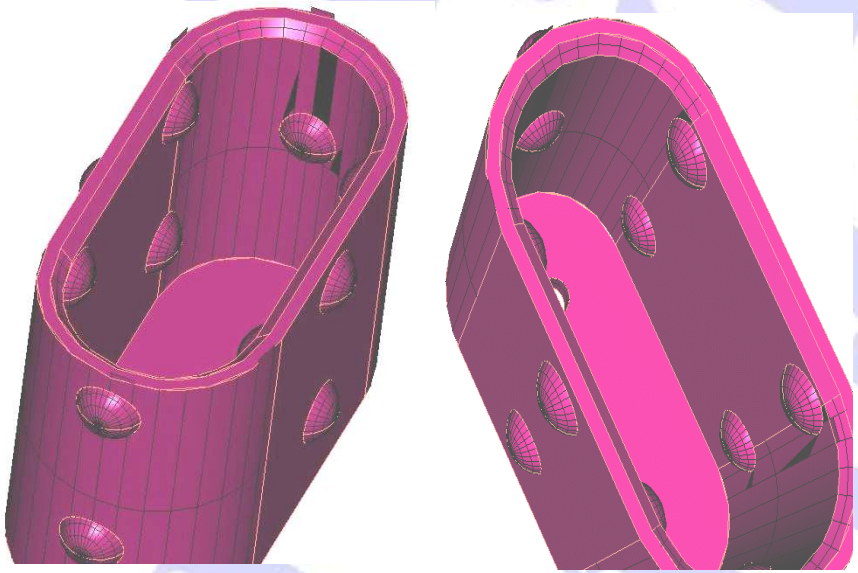
Project description:

- Band rolls over pulley and shows premature wear, resulting in high maintenance costs and production stops.
- Questions:
  - Why?
  - How to remedy?

Project deliverables:

- Numerical model built including dynamic friction.
- Misalignment of pulley dynamically varied.
- Critical wear factor identified and suitable corrective actions simulated and realized.
- Band has now normal lifetime.

3 Degree of freedom rubber damper



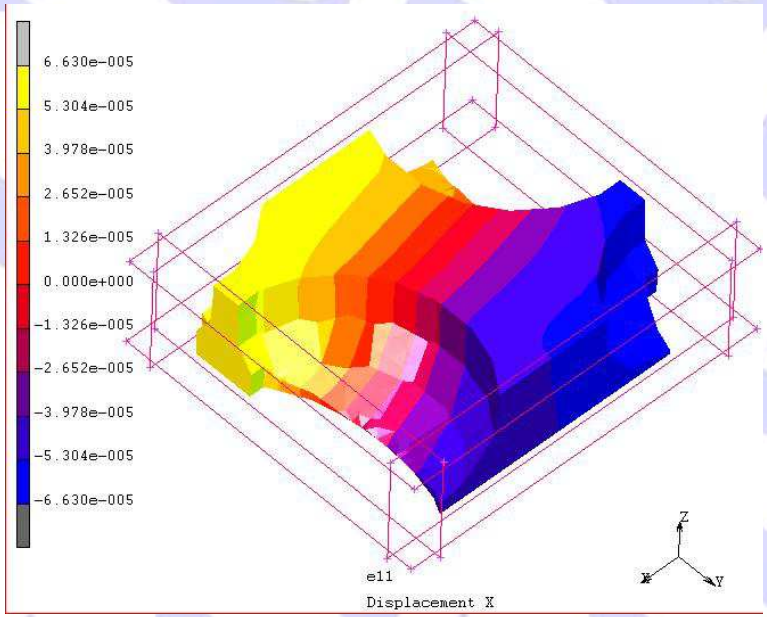
Project description:

- Two plastic parts connected to each other. Vibration from one part is not allowed to enter in second one.
- Question: design a low cost rubber damper, who acts in three directions.

Project deliverables:

- Rubber dampers.
- Small protrusions only make contact with plastic parts. The region between embodies the required resilience and damping.
- Material definition and choice.
- Works in broad temperature range.
- Completely Virtual Prototyped, First-Time-Right.

Multi-level constitutive material modeling



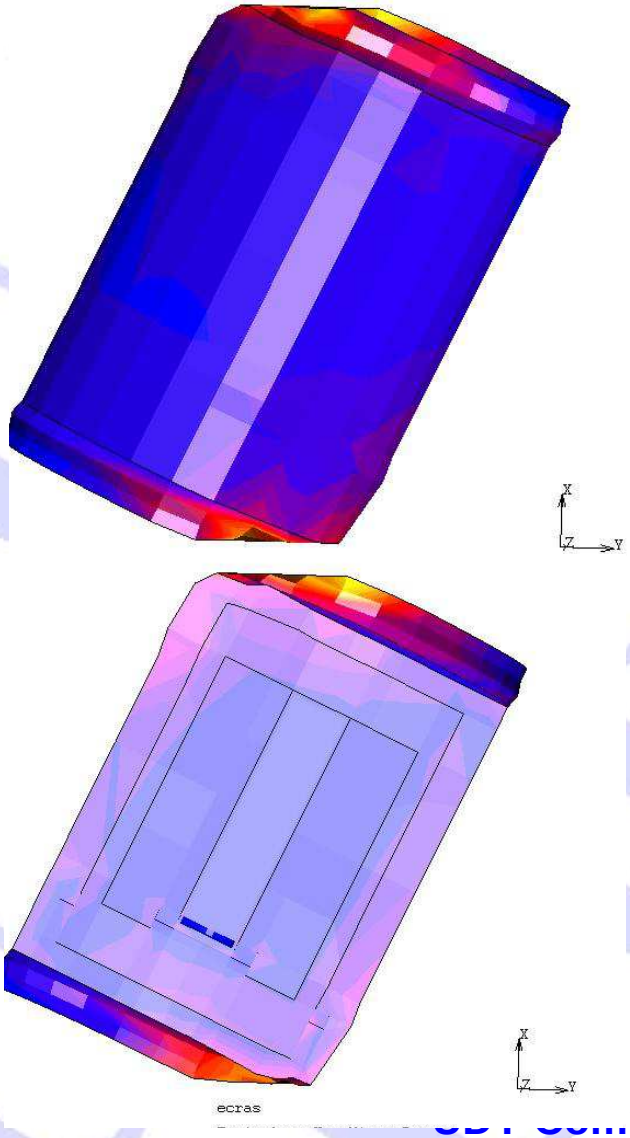
Project description:

- The material consists of 2 components arranged in a repetitive pattern
- Detailed meshing requires too much elements

Project deliverables:

- Using Representative Volume Unit (RVU) approach
- Derive anisotropic material properties from RVU
- Apply to large structure gives accurate results with reasonable number of elements

Crash analysis container



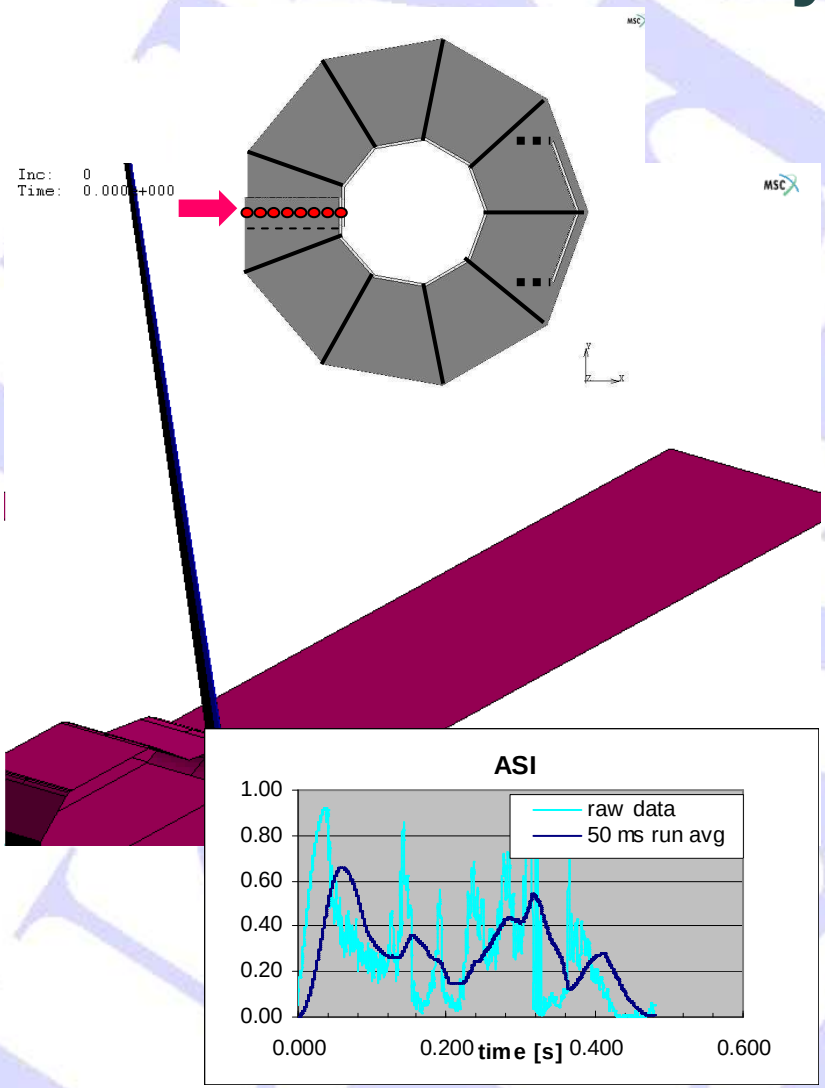
Project description:

- Nuclear waste transport consists of inner tube with cooling fins, and an outer thermal insulating cylinder
- After a number of crash and fire tests, the inner tube is not allowed to leak

Project deliverables:

- Container with inner tube and thermal management system completely modeled
- Drop test from 9 m height simulated in a number of different positions
- Damaged container subjected to 30 min fire at 800 deg C
- Tightness check on inner O-rings

Crash analysis traffic pole



Project description:

- Traffic pole which has flexibility to prevent personal injury according to EU standards
- Must be stiff enough to comply with static wind load for 50 years
- Flexibility of car front must be taken into account

Project deliverables:

- Complete pole design
- Special zip construction without any weld (no corrosion)
- Optimal material determined
- Simple to produce
- Complies with highest EU safety class HE100 (Acceleration Severity Index < 1)
- Patented

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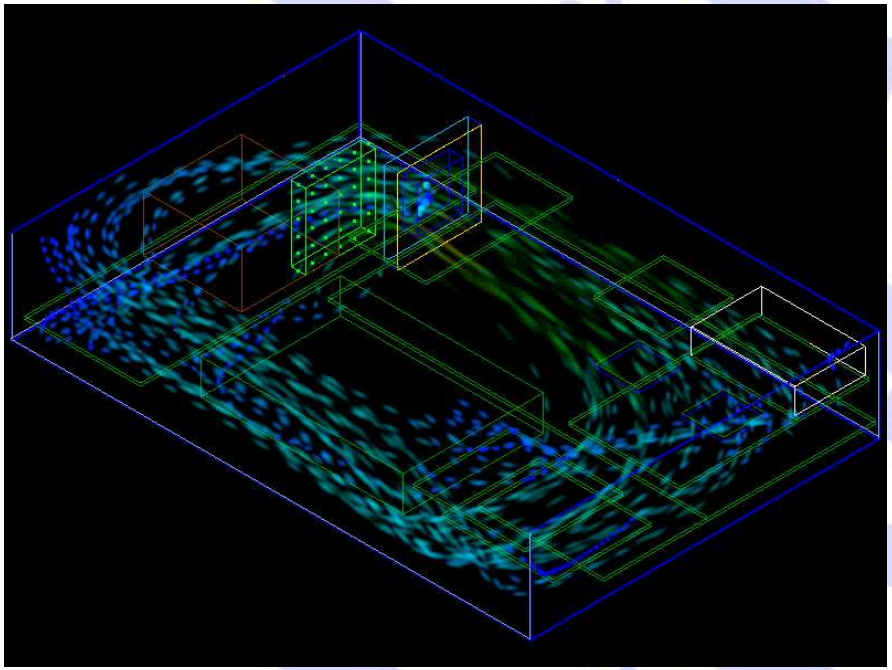
Cooling by forced air flow



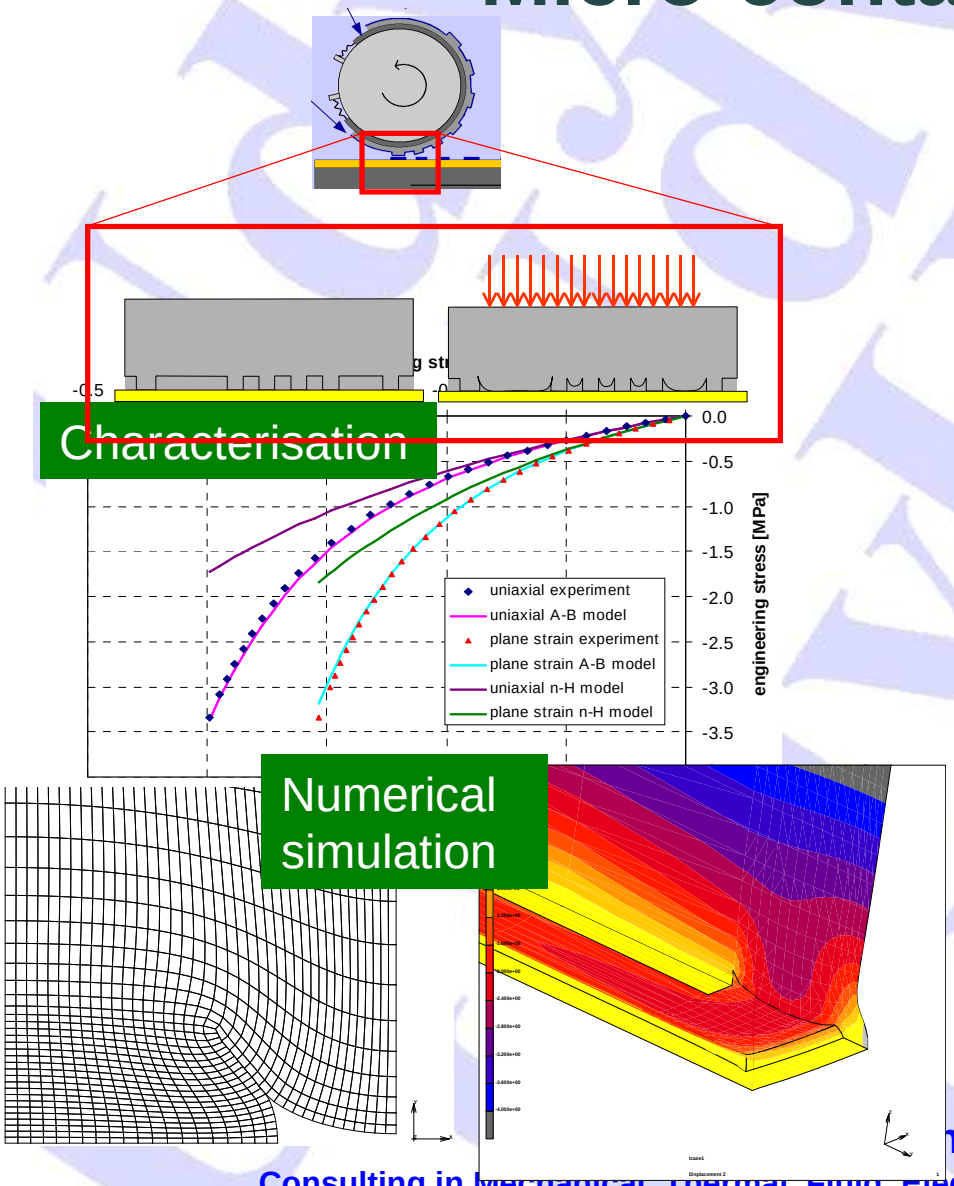
Project description:

- Cabinet contains heat generating electronics on PCB and cooling ventilator
- Temperature of critical components too high, due to air flow disturbance

Project deliverables:

- 3D airflow within cabinet simulated taking into account presence of components
- Algebraic and k-ε turbulence model for forced fan flow
- Optimum component and baffles placement to minimize air flow deviations
- Correct dimensioning of ventilator
- Different environmental temperatures considered

Micro-contact printing



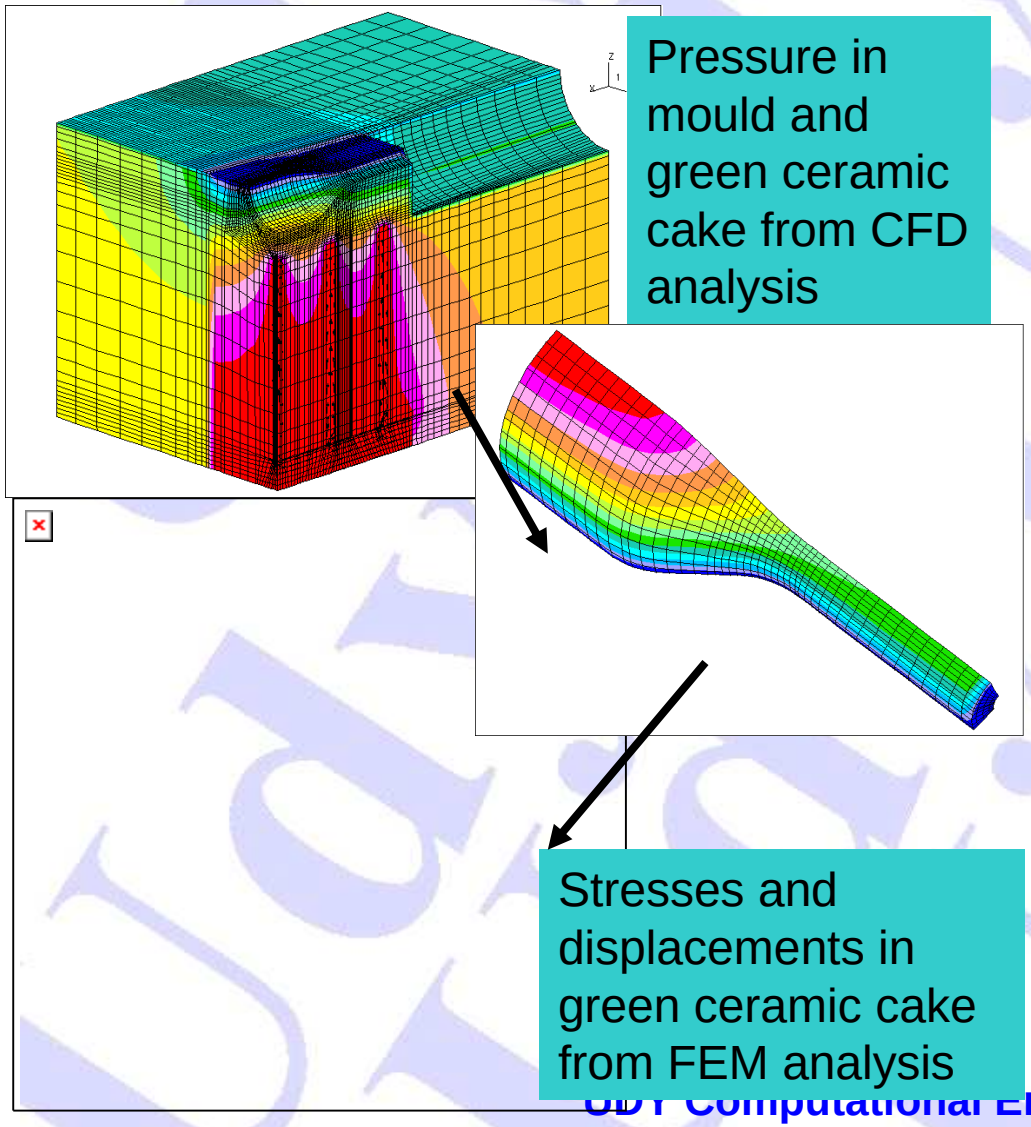
Project description:

- Rubber roll with small protrusions
- Buckling of protrusions not allowed
- Determine critical factors of buckling and material parameters influencing it

Project deliverables:

- 3D model built
- Periodic boundary conditions
- Rubber material characterized (Mooney, viscoelastic)
- Buckling phenomenon captured exactly using special arc-line methods
- Modifications proposed
- Design rules established

Handling of green (unfired) ceramics



Pressure in mould and green ceramic cake from CFD analysis

Stresses and displacements in green ceramic cake from FEM analysis

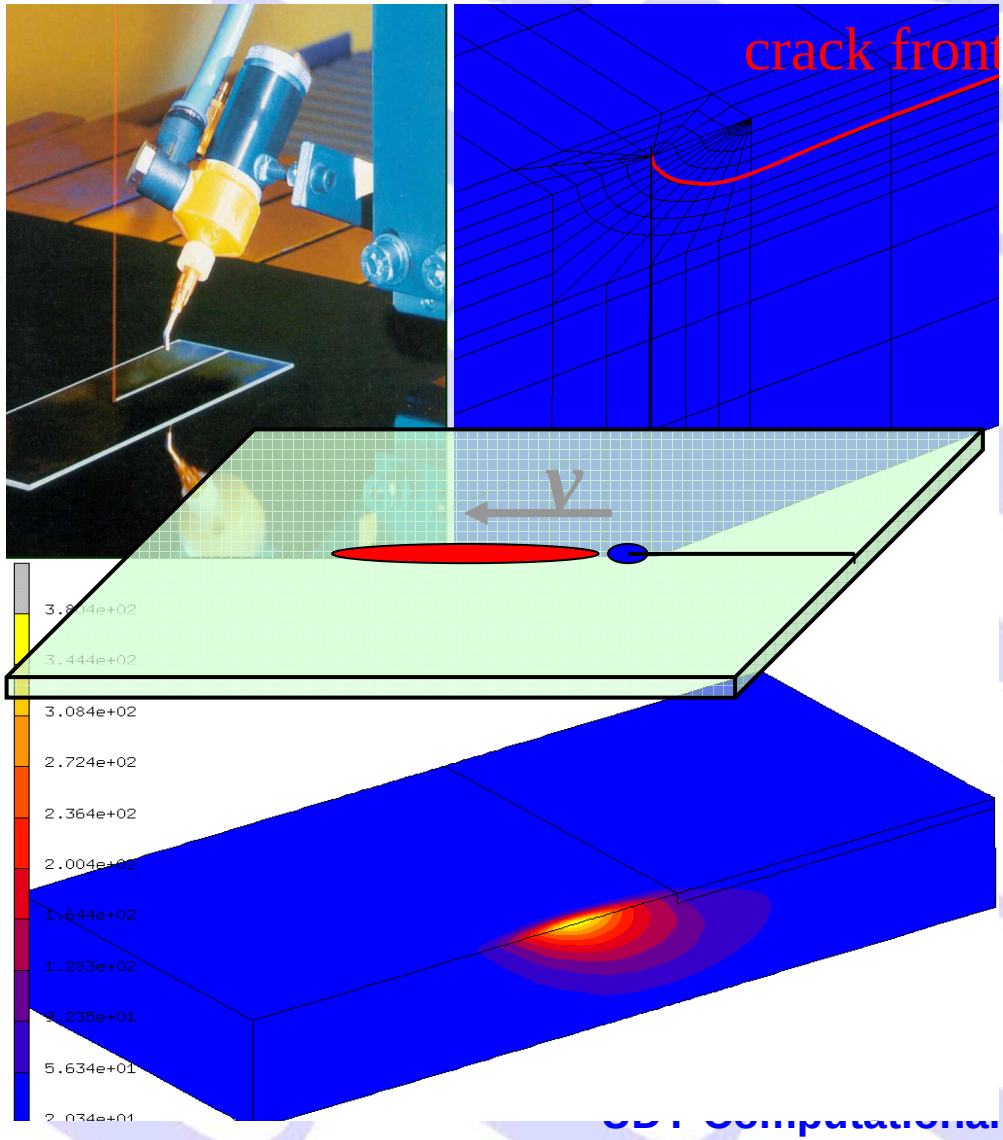
Project description:

- Improve release behavior of green ceramic PCA (polycrystalline oxide) burners

Project deliverables:

- 3D model
- Model describing stresses and strains introduced during handling
- Shape and handling optimization of burner geometry

Laser scribing and separation



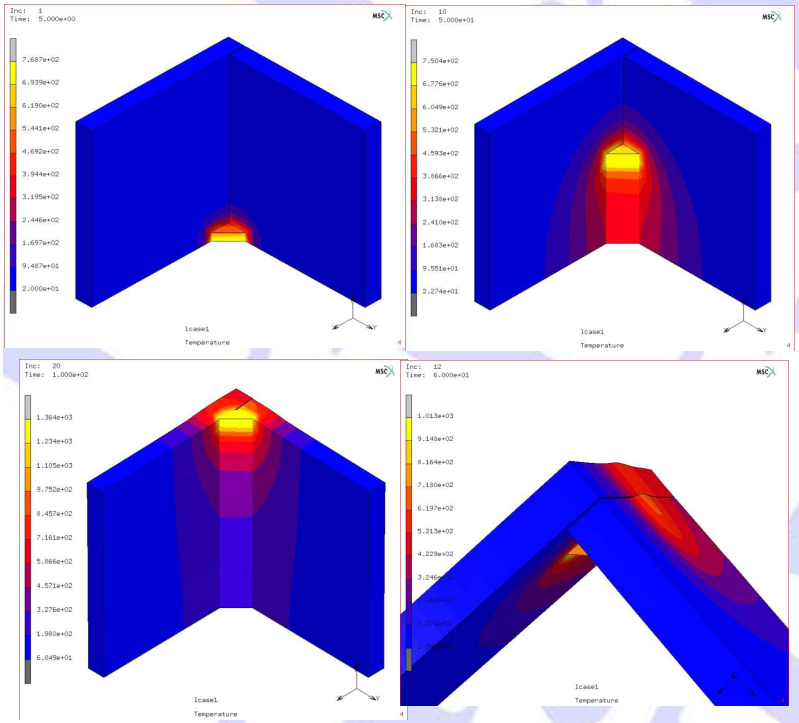
Project description:

- Pre-existing surface scribe is propagated by moving substrate under fixed oblate laser and round jet impingement spots
- Combination of heating and cooling induces localized tensile stress and causes crack propagation downstream

Project deliverables:

- Basic model verified against experiments
- Parametric model to study the influence of geometrical, material and process parameters
- Influence of extra upfront breaking beams is studied

Optimization of Hybrid Laser Welding



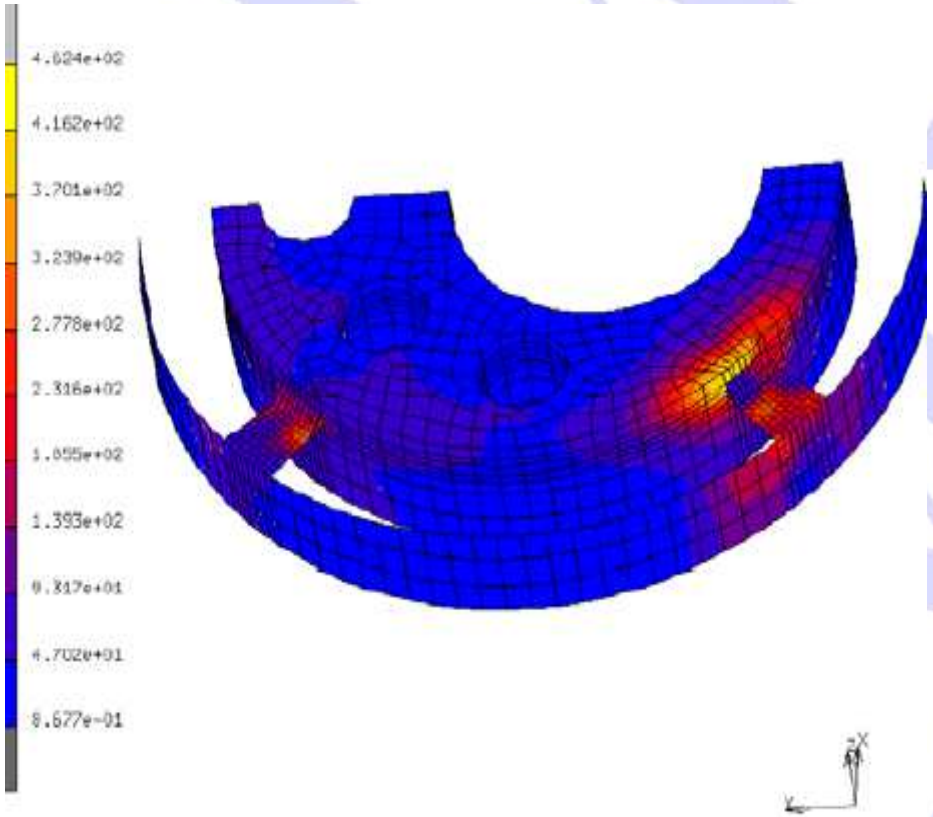
Project description:

- Two separate aluminum plates are welded together
- Natural convection
- What are temperatures, stresses and deformations as function of time.

Project deliverables:

- Coupled thermal and structural calculation
- Welding at constant of variable speed and power.
- Material added during welding
- Temperature dependent material properties, also “swelling”
- Changing contact conditions during welding accounted for

Sequential welding



Project description:

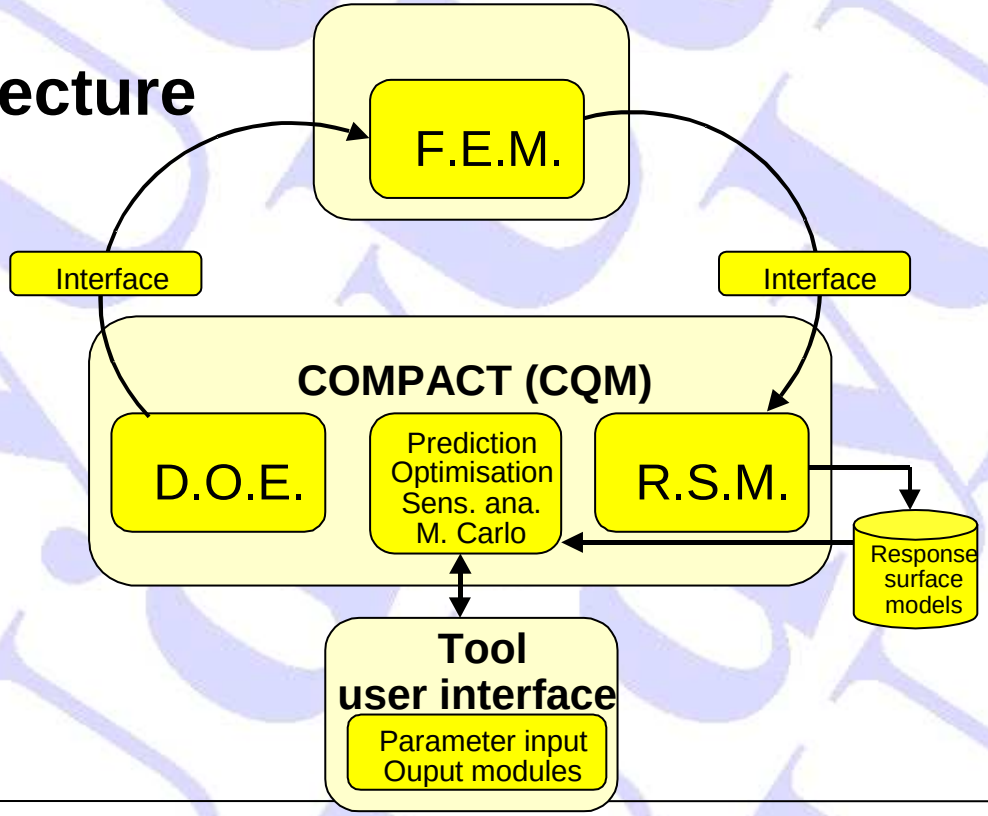
- External ring has leaf springs welded to central solid part
- Welded assembly is deformed

Project deliverables:

- Weld paths and fillers modeled
- Consecutive welding process simulated as in reality
- Weld jig adapted to produce exact centering of assembly

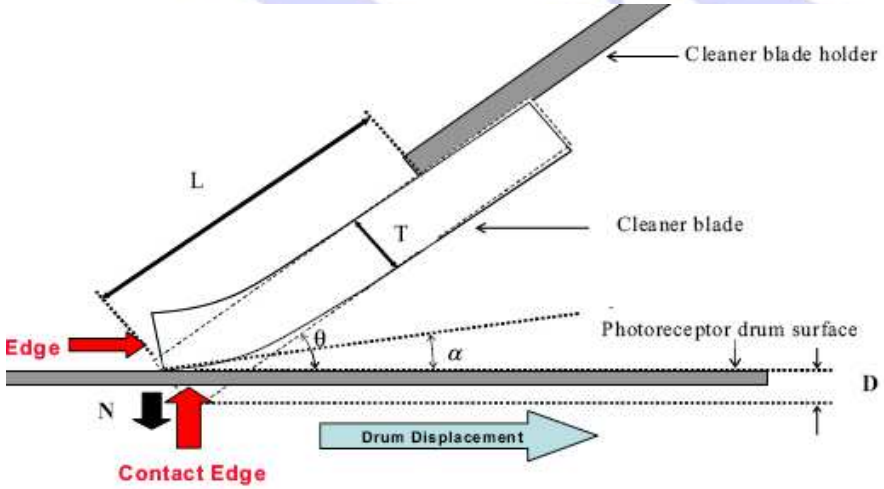
Design of Experiments (DoE) Response Surface Modeling (RSM) Robust Design

Tool architecture



3

Rubber cleaning scraper

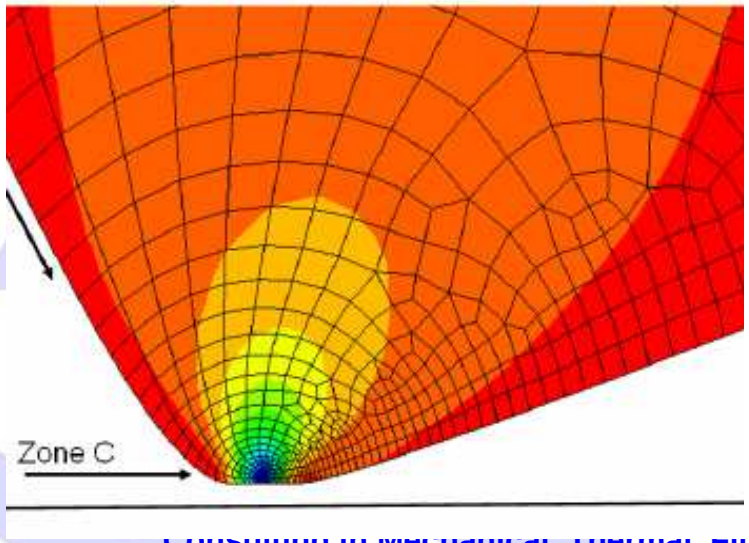


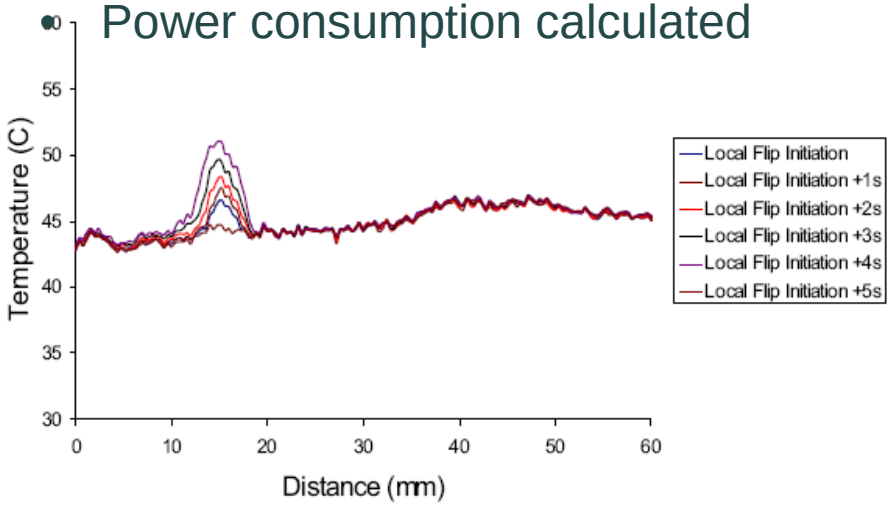
Project description:

- Rubber scraper removes dirt form drum
- Shows premature wear, scars and/or cracks

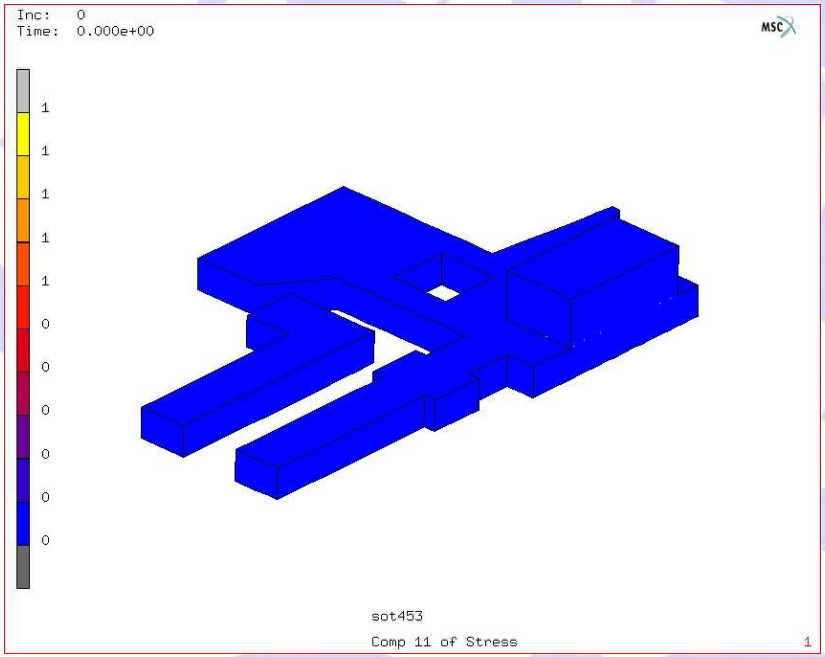
Project deliverables:

- Parametric model
- Detailed stress/strain distribution at tip required
- Heat generation due to friction
- Power consumption calculated





Overmolding



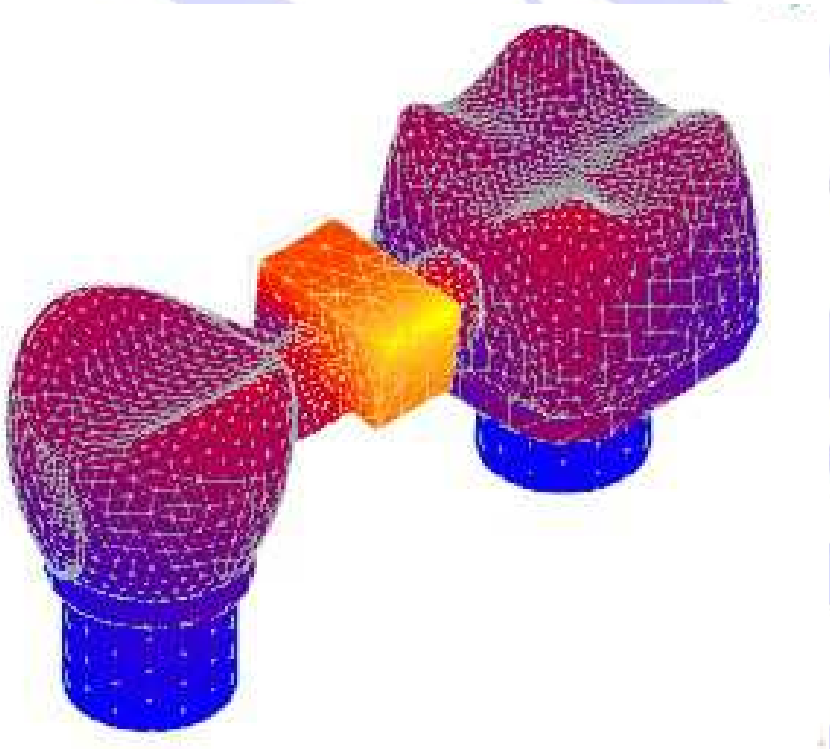
Project description:

- Metal and plastic parts are overmolded
- Causes cracks at sharp edges between overmold and inner parts due to stress concentrations

Project deliverables:

- Full 3D models of inner part and overmold
- Contact conditions established
- Stress concentrations calculated
- Part placement optimized and overmold material modified as to reduce stress concentrations at interfaces

Dental implants



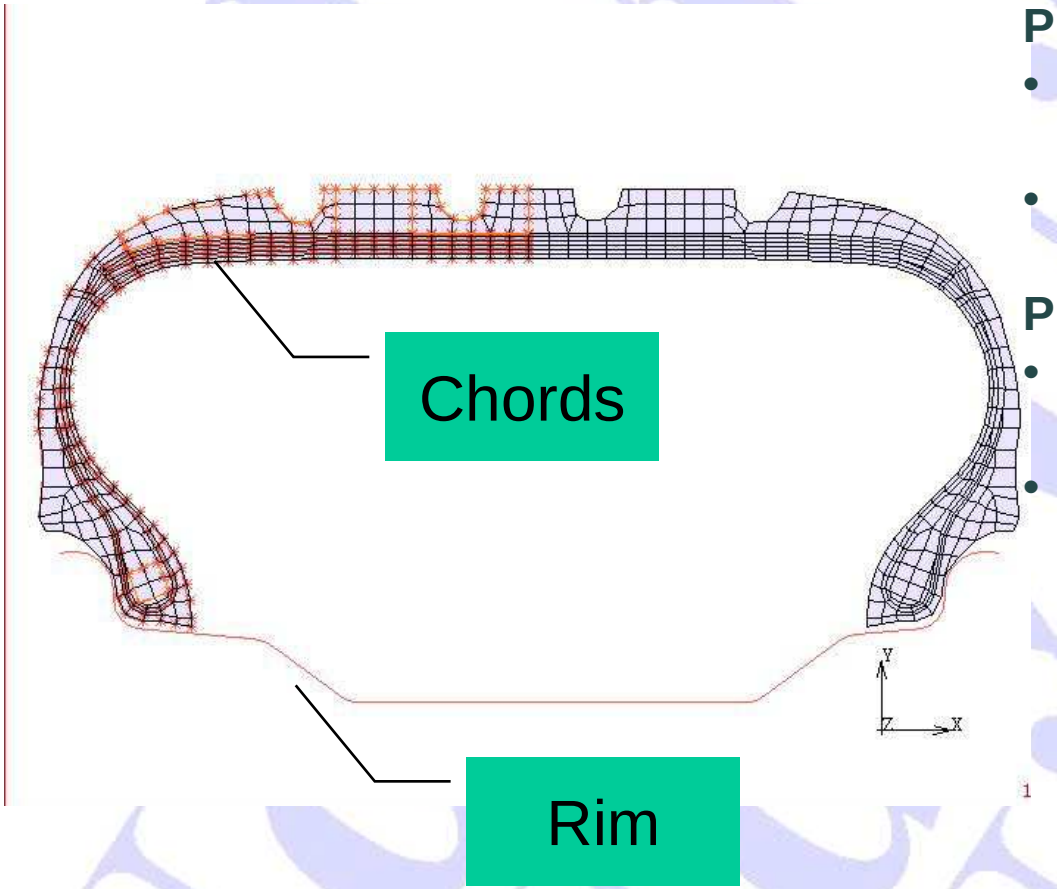
Project description:

- Pontic (floating artificial dent) anchored in neighbouring implant
- Load is vestibulo-occlusal of pontic

Project deliverables:

- Intricate geometry imported from STL
- Maximum stress determined
- Geometry optimized to decrease stress

Embedded bead/cords in tyre



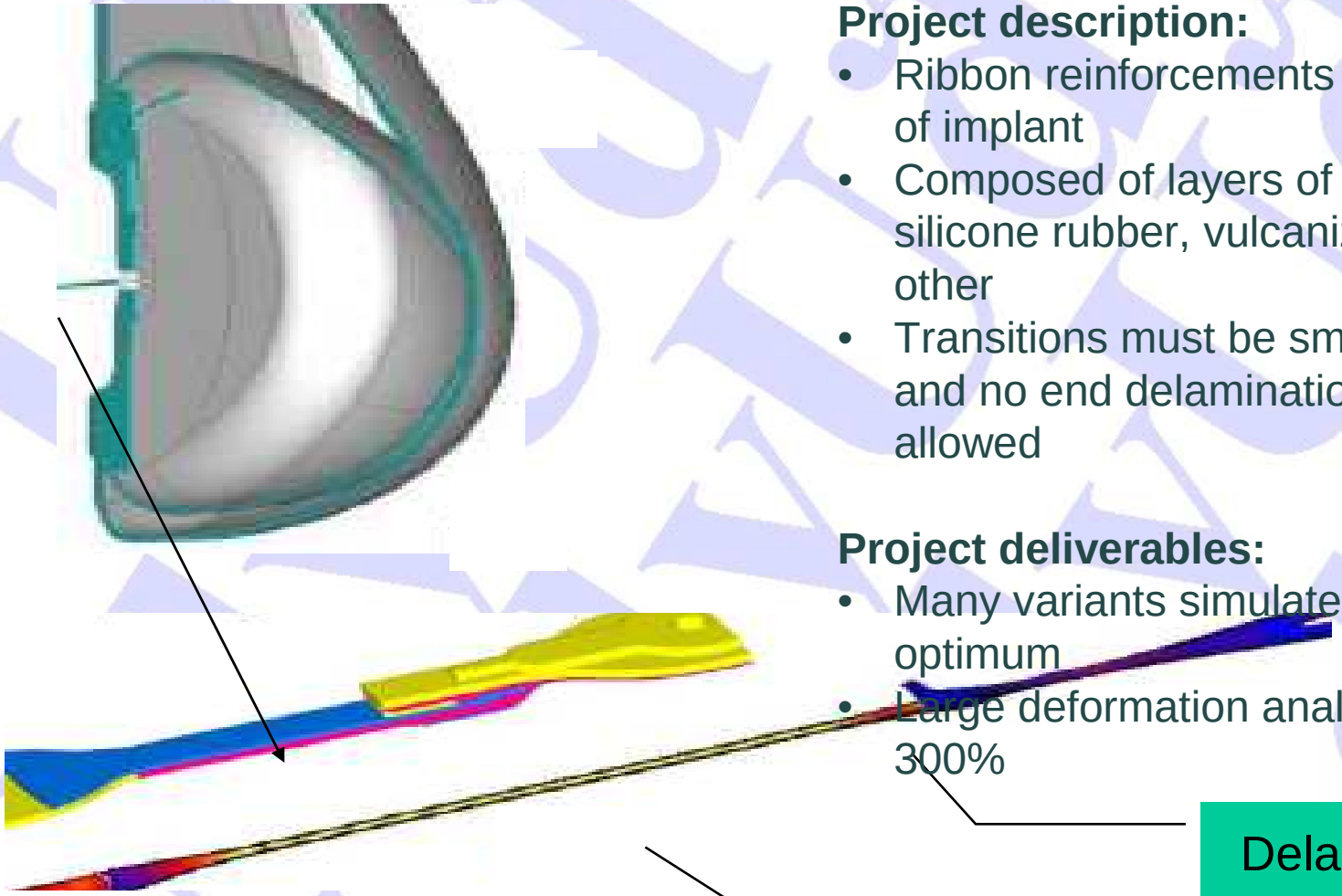
Project description:

- Tyre steel cords are embedded in rubber
- Determine optimal placement

Project deliverables:

- Chords embedded within solid require special elements
- Model can be expanded to 3D, including deformation and stress, to initiate 3D analysis with added loadcases

Breast implants



Project description:

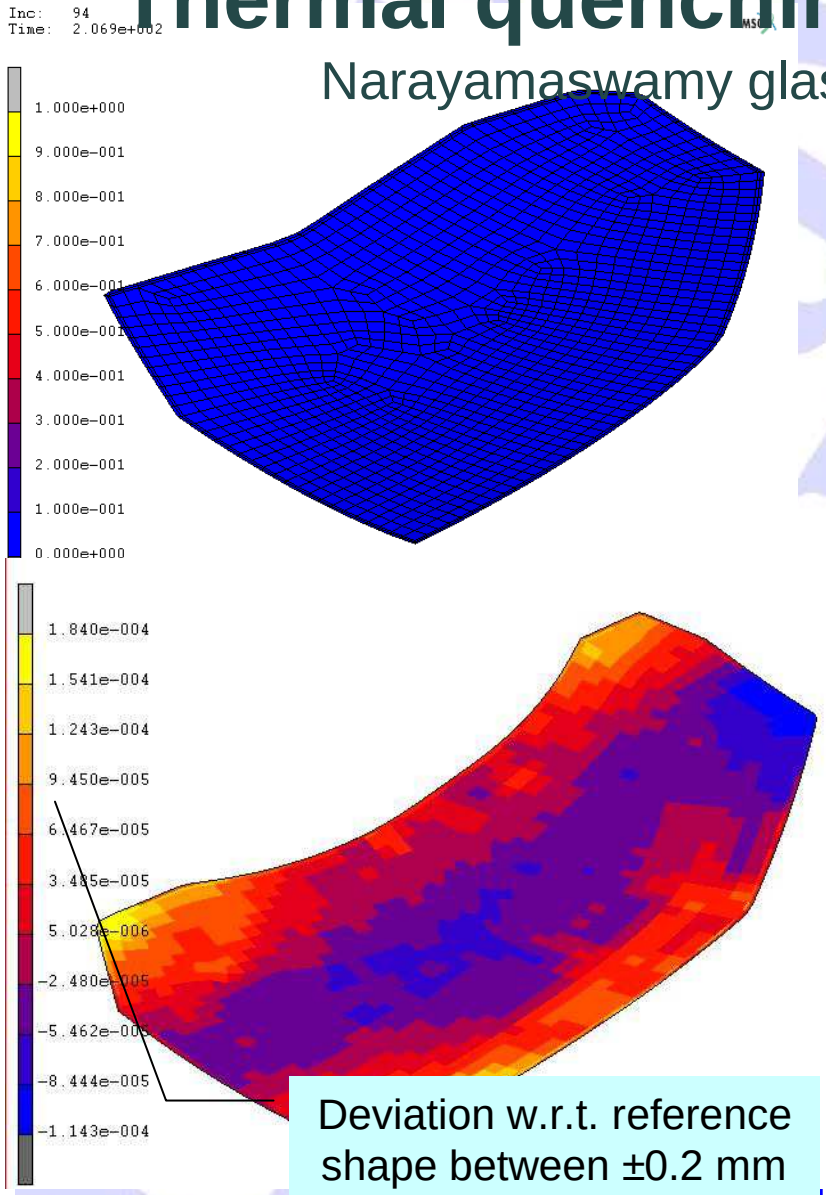
- Ribbon reinforcements at back side of implant
- Composed of layers of different silicone rubber, vulcanized on each other
- Transitions must be smooth and and no end delaminations are allowed

Project deliverables:

- Many variants simulated to arrive at optimum
- Large deformation analysis up to 300%

Thermal quenching process simulation

Narayamaswamy glass constitutive material model



Deviation w.r.t. reference shape between ±0.2 mm

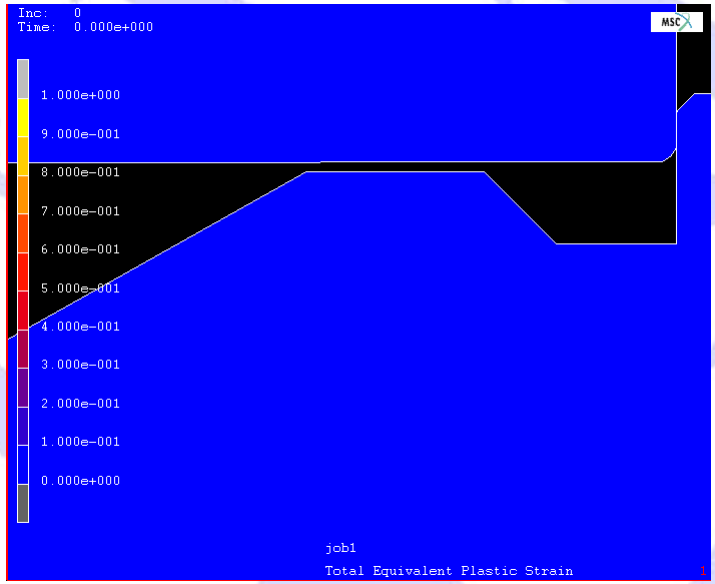
Project description:

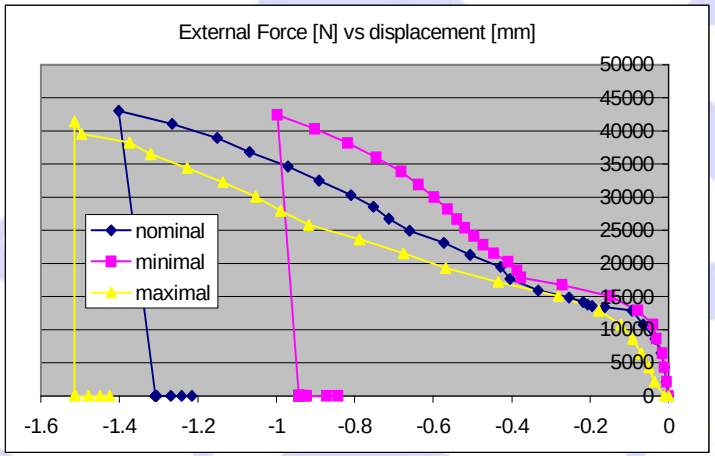
- Glass panel is heated to 665 C and pressed into curved shape
- Quenched and cooled down
- Problem: shape not accurate due to gravity (sag) and residual stress

Project deliverables:

- Narayamaswamy glass material model (with visco-elastic and structural relaxation) implemented
- Complete manufacturing process simulated
- Convection and radiation effects included
- Mold compensation calculated to arrive at matched shape with reference within ±0.2 mm (Top movie)

Clinching with high strain rate





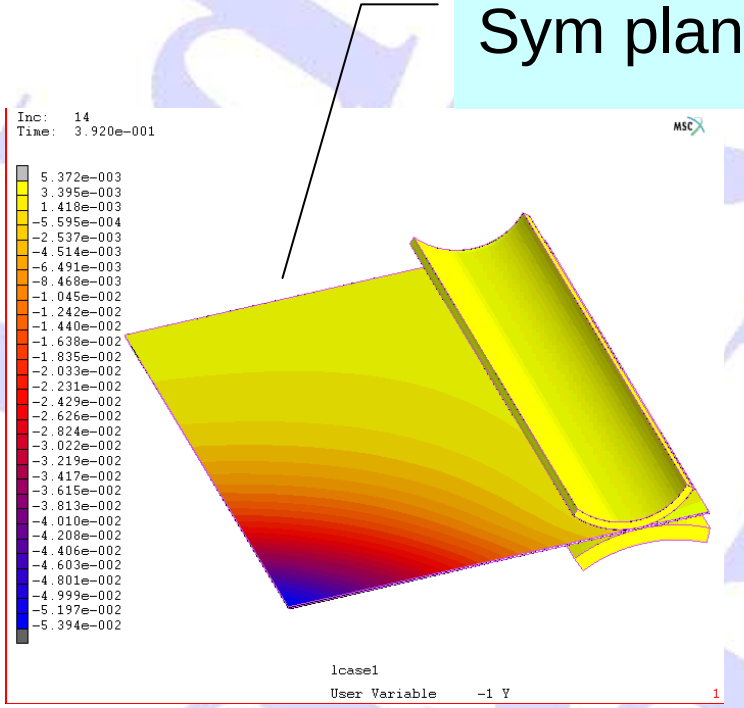
Project description:

- Inner part is pushed in the outer
- Steel “knife” scrapes material outer tube wall
- Cavity under the “knife” is filled and pressurized by the scraped material

Project deliverables:

- Clinching process simulated using continuous remeshing during penetration of “knife”
- Force-displacement characteristic verified against experiments
- Critical dimensions optimized to obtain leak-free clinch under internal pressure (>200 bar)

Sheet buckling during rolling



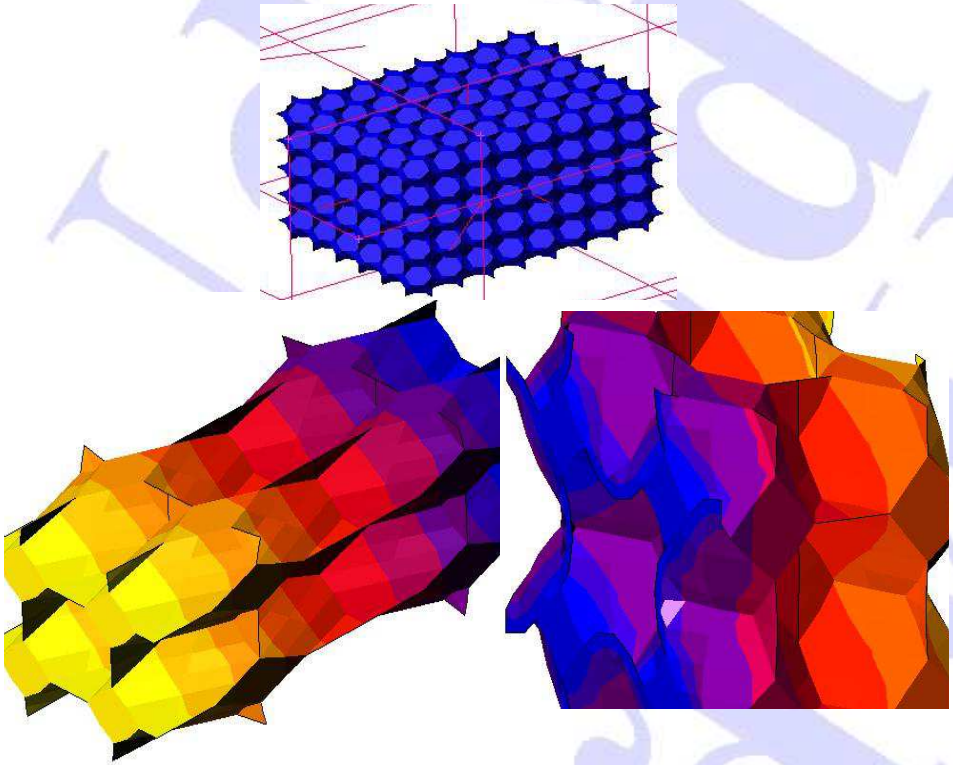
Project description:

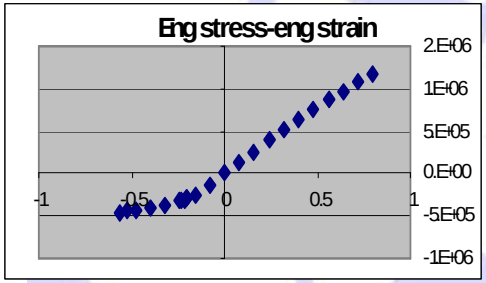
- Thin sheet is processed between two rolls
- Global deformation of sheet is large
- Calculate and show the fine-structure of local buckling

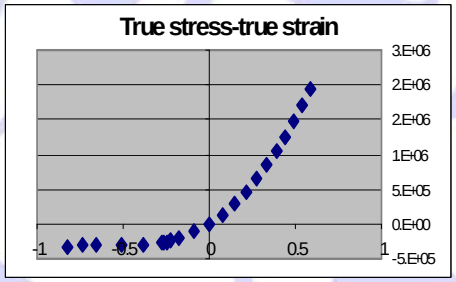
Project deliverables:

- Dynamic transient analysis with rolling friction contact
- Local buckling superimposed on large global deformation
- Special postprocessor to visualize fine structure of large global deformation

Foam modeling







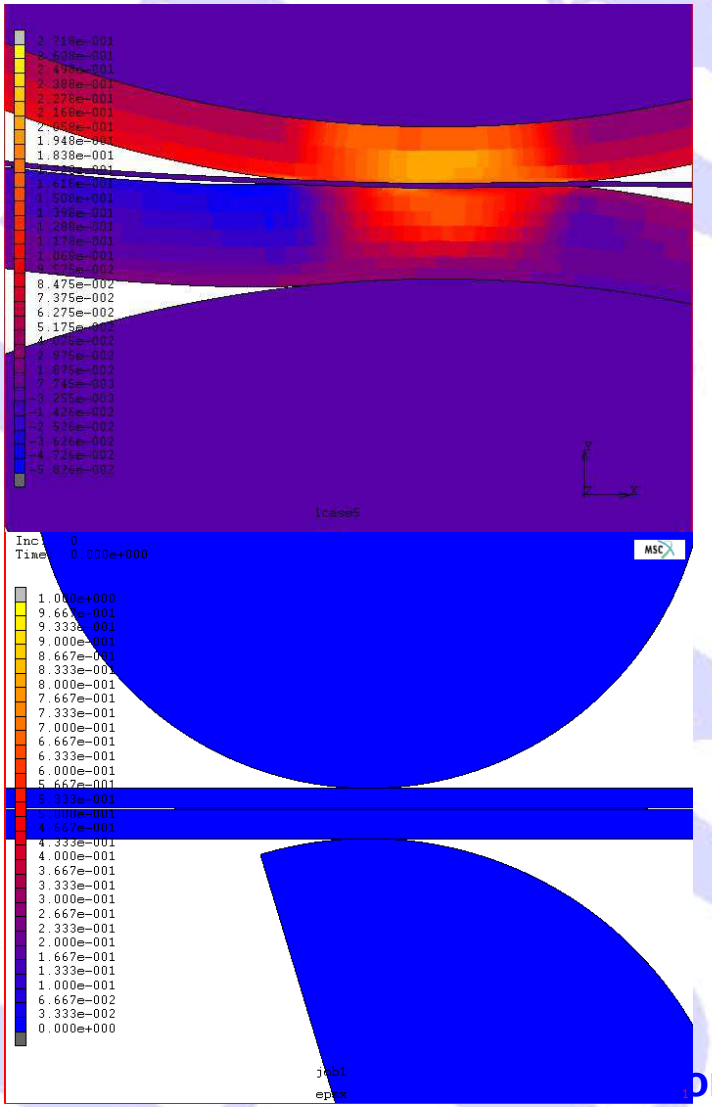
Project description:

- Starting from the cell geometry, wall thickness and bulk material, what are the material properties of the foam?
- How can these parameters be influenced to meet customer's needs?

Project deliverables:

- Automatic generation of 3D foam model starting from cell size, wall thickness and bulk material
- Bulk material can be each material including plastic and rubber with visco-elastic relaxation properties
- Basic stress-strain relations of foam extracted from model
- For thermal insulation purposes, the effective thermal conductivity is also determined

Laminating rubber rolls and bands



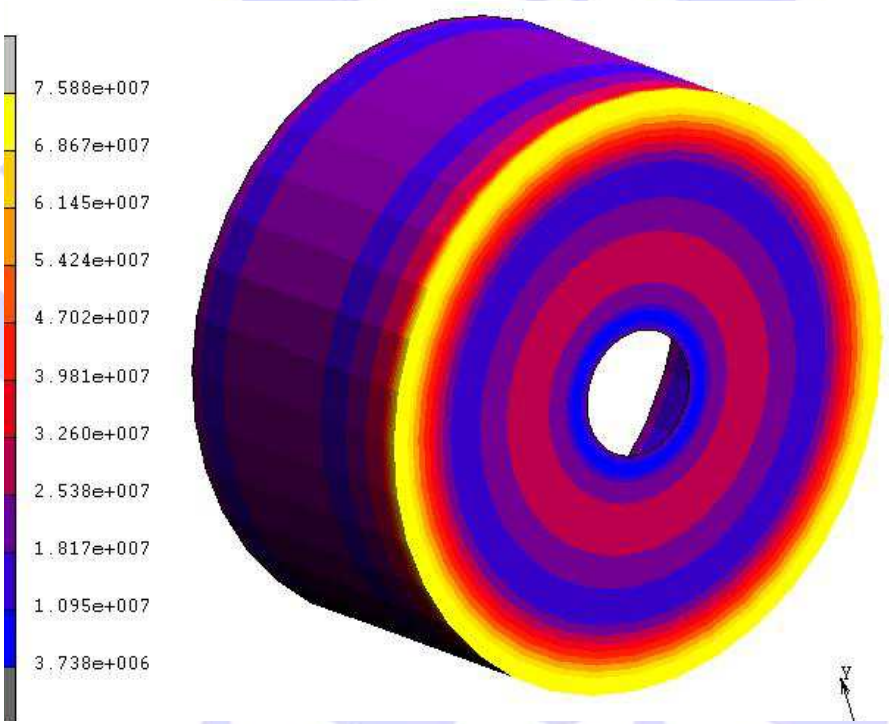
Project description:

- Thin sheet is laminated between two bands, each driven by a roll
- Determine conditions under which sheet sticks to a band and causes jams

Project deliverables:

- Detailed model with all necessary contact conditions, static and dynamic frictions (stick-slip)
- Special postprocessor to determine strain in the band direction
- Effect of sticking or non-sticking to bands modeled via Cohesive Zone Technique

Buckling of a high-temperature pressurized vessel



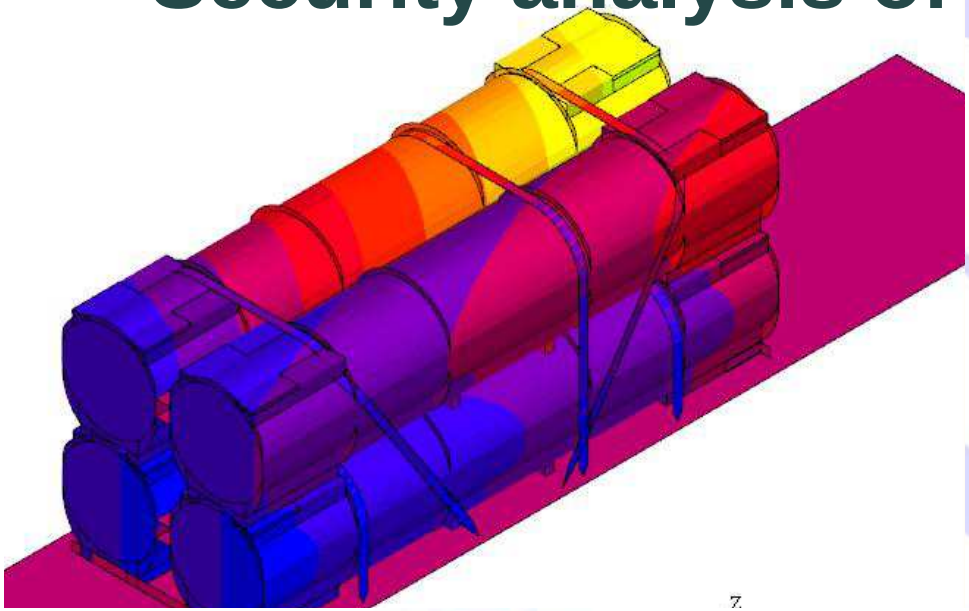
Project description:

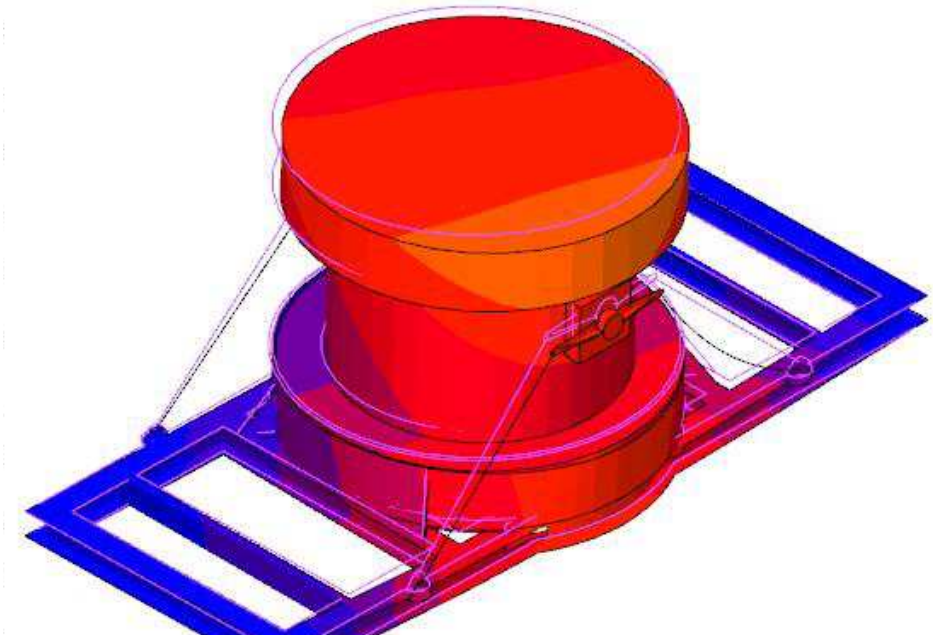
- Stainless steel vessel has a hole at the top through which high temperature gas is re-circulated during pressurization
- Top of vessel experiences creep-induced inward or outward buckling so that recirculation is hampered

Project deliverables:

- 3D model
- High temperature creep properties of stainless steel implemented (Norton creep method)
- Buckling phenomenon calculated and limits defined under which it is avoided

Security analysis of nuclear transport





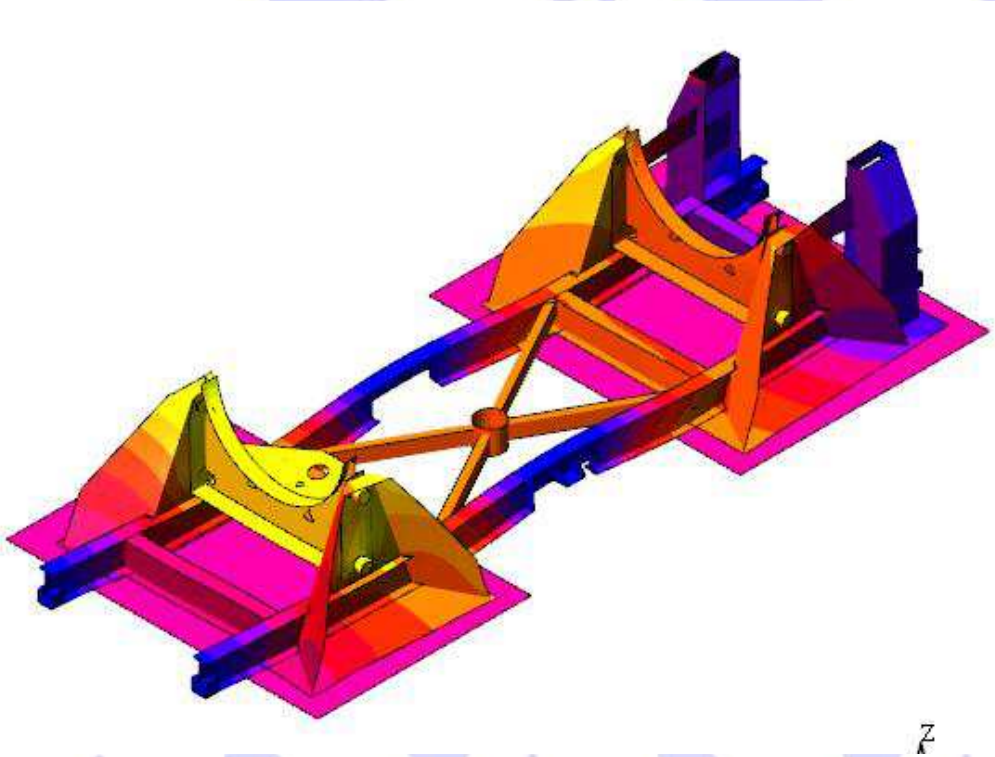
Project description:

- Stacked containers must be securely fastened to supporting chassis according to AIEA standards
- Design of fasteners

Project deliverables:

- 3D model with contact
- Dynamic acceleration load in different directions
- Design adapted to conform the AIEA safety standards

Crash analysis of chassis



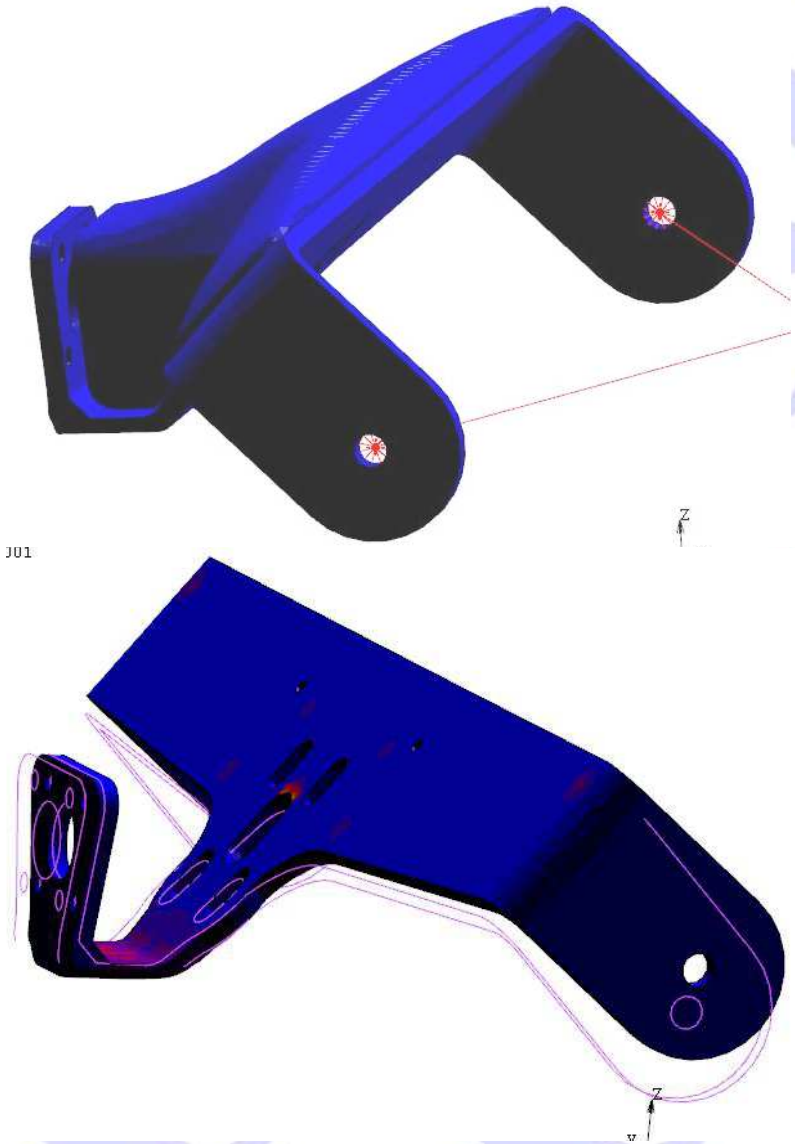
Project description:

- Chassis carries nuclear container
- Must comply AIEA standards (crash analysis)

Project deliverables:

- 3D model with contact conditions
- Dynamic acceleration load
- Chassis modified to comply to the standard.

Vibration fatigue

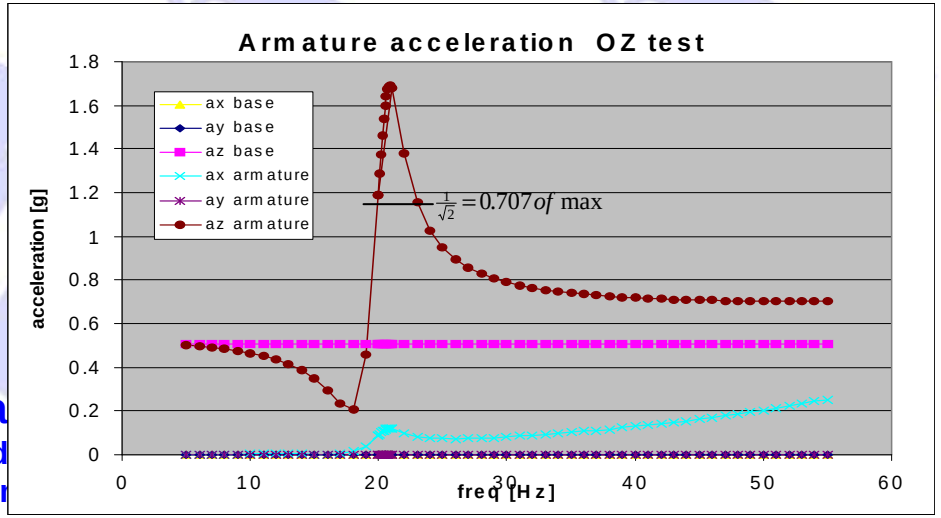


Project description:

- Light armature consists of steel brace backed by cast aluminum enjoliver must withstand high wind loads over extended period
- IEC 68-2-6 standard vibration test fails and is expensive to repeat on modified design

Project deliverables:

- 3D model takes into account correct contact conditions between brace and enjoliver
- IEC 68-2-6 standard vibration test implemented numerically
- Design modified virtually



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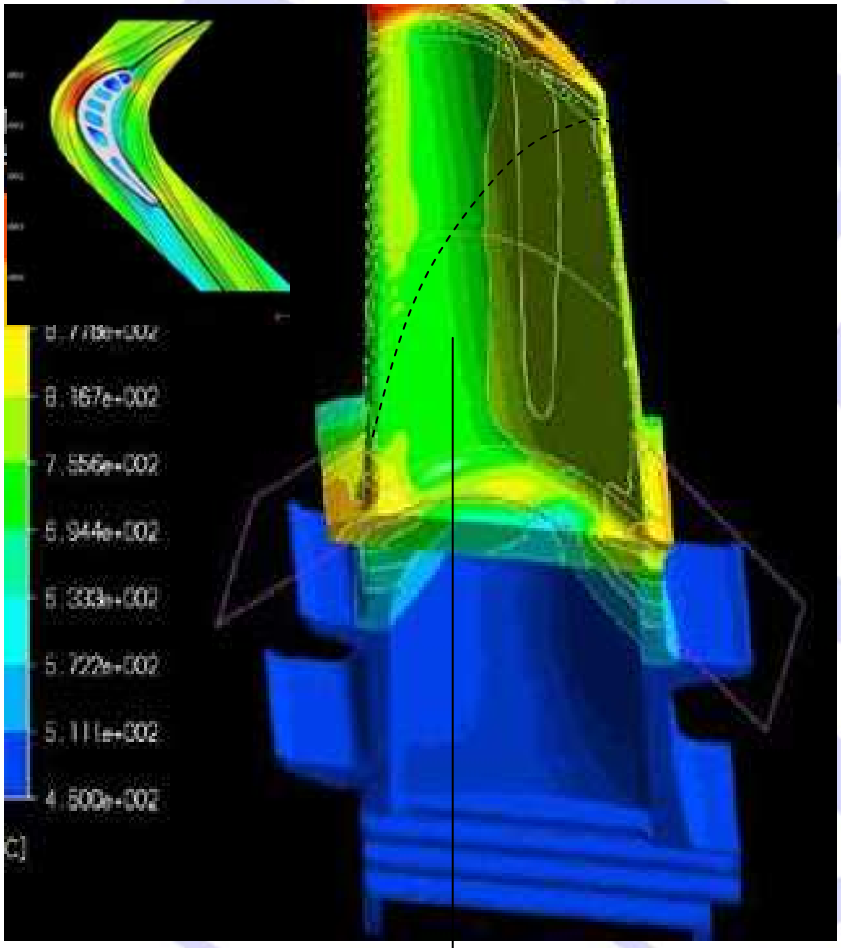
Kapellestraat 64 B-9220 Ha

Turbine blade thermo-mech creep analysis



Measuring path during rotation

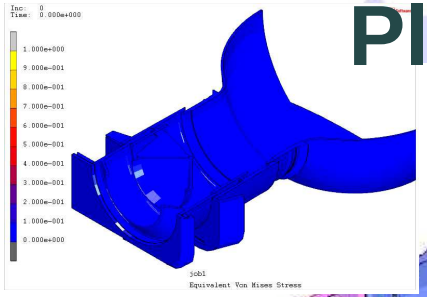
Project description:

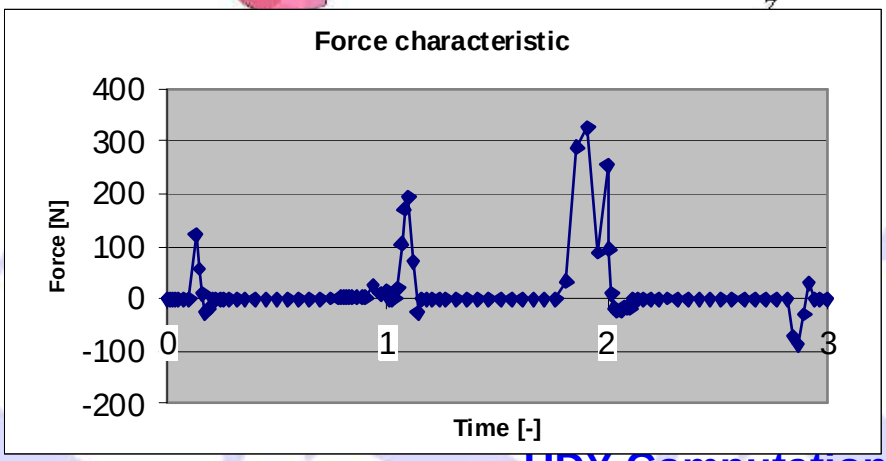
- Turbine blade rotates at high velocity, driven by steam externally and cooled by water internally
- How much is creep strain after 50000 h operating conditions?

Project deliverables:

- 3D model > 1 million elements to model the cooling channels and orifices
- CFD calculation to determine equilibrium temperature
- Thermo-mechanical calculation maps temperature field and applies centrifugal pre-stress, followed by creep steps up to 50000 h
- Special subroutine to extract temperature at intersection of blade surface with measuring “cone” to validate calculations against in-situ pyrometer measurements

Plastic bottle closure forces





roject description:

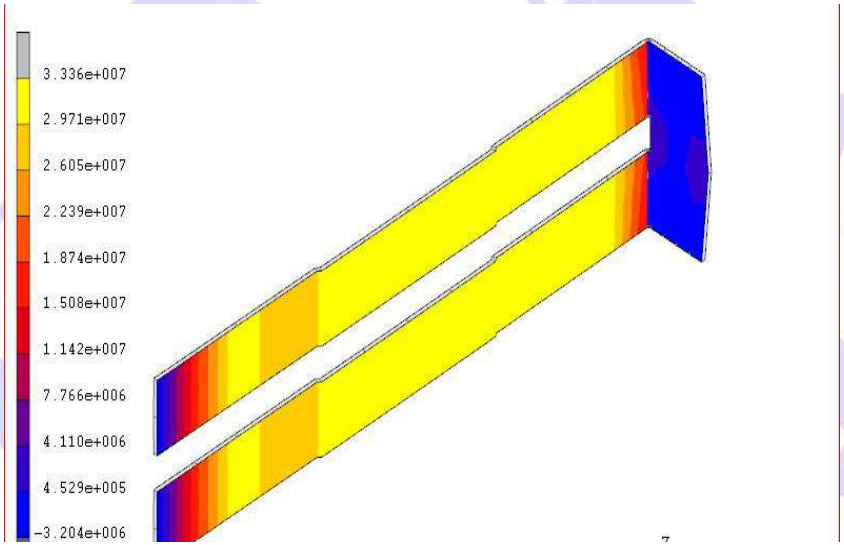
Plastic bottle is closed by cap and slider by snap-fit notches
What are the forces needed to close and open?

roject deliverables:

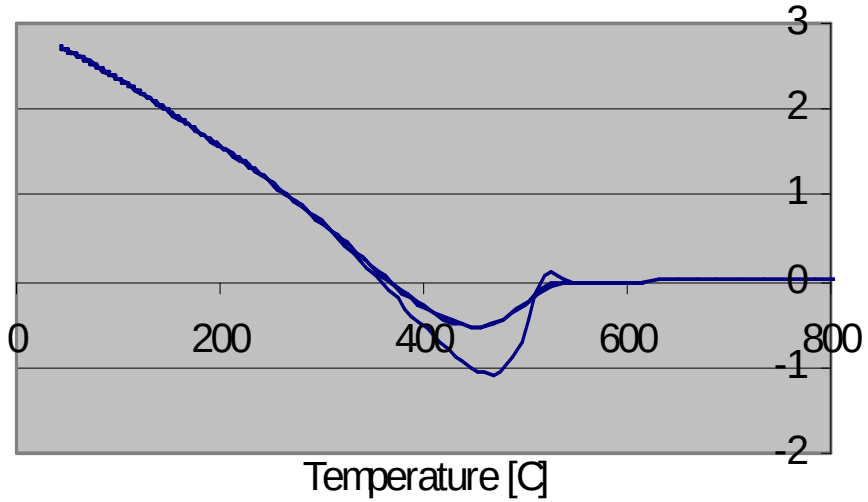
3D model with 3 contact bodies with friction
Closing and opening forces determines
Original design gave too high forces. Design adapted to obtain lower forces

- Variation in material parameters to obtain low and high limits of forces

Bending test on enameled steel



uy [mm] vs temp both runs combined



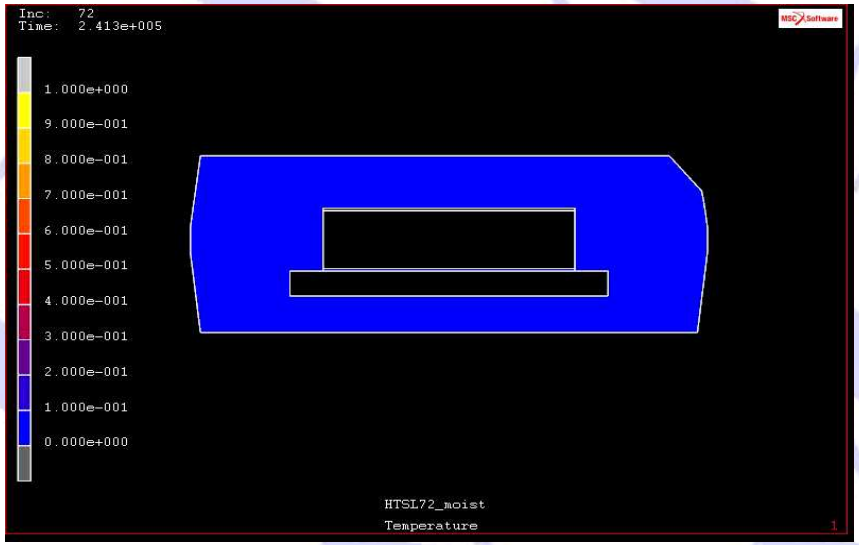
Project description:

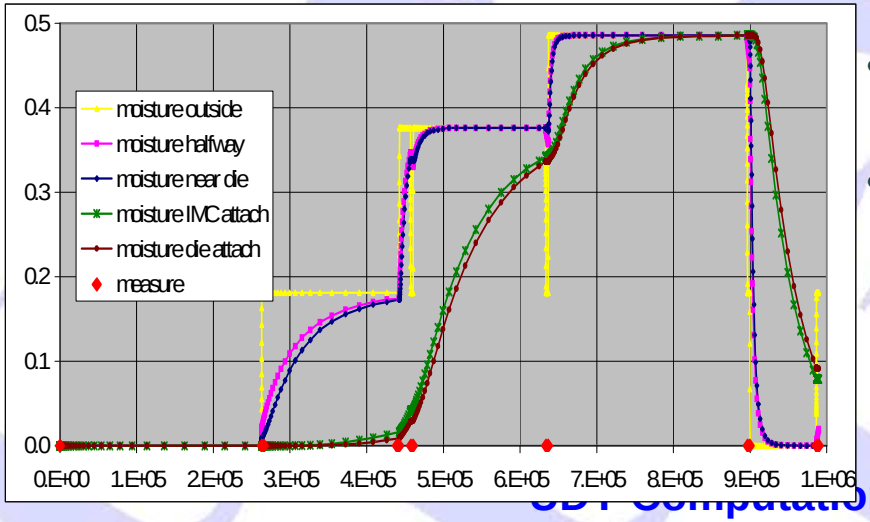
- Steel sample is coated with enamel and subjected to cool-down and warm-up (Klotz test)
- Due to intricate interaction of different CTE's and relaxation behavior of enamel, the sample bends differently during cooling-down and heating-up

Project deliverables:

- Visco-elastic enamel material parameters determined including rate-dependent effects (Narayamaswamy-Tool)
- Bending behavior exactly reproduced
- Insight in bending mechanism to correct enamel process parameters (cool-down rate, radiation effects etc) for production of enameled white goods

Moisture penetration and swell





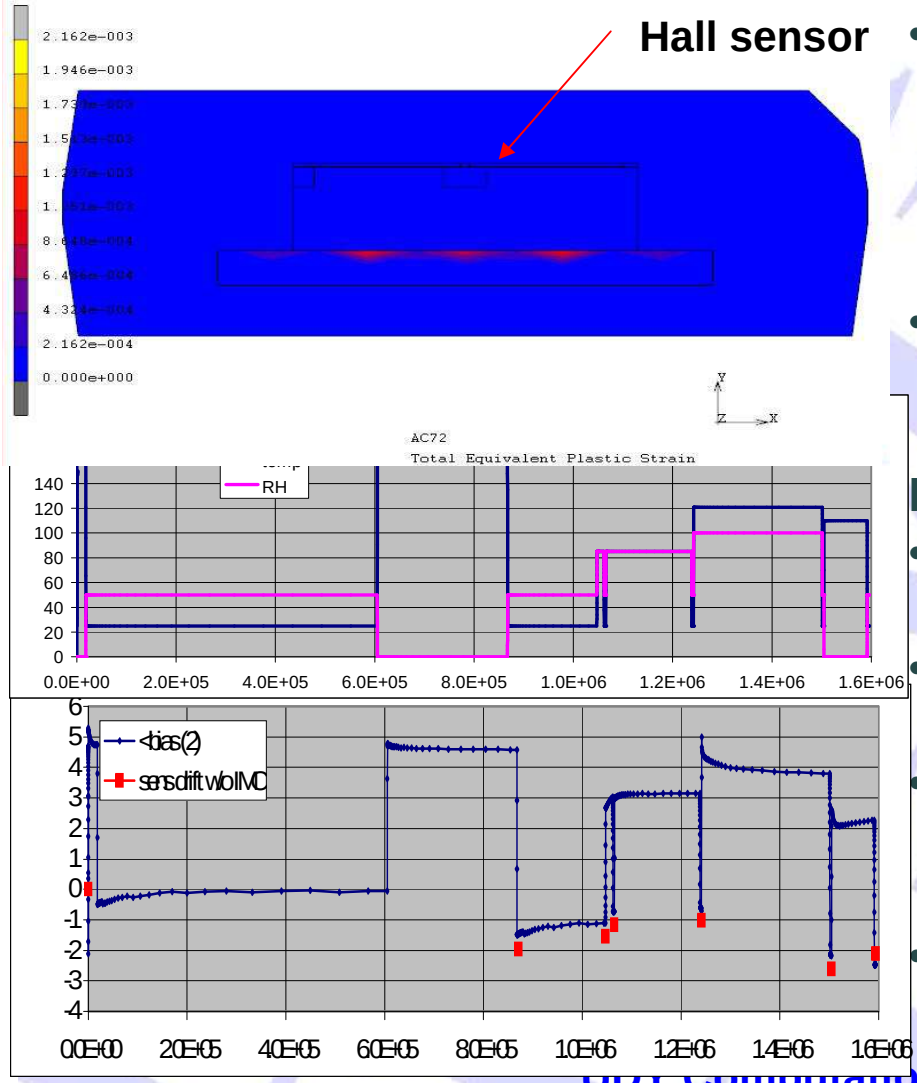
Project description:

- Plastic encapsulation of glued structure
- Thermal and humidity environment changes a.f.o. time
- Plastic and glue swell
- Causes damage at inner top surface

Project deliverables:

- Moisture penetration modeled via user programming
- Influence of glue on damage at inner top surface identified
- Remedied by choice of other combination of glue and encapsulant

Electronic sensor drift



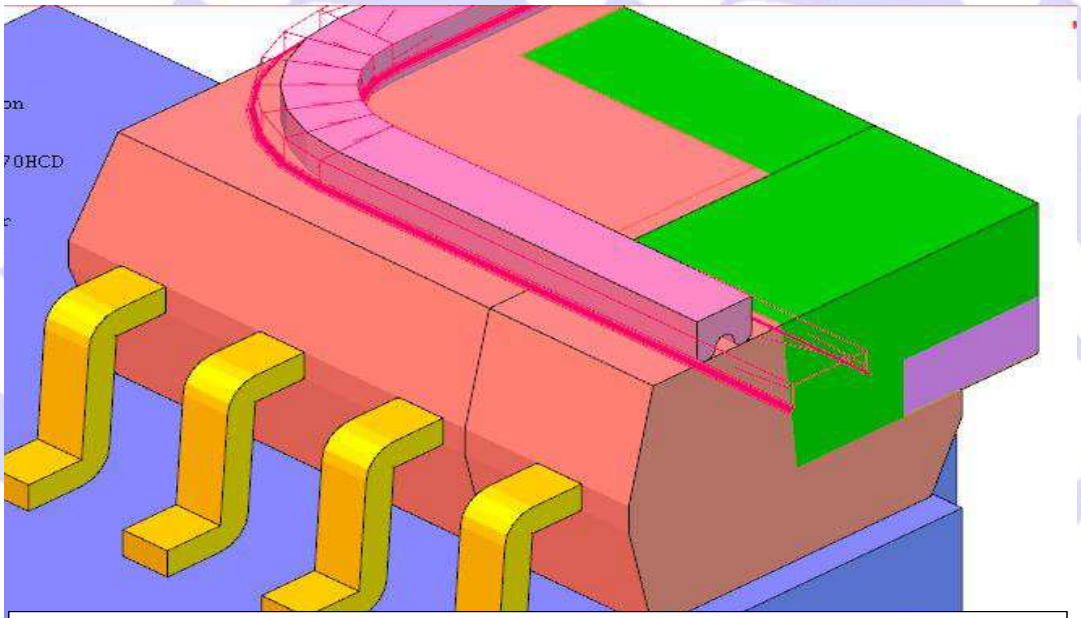
Project description:

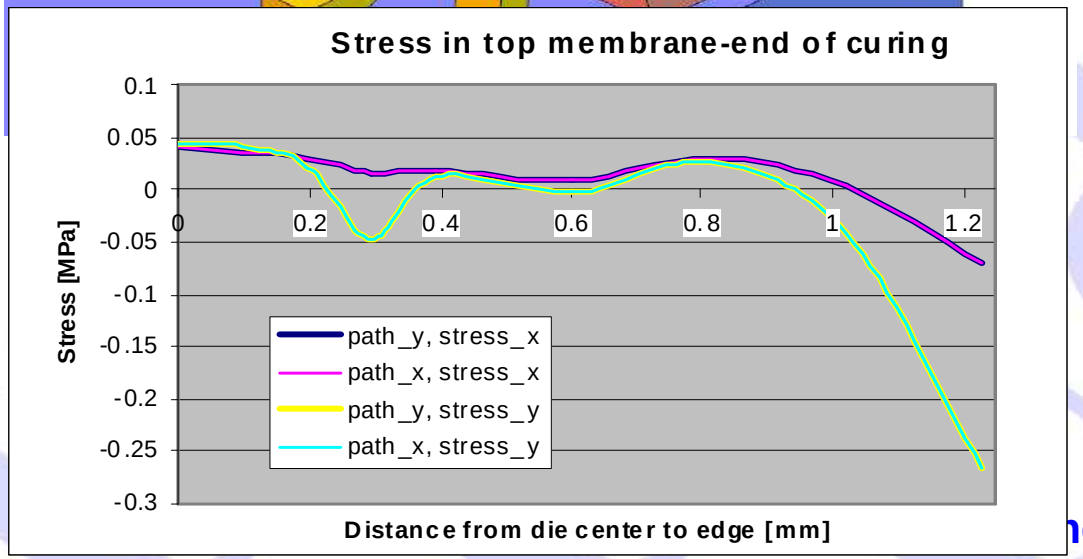
- Signal from magnetic Hall sensor on top of chip is influenced by
  - •Leadframe and die attach
  - •Material parameters
  - •Temperature and humidity
- Find the key influencing parameter to minimize drift

Project deliverables:

- Multi-physics coupled model
  - •Mechanical, Thermal, Humidity
- Visco-elastic, creep and plastic material properties
- Evolution of drift during combined changing of temperature and humidity simulated
- Red dots are from measurements

Pressure MEMS sensor





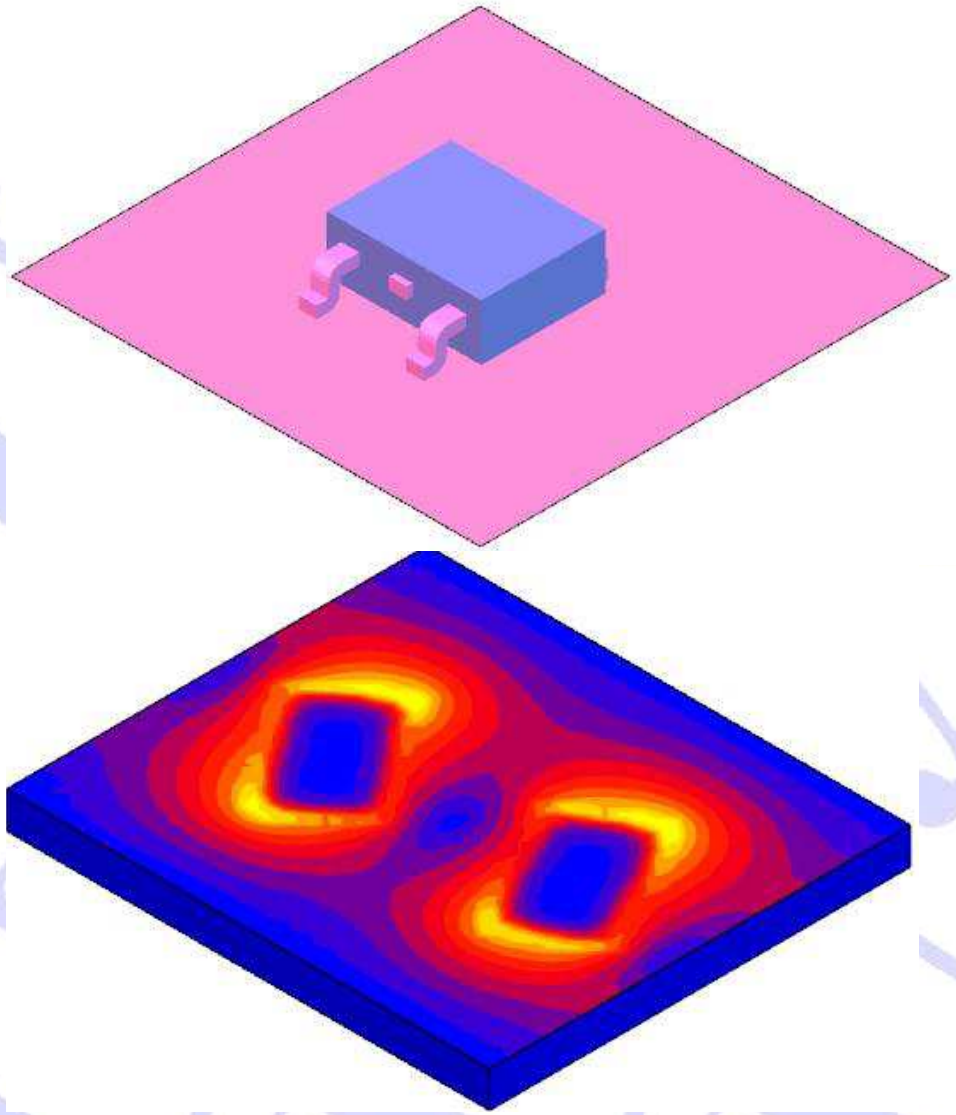
Project description:

- IC pressure sensor package has gel cavity to sense the pressure
- Rubber O-ring at top for air-tight connection of the vacuum
- What is influence of different gel materials on output signal
- What is influence of mounting pressure on O-ring tightness

Project deliverables:

- Curing of gel simulated
- Orthotropic material parameters for Si to extract correct signal
- Influence of die attach glue
- Contact analysis for O-ring

Power FET



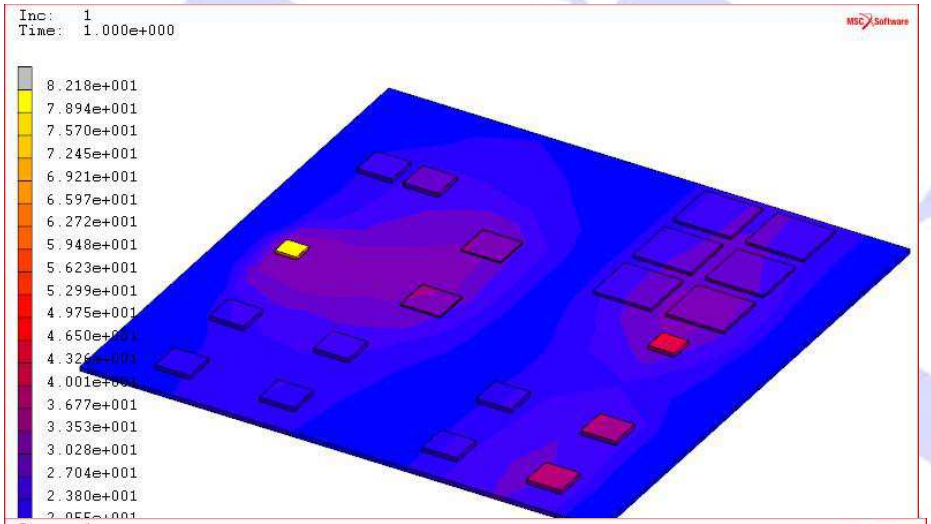
Project description:

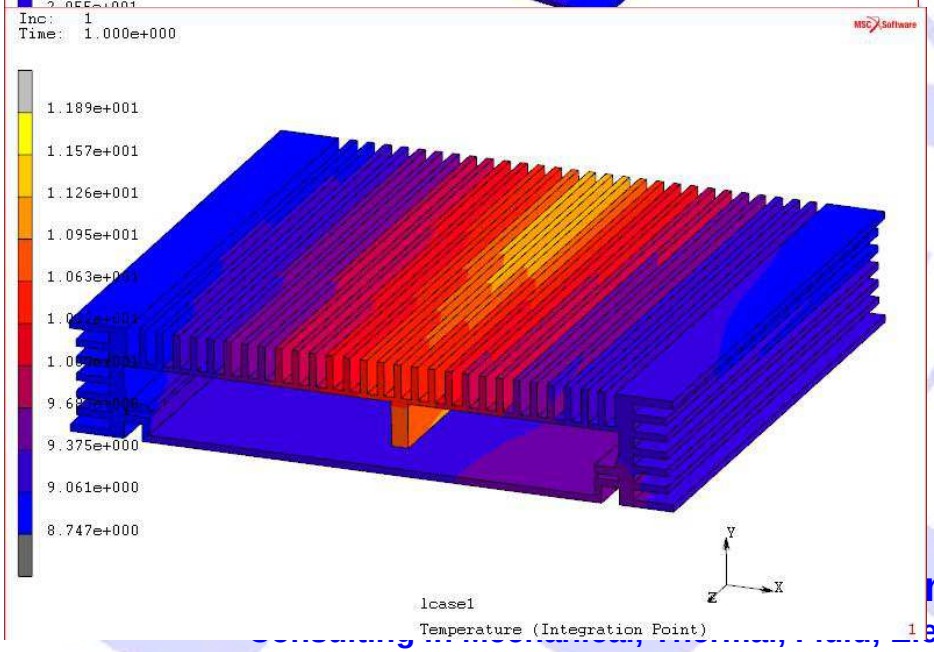
- Power FET package mounted on PCB
- 200 A current passes through stitches and heats the epi-layer
- What is current density and temperature during continuous and pulse loading

Project deliverables:

- Thermo-mechanical-electrical multi-physics analysis
- Many material parameters all temperature dependent
- Thin top layers of silicon die modeled in detail
- Die and package designed to arrive at required specs

Thermal management of PCB in electronic cabinet





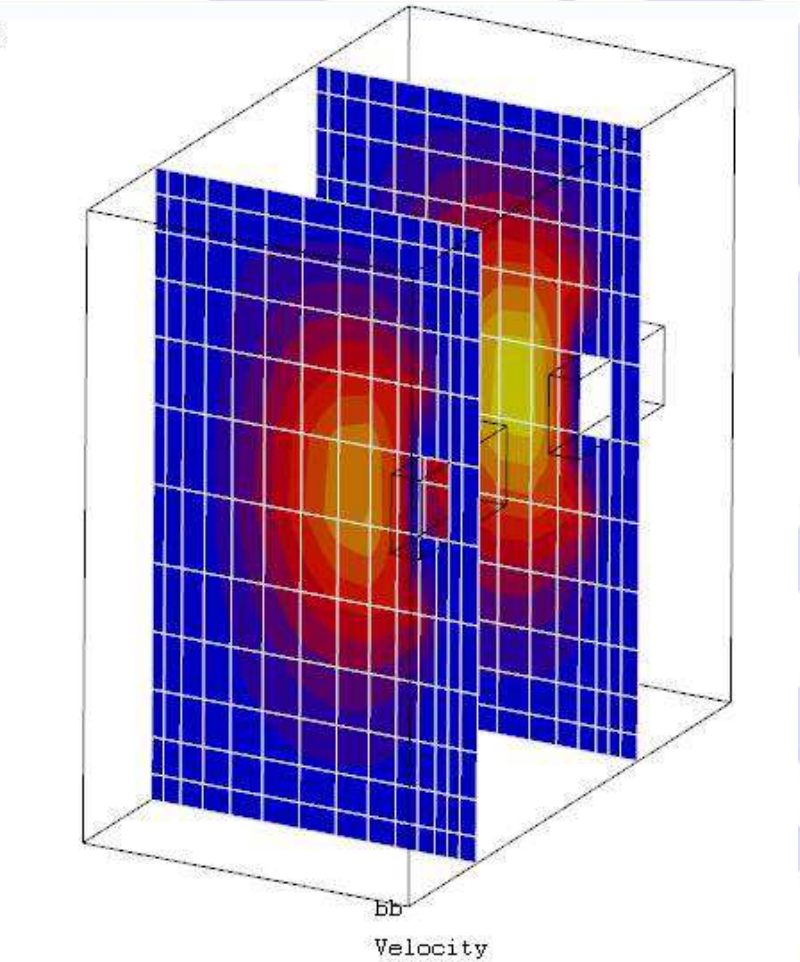
Project description:

- Electronic cabinet contains PCB with a number of chips
- PCB has 11 internal layers and thermal via's
- Maximum junction temperature required to be below 120 C without using fans

Project deliverables:

- 3D model of PCB and cabinet
- Detailed model of PCB including all layers and via's
- All junction temperatures determined
- PCB and cabinet redesigned to lower the max temperature below required limit

Natural convection airflow over chips in cabinet



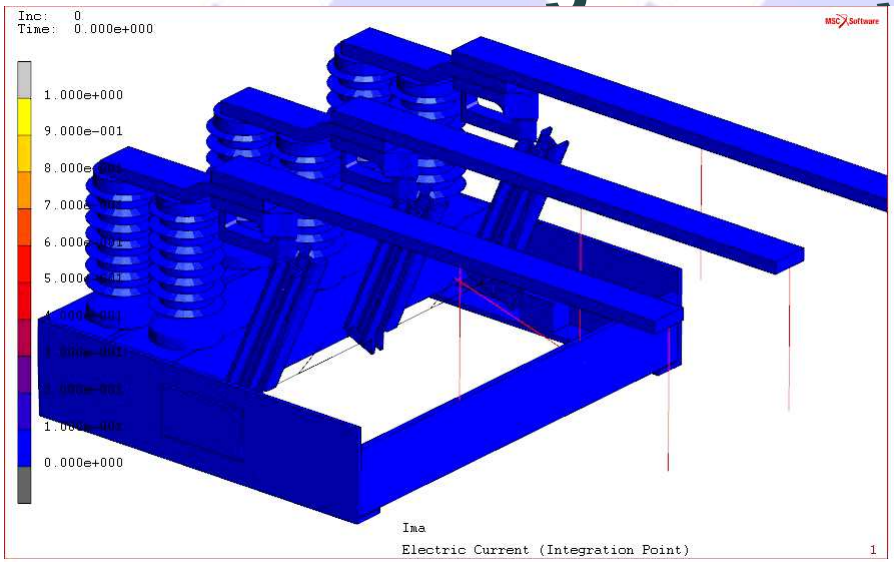
Project description:

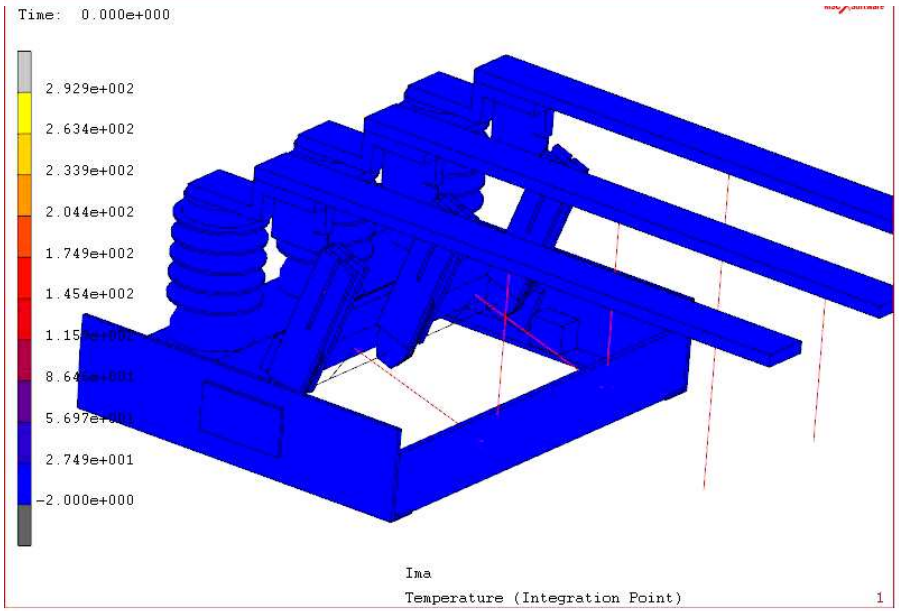
- Power chips are mounted on vertical printed circuit board
- Cooling only by natural convection required

Project deliverables:

- 3D CFD model
- Airflow inside cabinet simulated
- Maximum temperature at chip package surface determined
- Using Rth value from chip supplier, maximum junction temperature determined
- Redesign of cabinet and PCB layout to lower the junction temperature

3-Phase high-voltage earthing switchgear





Project description:

- Switch must withstand 15 kV 50 Hz shortcut to earth during 1 s without damage
- Simulation challenges:
  - •Transient calculation of 50 cycles
  - •Magnetic field, forces and current in conductors
  - •Mechanical, electrical and thermal contact
  - •Shock impact and rebound
  - •Joule heating
  - •All in 1 software environment

Project deliverables:

- 3D coupled multi-physics model (Magnetic, Electrical, Mechanical, Thermal)
- Family design of 30-50-62 kA versions
- Completely virtual-prototyped → all first physical prototypes certified!

onal Engineering

3-Phase high-voltage earthing switchgear

Device description

- The switchgear is used to disconnect (“earth”) from the high-voltage mains supply (15 KV) in emergency case
- This is achieved by “shooting” earthed rotating spring-loaded “knives” into the high-voltage conductors
- The electro-magnetic forces on the conductors are very high and time dependent causing vibration which tends to hamper the contact. This causes sparks, damage to the contacts and extra heating
- Good contact must be realized in very short time to prevent explosion of the switchgear. Springback must be minimal

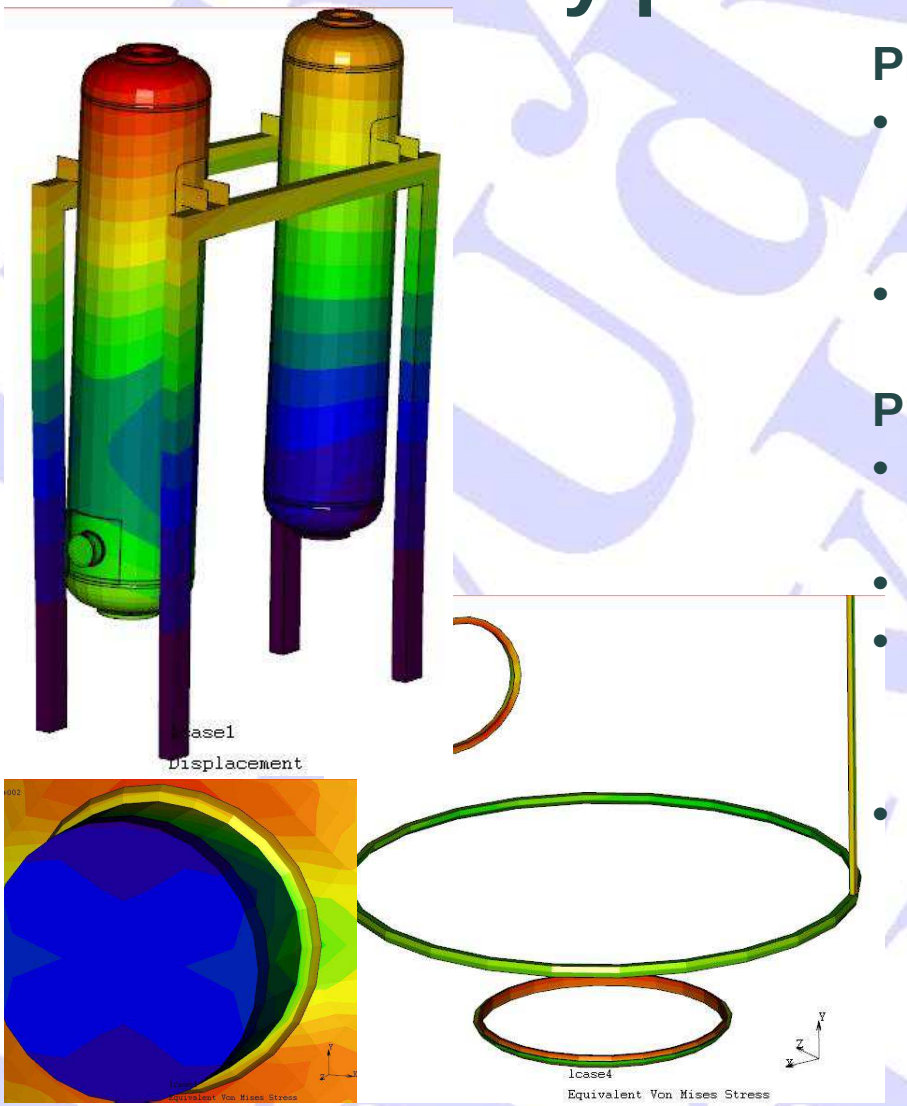
Simulation challenges

- One simulation environment is mandatory because of 4 coupled fields (magnetic, electric, mechanical and thermal) which must converge during each time step→ MSC.MARC with user subroutines
- Transient dynamic calculation of 50 sinusoidal mains cycles (1000 time steps of 1 ms)
- Non-linear material properties, e.g. temperature dependent and plasticity
- Calculation of magnetic induction and forces on conductors via user subroutines
- Simultaneous electrical, thermal and mechanical sliding contact during each time step
- Behavior of impact and rebound of “knives”
- Local heating-up from the air-spark prior to contact
- Joule heating during contact

Project deliverables and benefits

- Complete virtual design of a family of 15 kV earthing switchgears for 30-50-62 kA (all components such as “knives”, contact surface geometry, pre-stressed springs, isolators etc)
- CAD models made FROM optimized FE model saves “drawing” time
- After virtual optimization, the physical prototypes are tested and certified by official testing laboratory
- Virtual optimization of model learns what can go wrong and leads towards patented design
- All prototypes first time right means huge saving in time and certification costs
- Unique quality product at competitive price
- Less than 6 months from idea to production

Weld reliability pressure vessels ASME 553



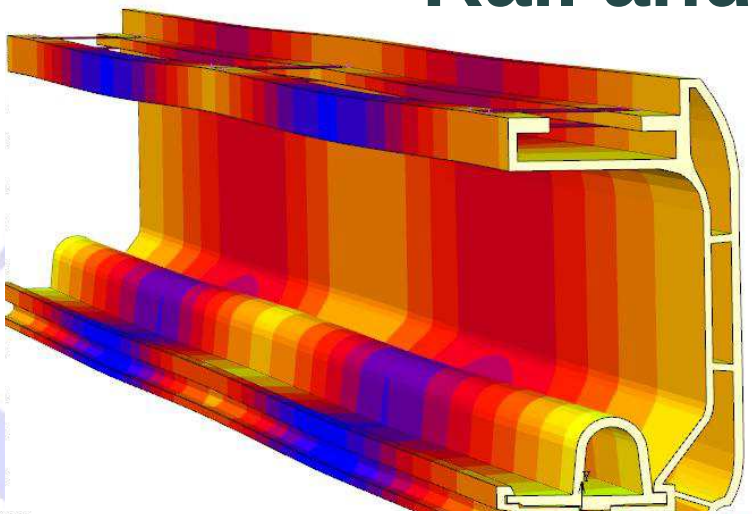
Project description:

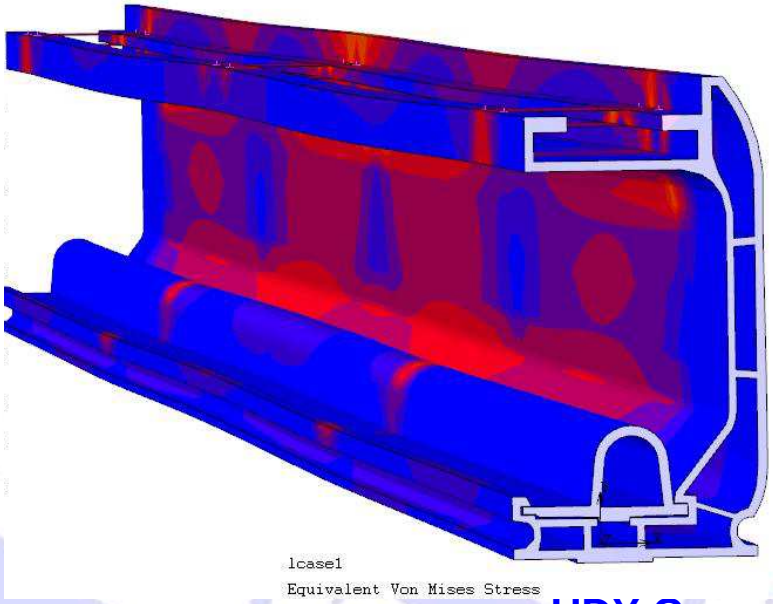
- Two tandem pressure vessels are temperature cycled (alternating) with hot/cold gas
- What is fatigue lifetime of weldments

Project deliverables:

- Coupled thermo-mechanical 3D model of vessels including frame
- Nozzle and weldments meshed in detail
- Fatigue lifetime and stress linearization of weldments determined according to ASNE 553 procedure
- Vessels improved as to reach required 20000+ cycles

Rail and roller bracket



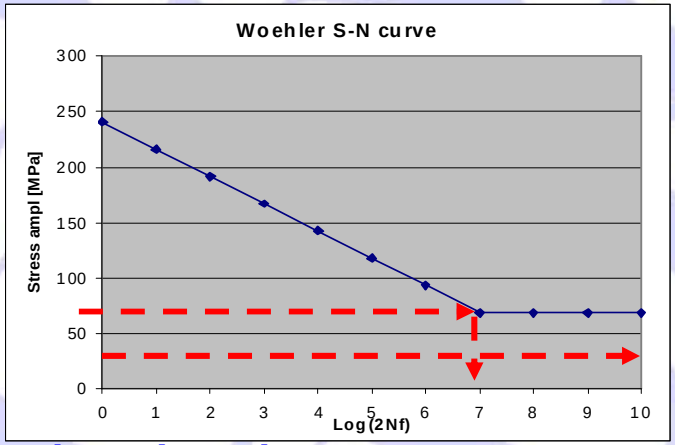


Project description:

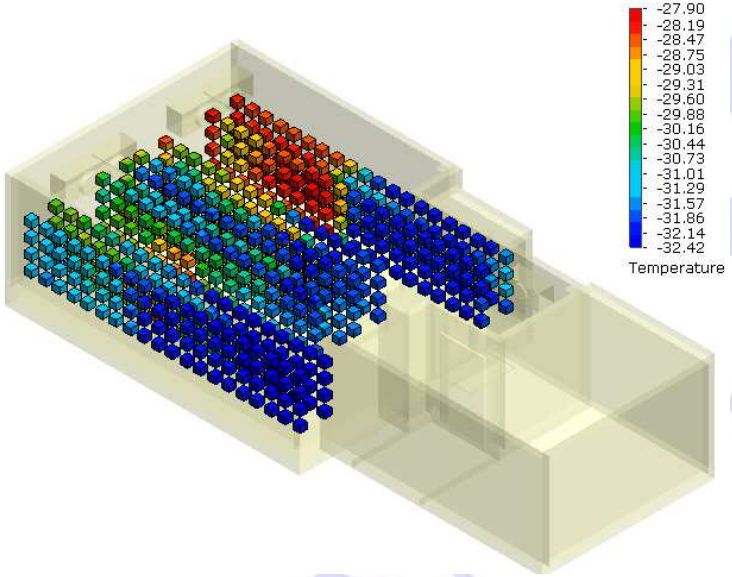
- Rail and roller bracket for sliding door cooling house

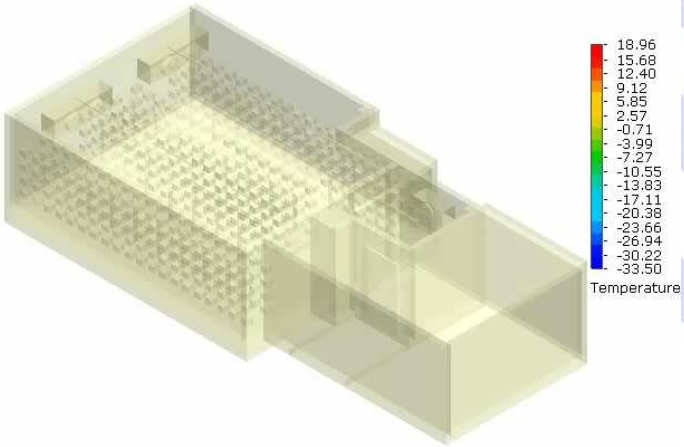
Project deliverables:

- 3D fully coupled Multi-physics model
- Moving bracket over rail causes time-varying deformations and stress
- Fatigue lifetime determined and thicknesses adapted as to reach “infinite” lifetime



Freezer room





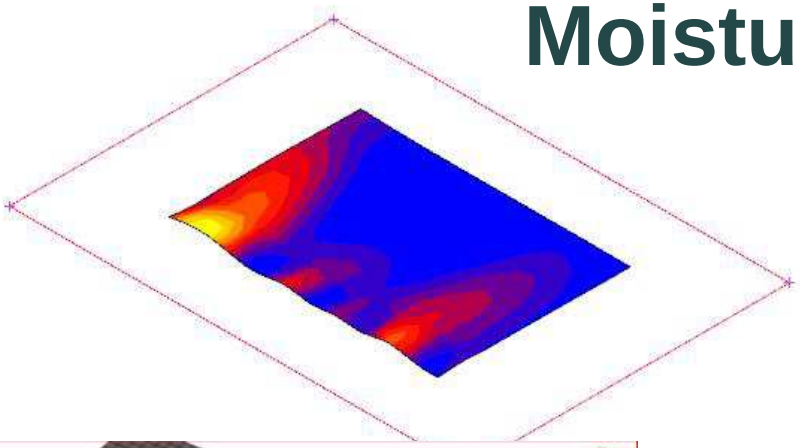
Project description:

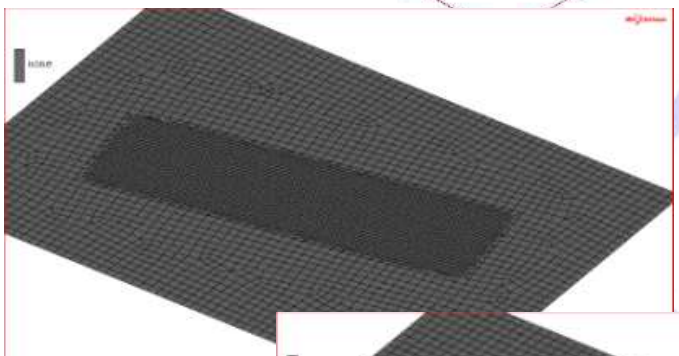
- Complete design of freezer room for pharmaceutical recipients

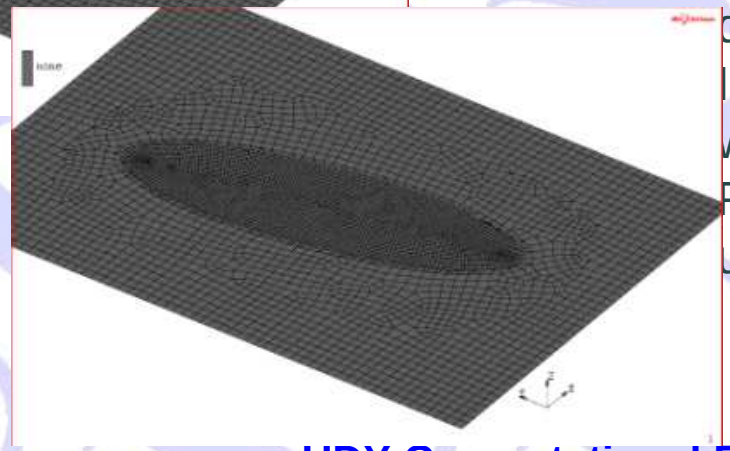
Project deliverables:

- 3D CFD model of room wall, doors, lobby, fans and recipients
- Simulated:
  - •Cool-down time of recipients
  - •Effect of fan switching left <> right
  - •Effect of door open/close
  - •Effect of addition of new recipients
  - •Etc

Moisture ingress







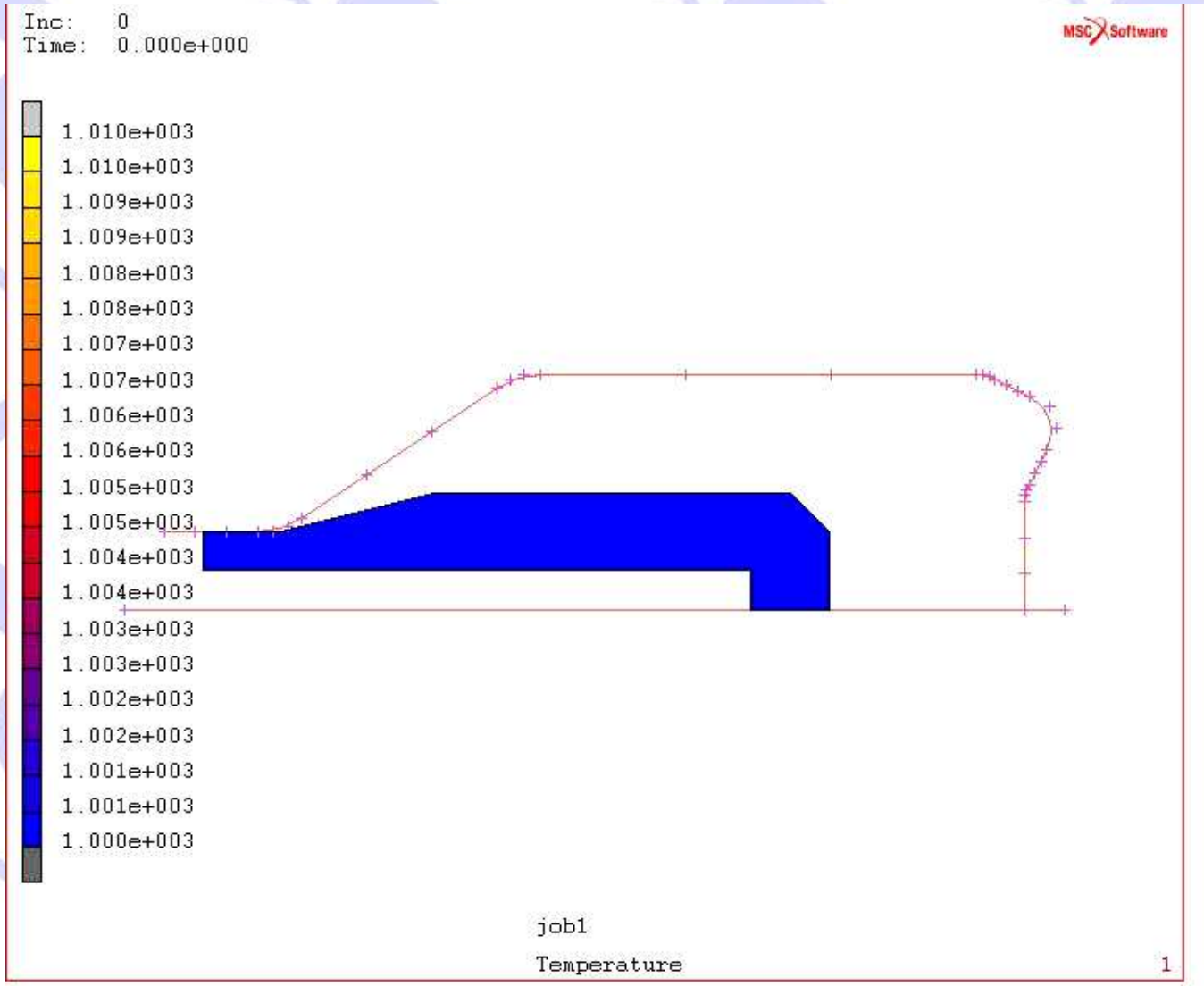
Project description:

- Moisture ingress in paper (from environment and/or ink) wrinkles paper
- This hampers print quality

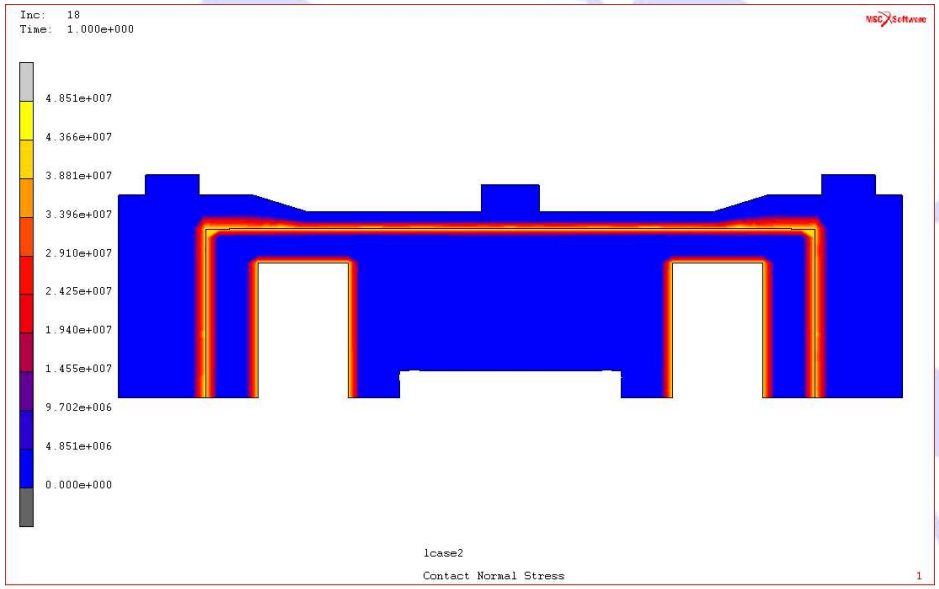
Project deliverables:

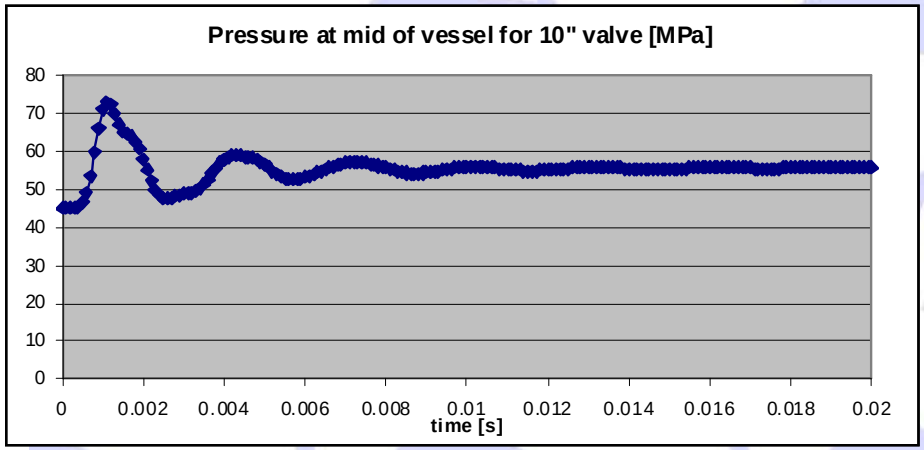
- Moisture ingress simulated using ingress mechanism from literature
- Also side ingress
- Moisture distribution imported in FE model to calculate resulting deformations for paper on flat surface
  Influence of time, paper thickness, wetting surface, etc
  Parametric model for non-specialist users

Blowforming of bottle



Explosion of valve in tank





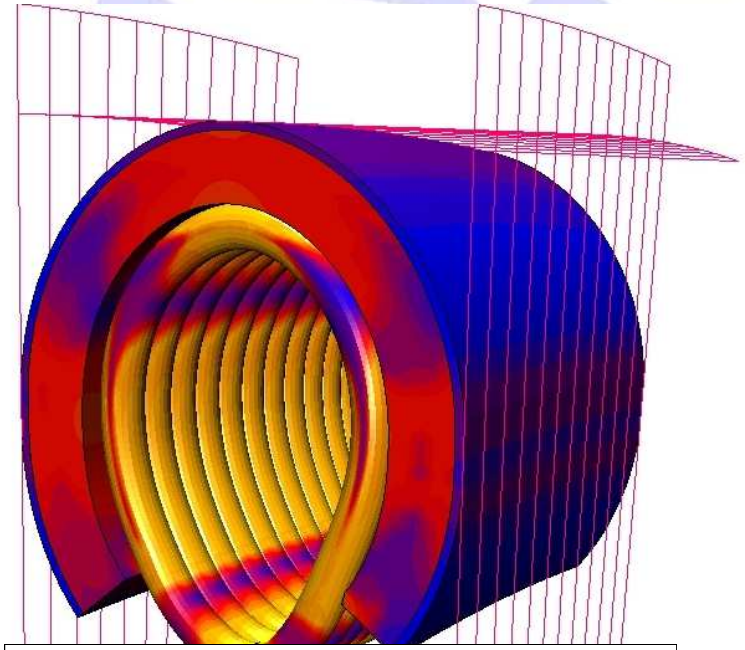
Project description:

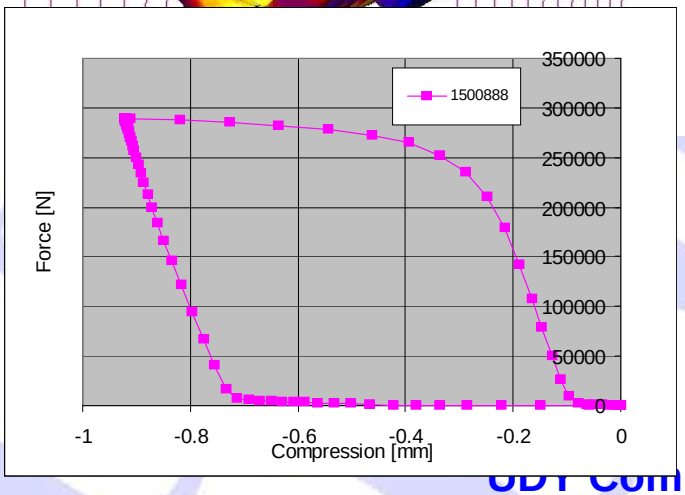
- Tank is used to test underwater explosions of e.g. valves
- Design of lids, wall thickness, radial reinforcements

Project deliverables:

- Tank, lids, valve and dead volumes modeled as axi-symmetric
- Transient dynamic calculation of pressure taking into account the varying compressibility of water
- Tank design adapted to withstand the required explosions

Spring-loaded metal seal





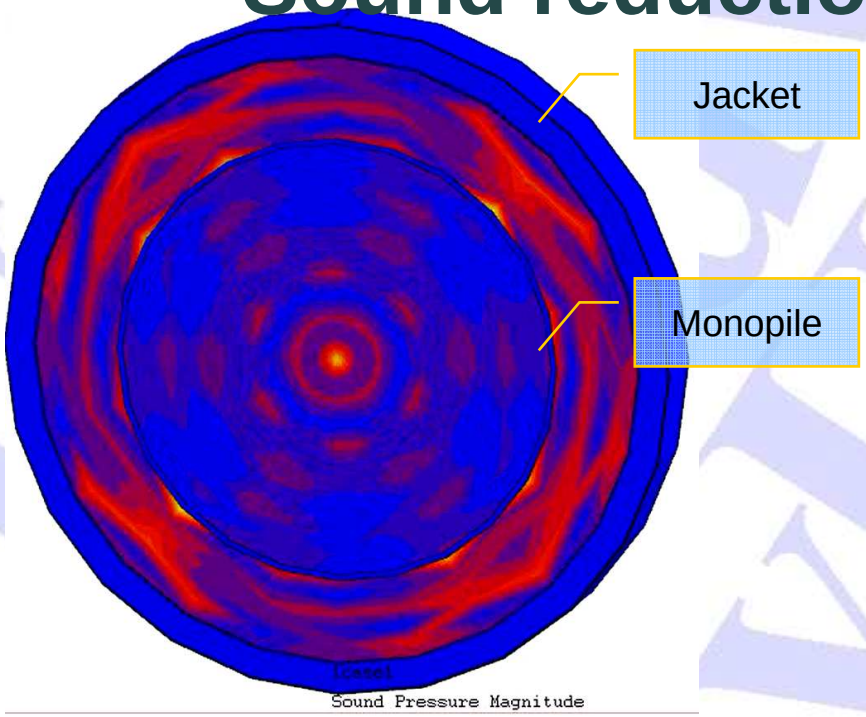
Project description:

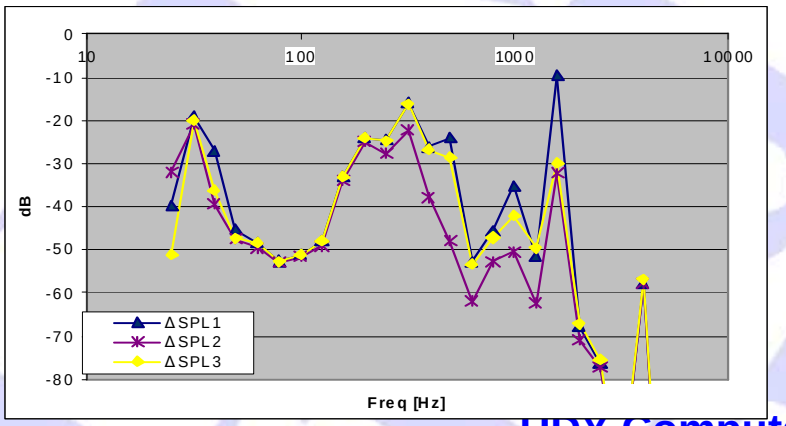
- Metal seal used for UHV (Ultra high vacuum) has internal spring to enhance its stiffness when pressed in groove
- Coating (tin, silver, gold) used to fill roughness of contacting surfaces designed
- Problem: contact stress decreases to zero a.f.o. time, hence possible leaks

Project deliverables:

- 3D model (sector) of contacting bodies
- Influence of heat treatment on plasticity and creep
- Compression and spring-back
- Indentation simulations on coating materials
- Predictive model to design all aspects of spring-loaded coated metal seals

Sound reduction pile sinking





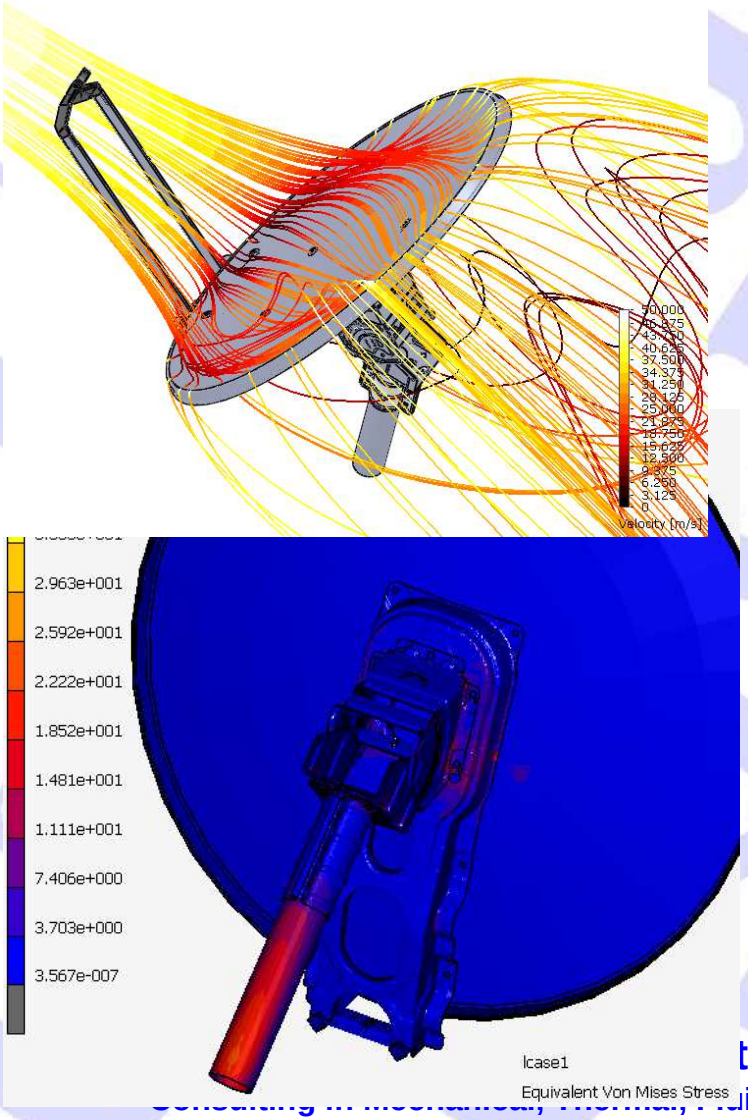
Project description:

- Sinking of monopile cause disturbance of environmental sea life due to high sound levels

Project deliverables:

- Addition of surrounding jacket to isolate the sound radiation
- Transmission loss (and cost) optimization of width, thickness, inner sound absorbent coating and/or linings etc
- First-time-right, hence important cost savings

Wind load and deformation



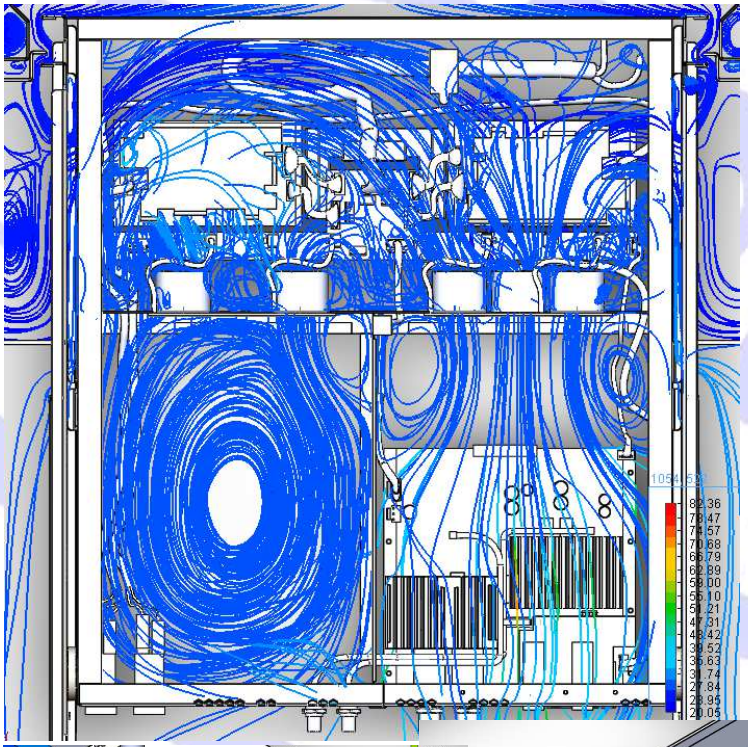
Project description:

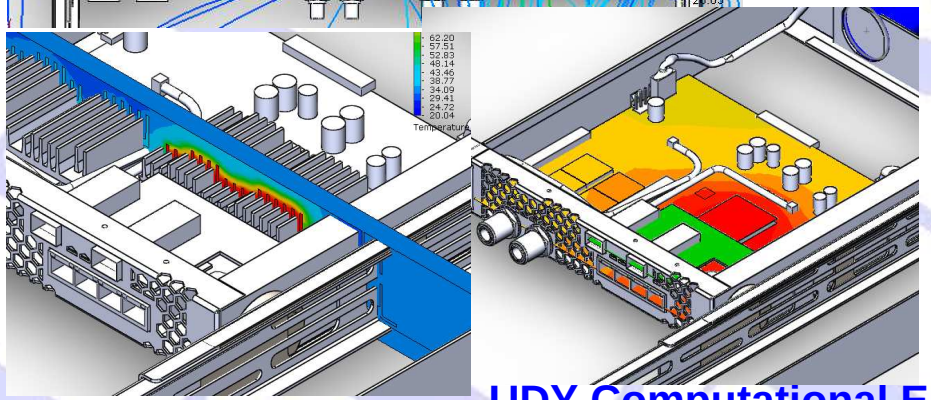
- Disc antenna must withstand wind load up to 180 km/h without losing its pointing accuracy
- What is deformation and stress

Project deliverables:

- Wind load applied via CFD flow analysis (several wind directions)
- Pressure on disc imported in FE program
- Deformation and stress calculated
- Supporting structure adapted as to comply to required pointing accuracy < 0.15 degrees

Server thermal management





Project description:

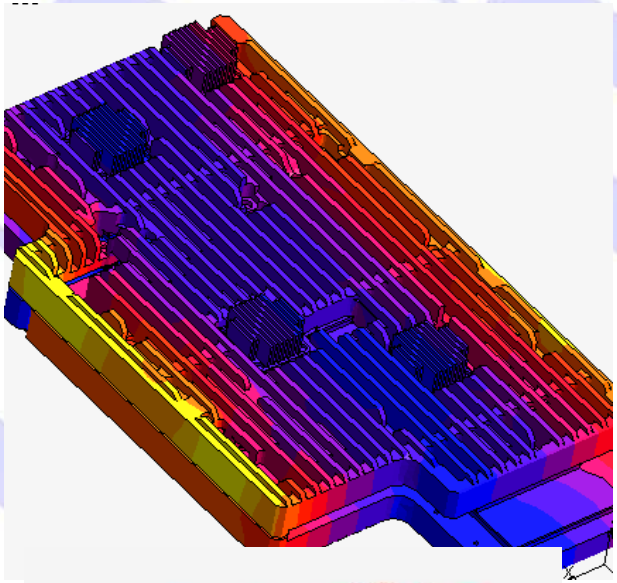
- Server installed in server room has decreased lifetime due to inadequate cooling
- Requires new rack design

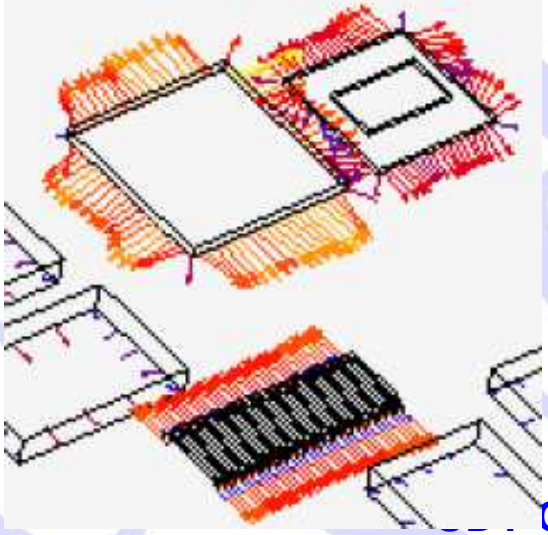
Project deliverables:

- Server interior and exterior modeled, including heat sink details and internal fans
- Air flow and temperatures of critical chips (BGA's) calculated

Better fan configuration implemented to overcome air passage blocking of heat sinks

Reliability of electronic device





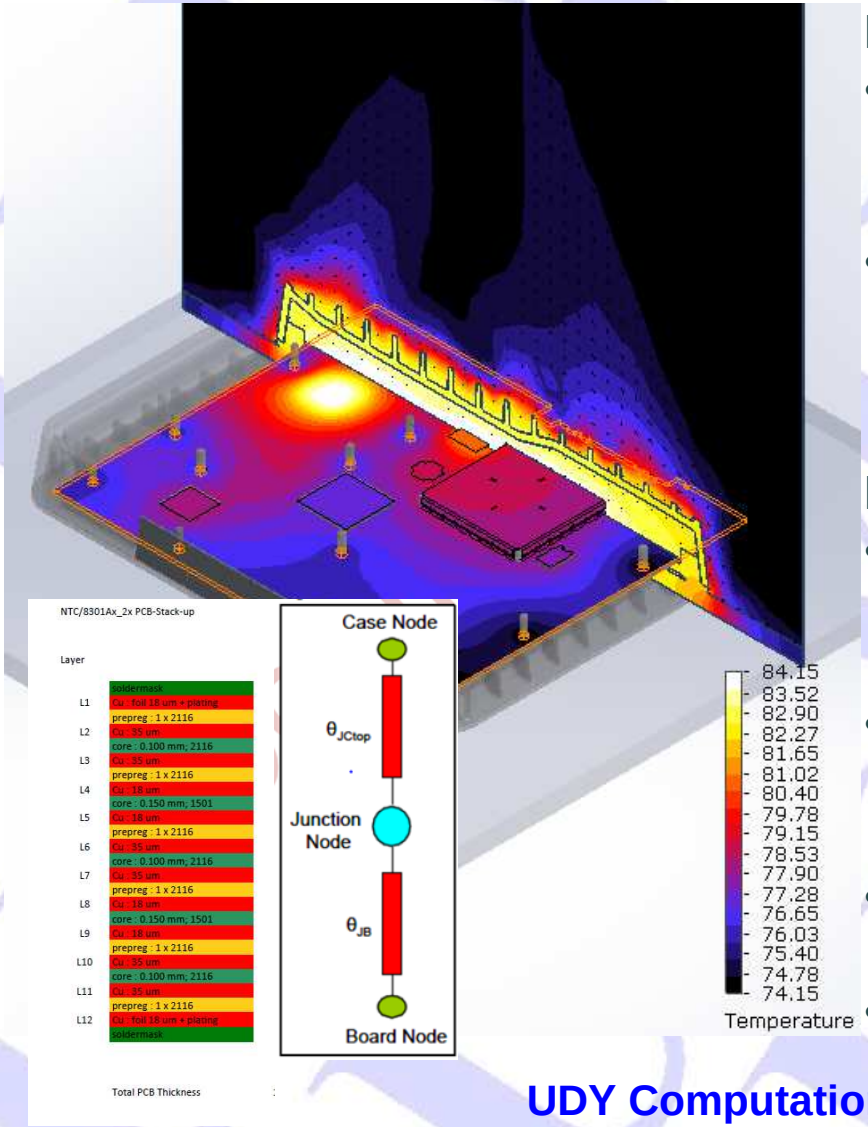
Project description:

- Electronic device is subjected to high external and internal thermal loads
- This decreases the lifetime of the internal components and solder interconnections
- Need cabinet with better heat transfer to environment

Project deliverables:

- Several new cabinets with integrated heat sinks designed
- Complete thermal modeling of external and internal (PCB's and critical BGA's) components
- Calculation of forces on solder interconnections of BGA's and connector

Thermal management of PCB in enclosure



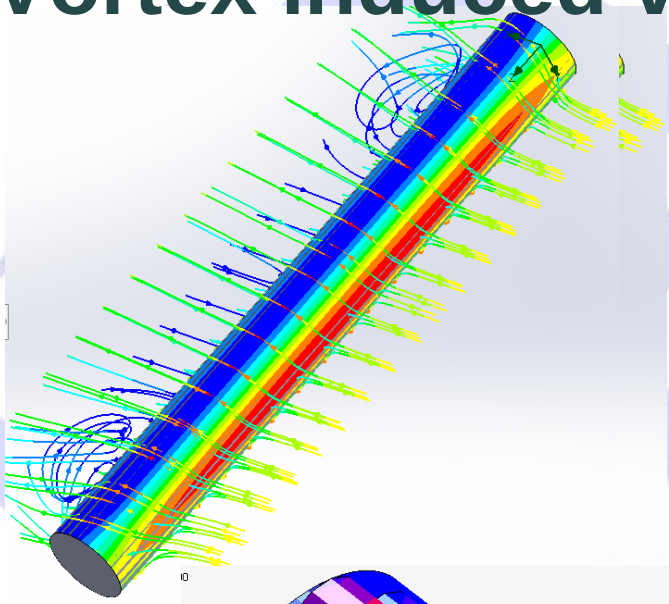
Project description:

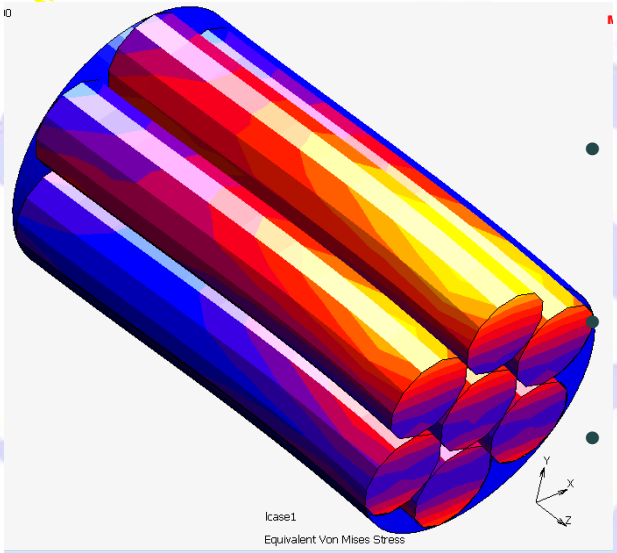
- High speed modem operates at environmental temperature of 50 C and at high altitude
- Maximum junction temperature allowed is 100 C for both table top and wall mount

Project deliverables:

- PCB with most power consuming chips and die-cast aluminum enclosure with ribs modeled in 3D
- Global and local thermal characteristics of PCB lay-up (12 layers) determined with tool
- Combined internal, external flow and conductivity
- Final junction temperature determined from 2-Resistor network

Vortex induced vibration of mooring cables





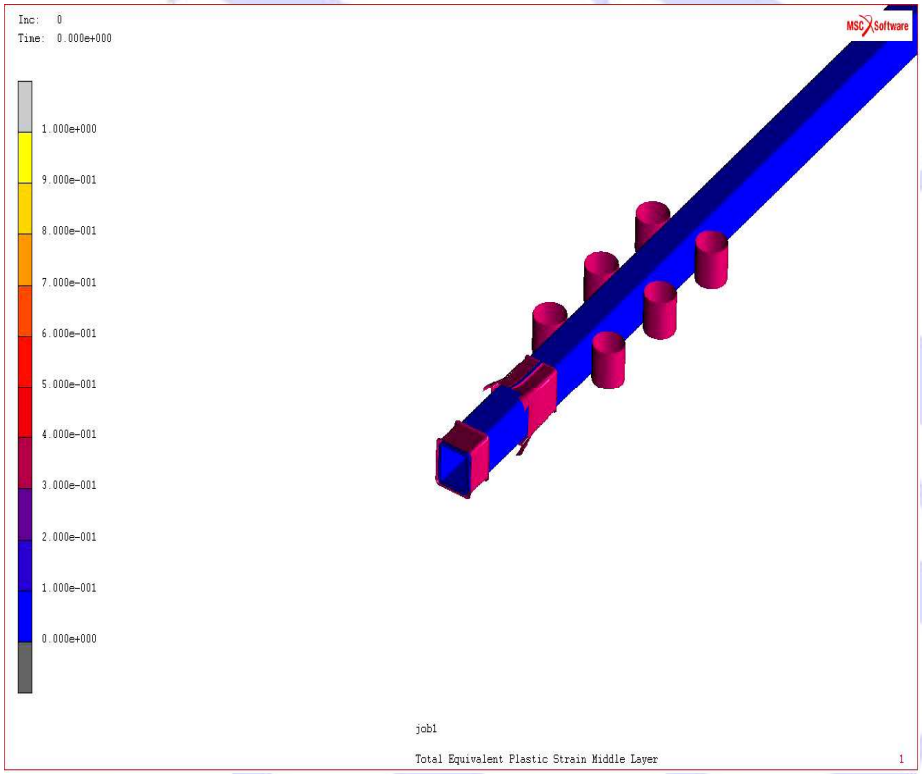
Project description:

- Offshore oil rig is subjected to varying loads (from swell to choppy sea) which cause its mooring cables to wobble
- This results in varying tensions and stress/strains in the mooring cables and decreased lifetime

Project deliverables:

- Wave interaction applied as mechanical impedance (per element, obtained from CFD analysis)
- Strains transferred to detailed local models which includes sub-ropes and winding (end) details
- From local stress, fatigue lifetime is determined
- Model updated to include effect of friction between sub-ropes

Freeform bending



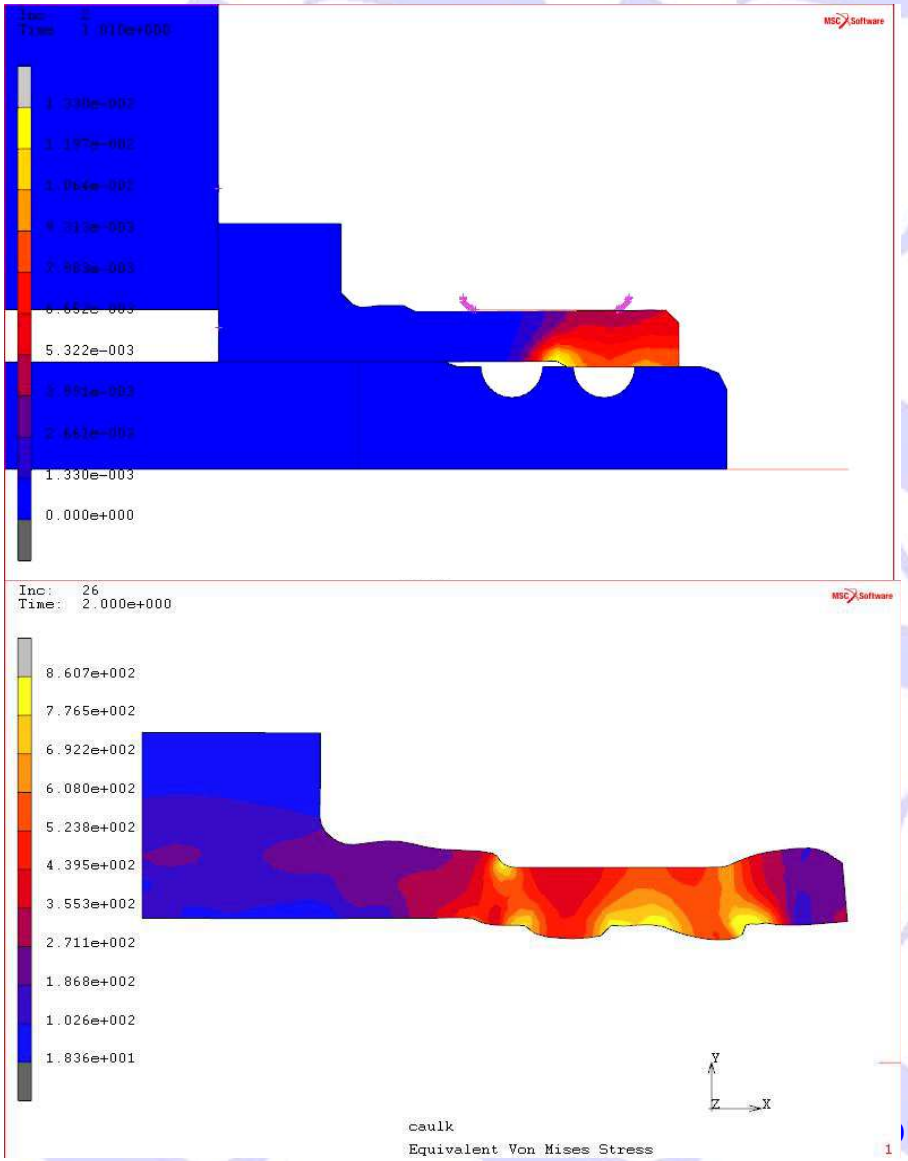
Project description:

- Freeform bended profile has unwanted deviations from target shape due to changing plasticity properties of material batch

Project deliverables:

- Influence of material yield stress and hardening variations on final shape of freeform bended profile simulated
- Design rules provided to control the deviations, depending on material parameters

Shrink fit and caulking



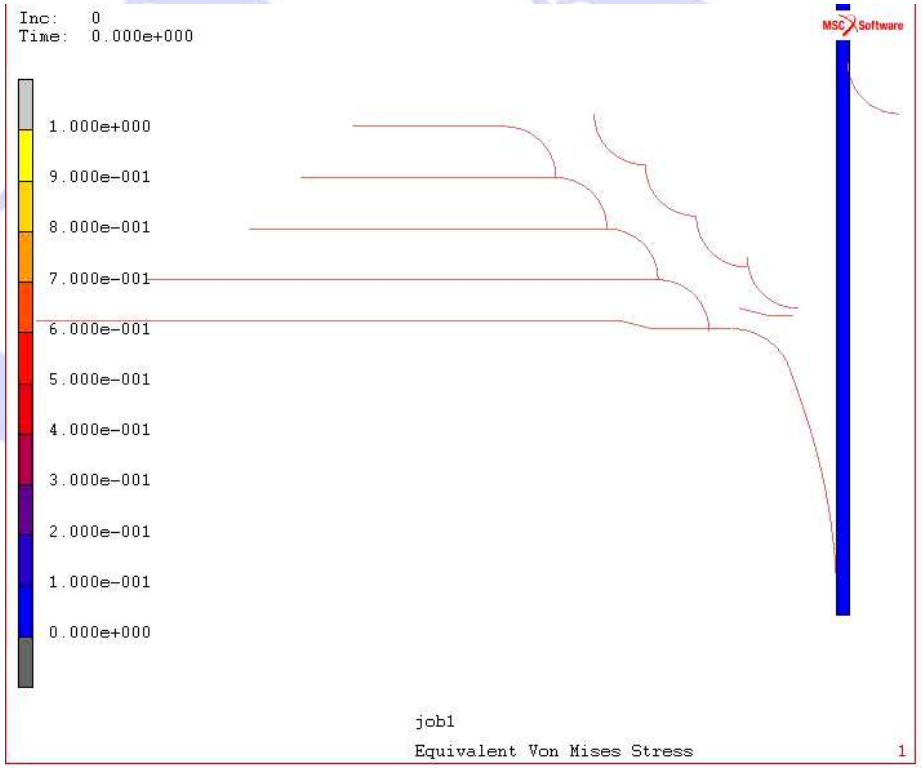
Project description:

- Armature of electromagnetic switch valve must be fixed to the plunger without changing its position
- Bushing is press fitted over plunger and then is caulked into the groves of the plunger
- Determine process conditions so that plunger position drift remains within tolerance
- Determine the fatigue lifetime of valve plunger

Project deliverables:

- The press fit and caulking highly non-linear process is modeled completely
  - Large strains and plasticity
- Process condition to minimize plunger drift and fatigue lifetime determined

Multi-stage forming



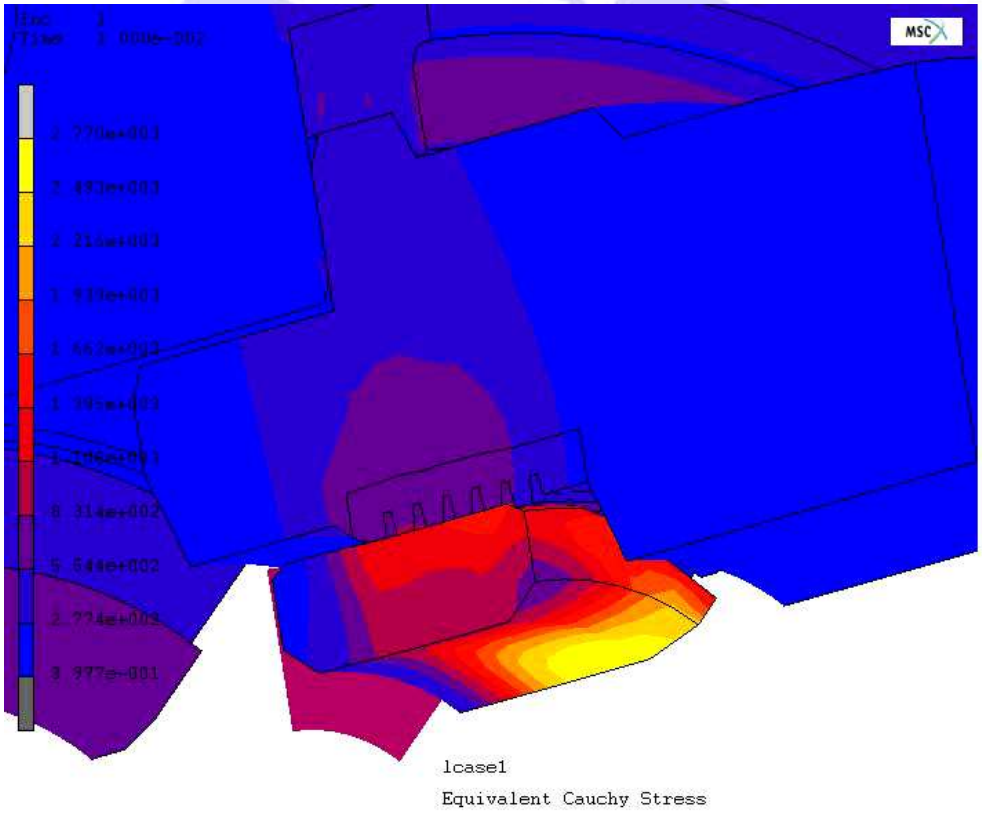
Project description:

- Barrel is formed using multi-stage forming
- Final shape is influenced by die geometry of the dies and material parameters
- Determine influence of die geometry and material parameters

Project deliverables:

- Multi-stage process modeled in detail
- Material model developed (strain rate dependent plasticity)
- Friction model developed
- Compared with experiments
- Die geometry adapted to obtain wanted geometry accurately

3D Insertion simulations



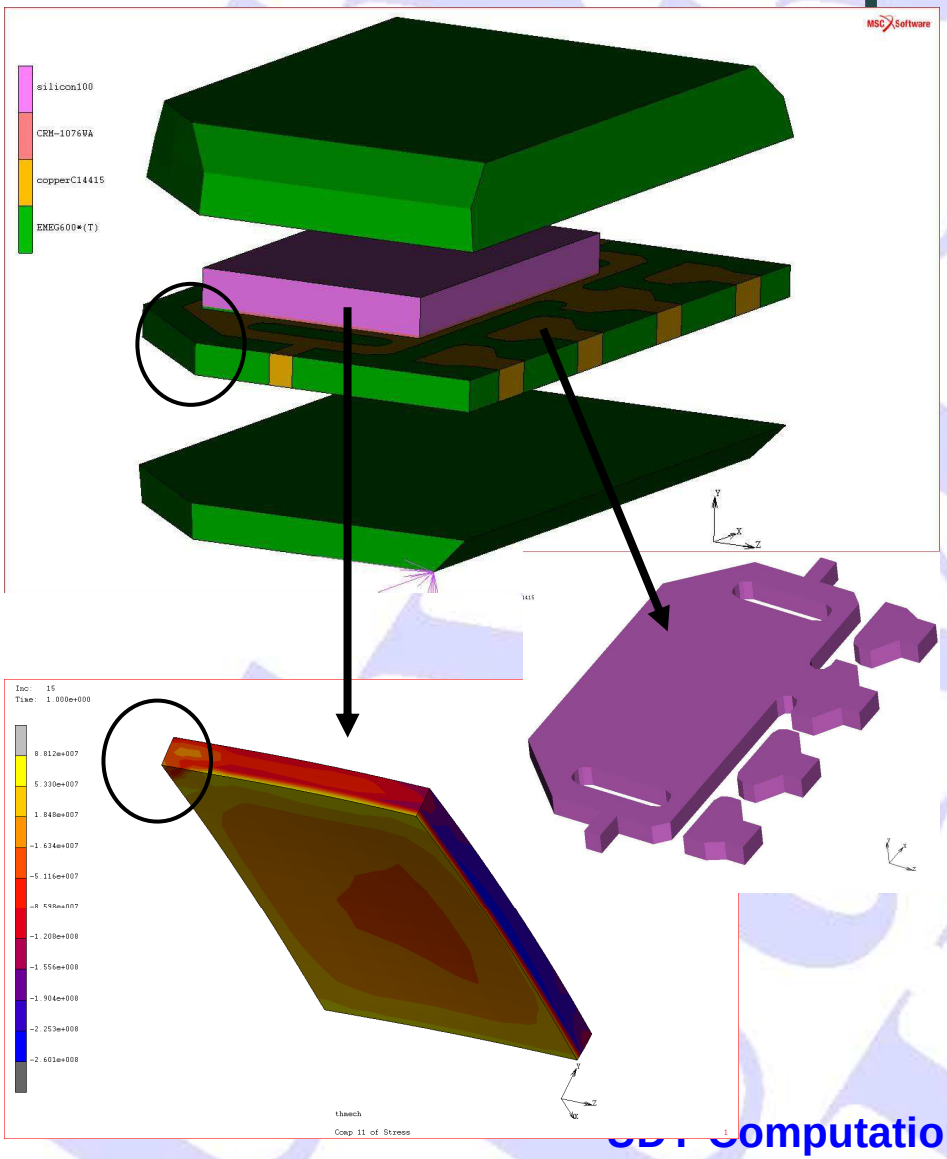
Project description:

- Bushing is inserted in body with corrugated internal surface
- Determine stress in bushing and body
- Optimize corrugation geometry as to not exceed the stress limit

Project deliverables:

- Highly non-linear insertion process modeled in detail
- Friction model developed
- 3D mesh is refined automatically to capture accurately the corrugation details
- Stressed determined
- Corrugation geometry optimized

Chip crack



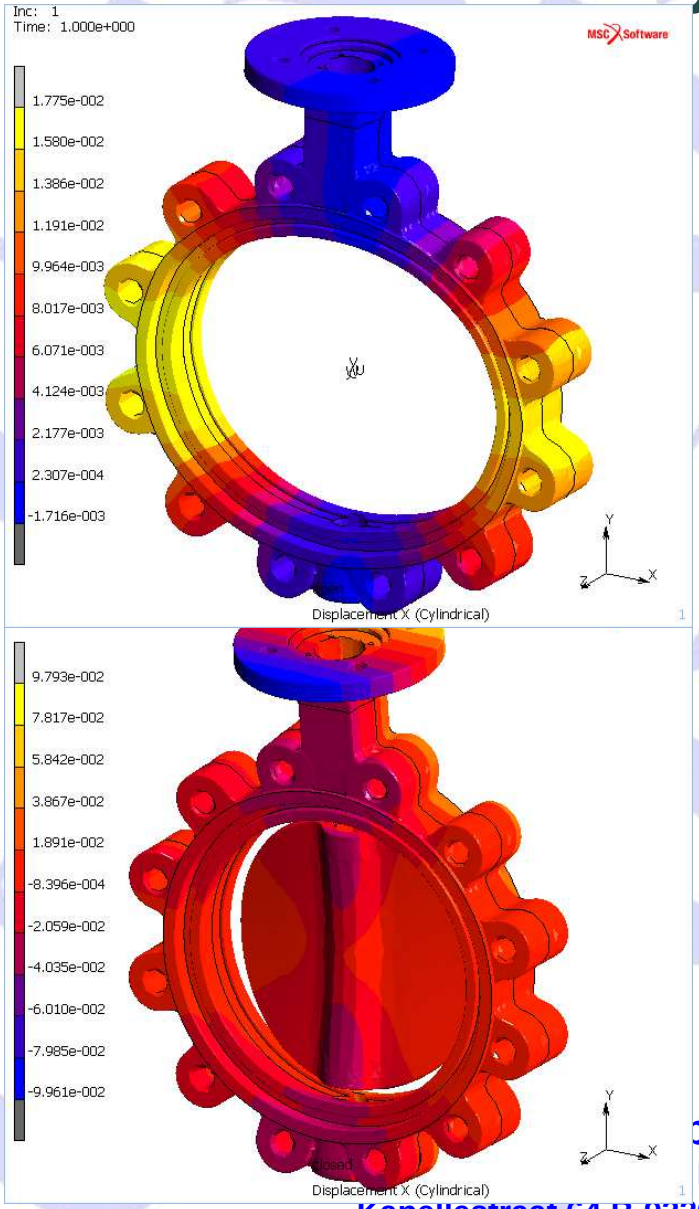
Project description:

- Silicon chip is mounted on leadframe with 45 deg corners and encapsulated in the package
- Chip cracks during field-use at corner
- Determine influence of different parameters on chip stress behavior

Project deliverables:

- 3D thermo-mechanical model with temperature dependent material parameters
- The manufacturing process is simulated (die attach, encapsulation) to determine the zero hour initial stress
- The chip is powered
- Stress in chip is determined and found being too high
- Model adapted as to decrease corner stress

Butterfly valve design



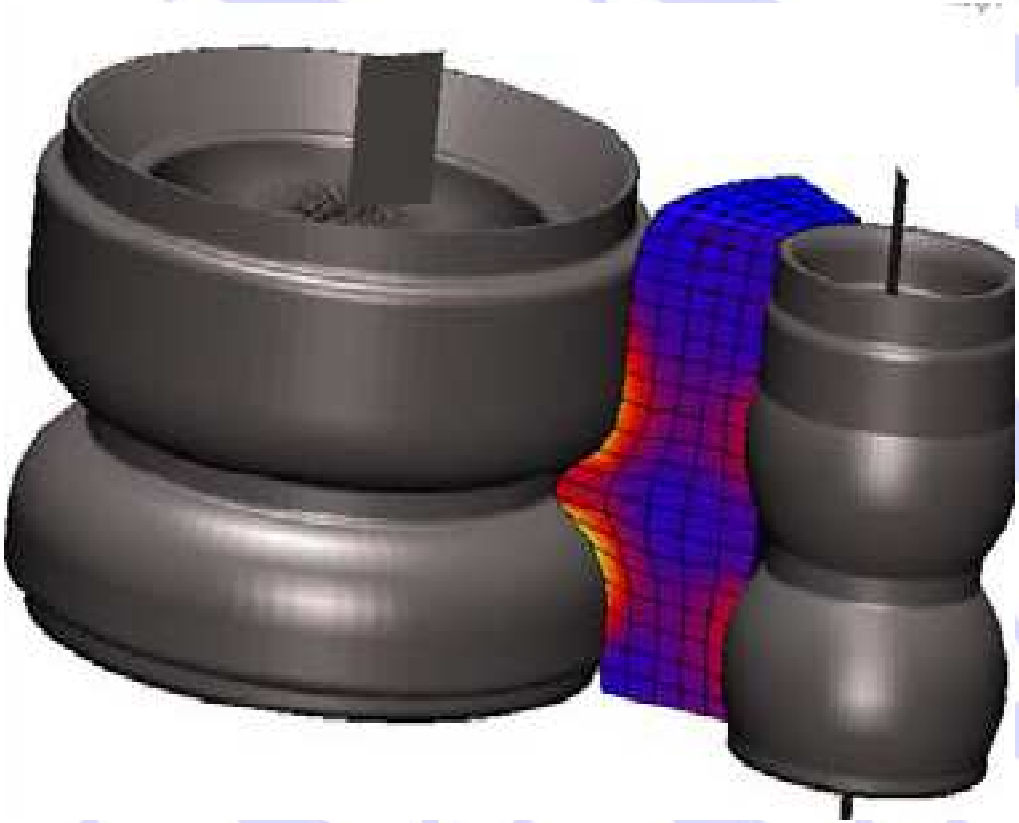
Project description:

- Butterfly valves must withstand safely specified pressures in both open and closed position
- Determine deformation and stress in valve house and disc under maximum pressure conditions

Project deliverables:

- 3D model of valve house and disc
- Pressure applied in both open and closed positions
- Stress and deformation determined

Steel rolling



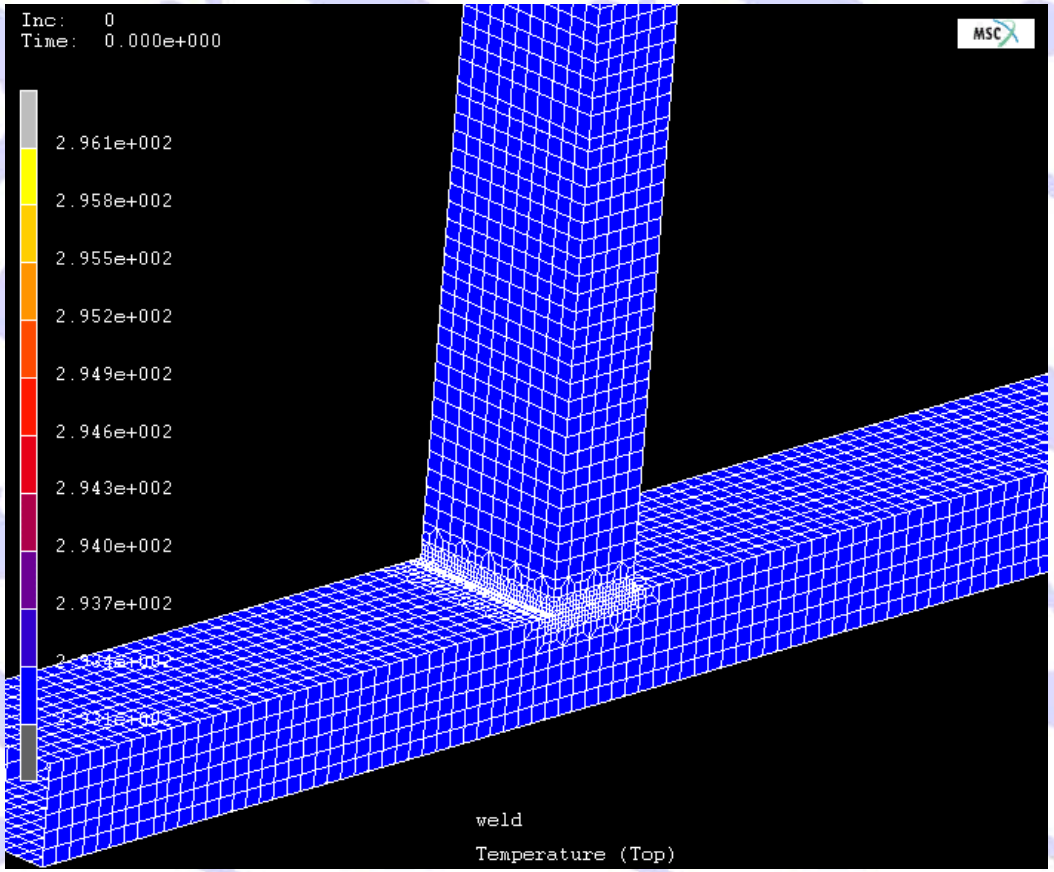
Project description:

- Two rigid rollers compress a deformable ring sector
- It is difficult to abtoin the correct final shape

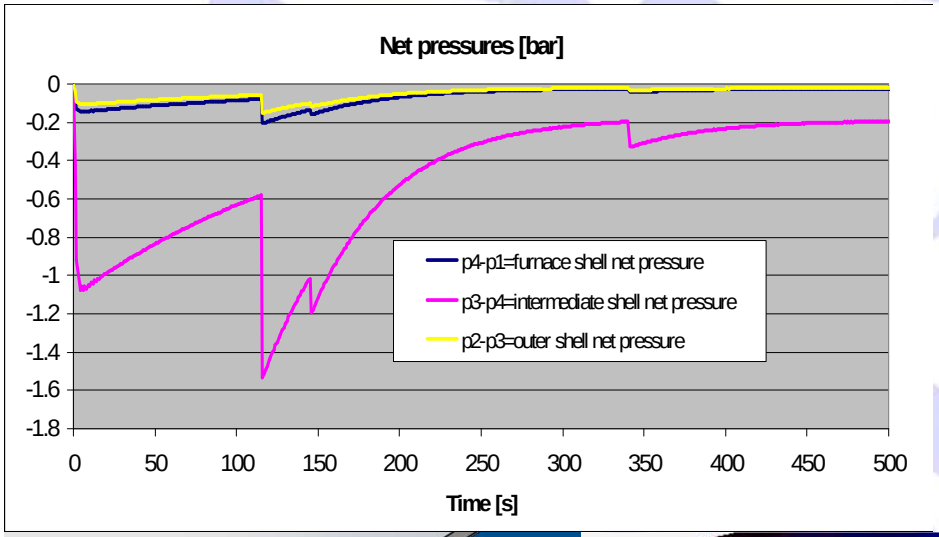
Project deliverables:

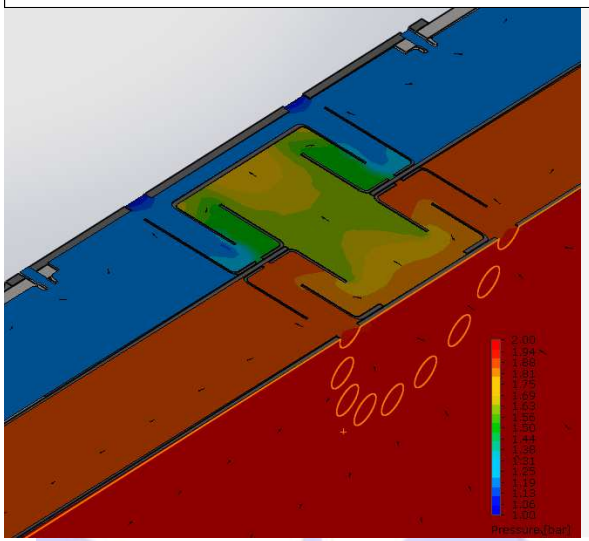
- Coupled heat transfer-structural analysis
- Large strain temperature dependent plasticity
- Adaptive remeshing during analysis
- Process parameters (blanket and roller temperatures, rotation speed, compressive force, spring-back, etc.) optimized to arrive at correct final shape

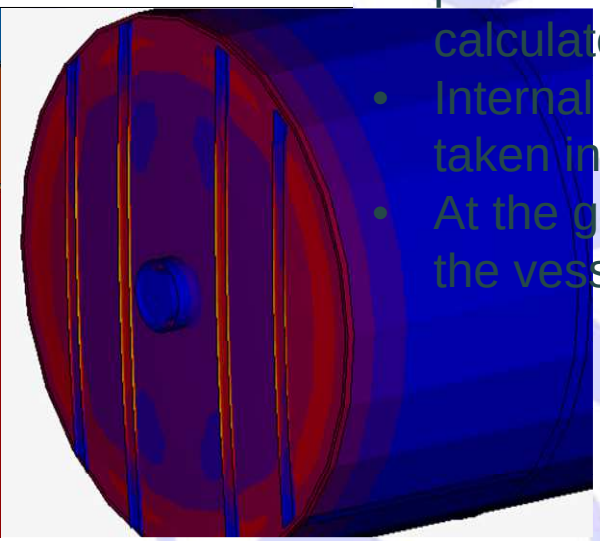
Welding animations



Pressure vessel transient simulation







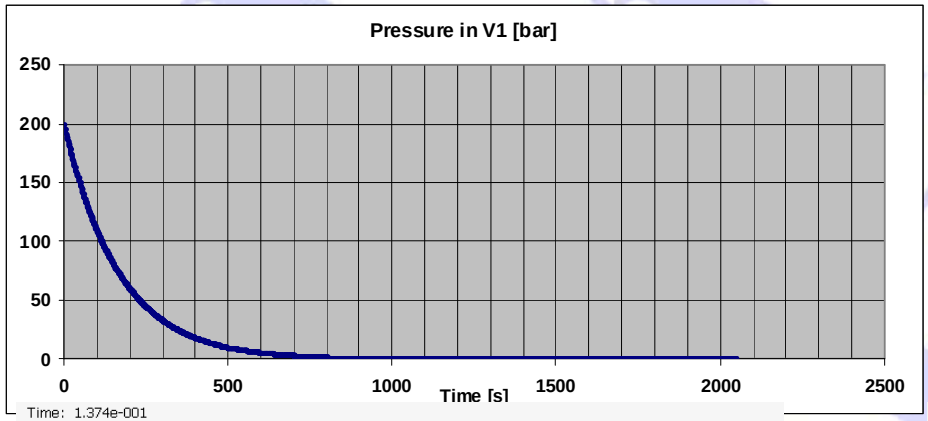
Project description:

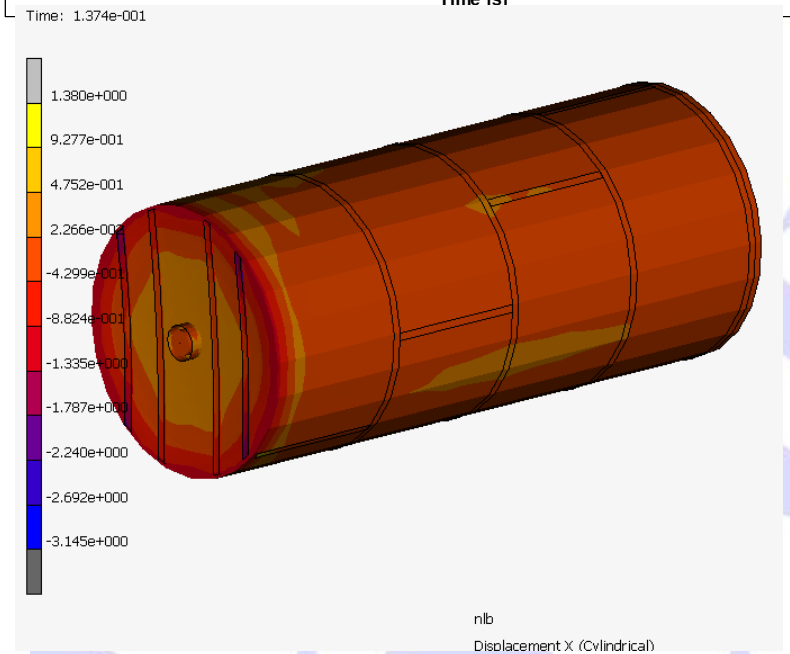
- Pressure transients in piping and pressure vessels
- Can cause damage

Project deliverables:

- Coupled Fluid-Structure interaction in the time domain (up to 2000 s)
- Given the pressure input history, the pressure build-up and –down is calculated as function of time
- Internal flow resistances at orifices taken into account
- At the greatest pressures, the stress in the vessels is calculated

Pressure vessel buckling



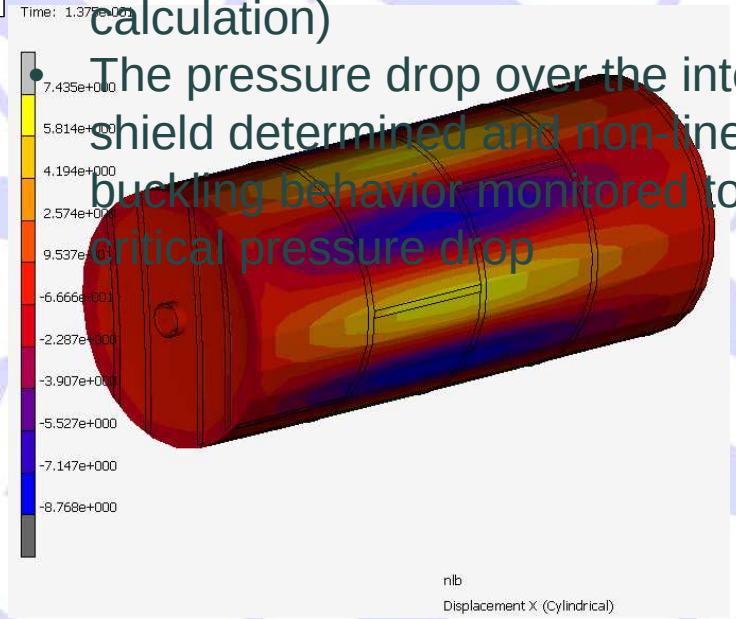


Project description:

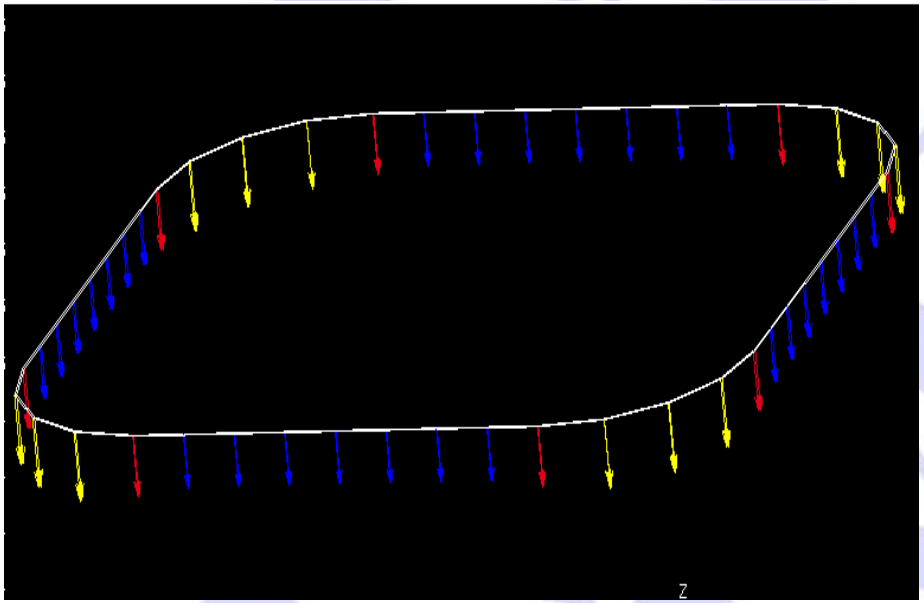
- Flow reversal in pressure vessel can cause buckling of internal shield when suction flow rate is too high

Project deliverables:

- Pressure as function of time calculated for given flow resistance (CFD calculation)
- The pressure drop over the internal shield determined and non-linear buckling behavior monitored to find the critical pressure drop



Seal design



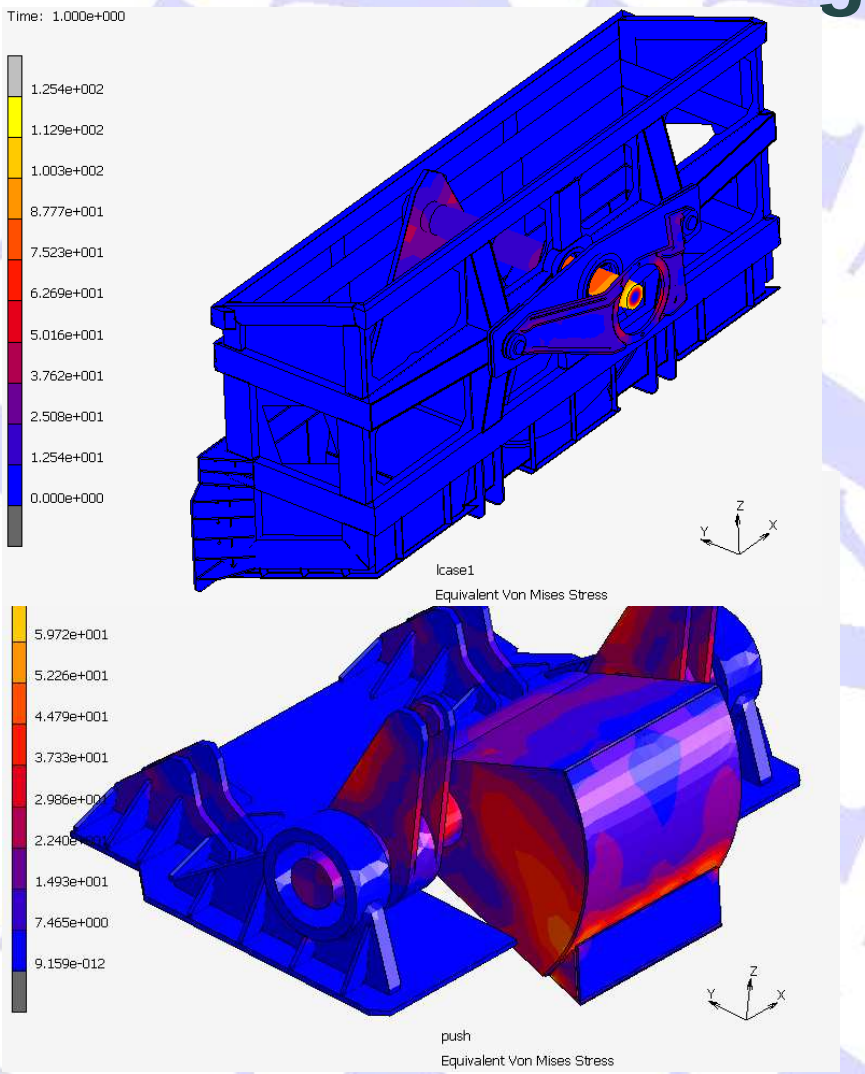
Project description:

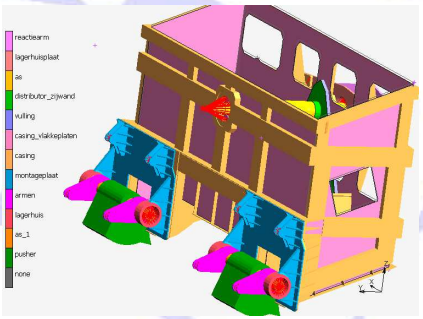
- Rectangular seal of high-vacuum vessel leaks due to varying contact forces in straight and curved seal portions when flanges are compressed

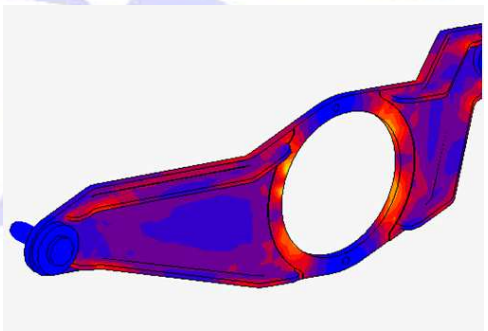
Project deliverables:

- Seal nonlinear force-displacement characteristic accurately simulated on reduced model
- This characteristic imported in full model as non-linear spring
- The contact pressure in the bends is much higher than in the straight portions of the seal
- Bolt tensioning scheme simulated to obtain equal contact forces, even if flanges have finite stiffness

Garbage chute







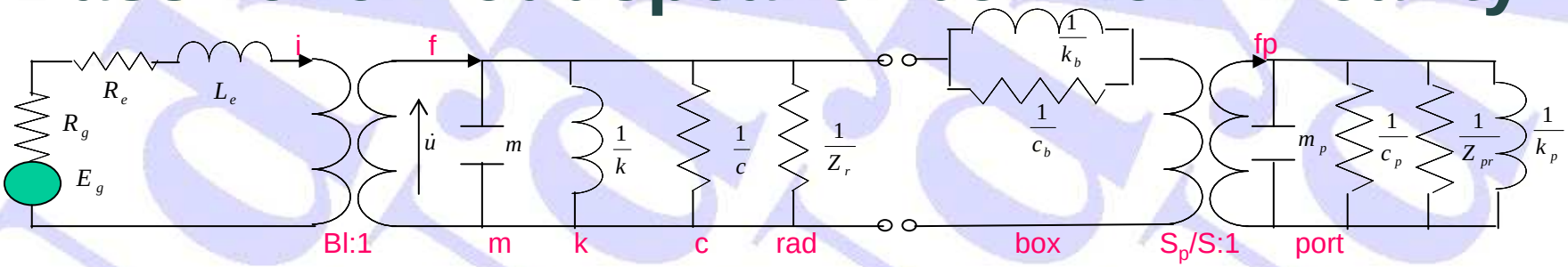
Project description:

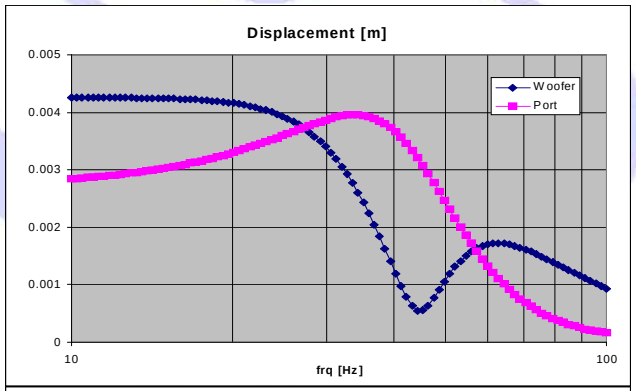
- Garbage chute distributor and pushers can lock due to garbage jam
- Causes high stress in axle, motor reaction and pusher arms

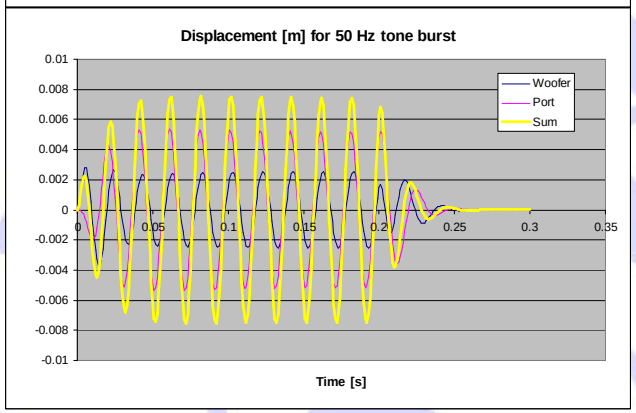
Project deliverables:

- Global and sub-models created
- Overall and local stress calculated in locked positions using garbage material model
- Fatigue lifetime determined and design updated to guarantee intended lifetime

Bass-reflex loudspeaker box non-linearity







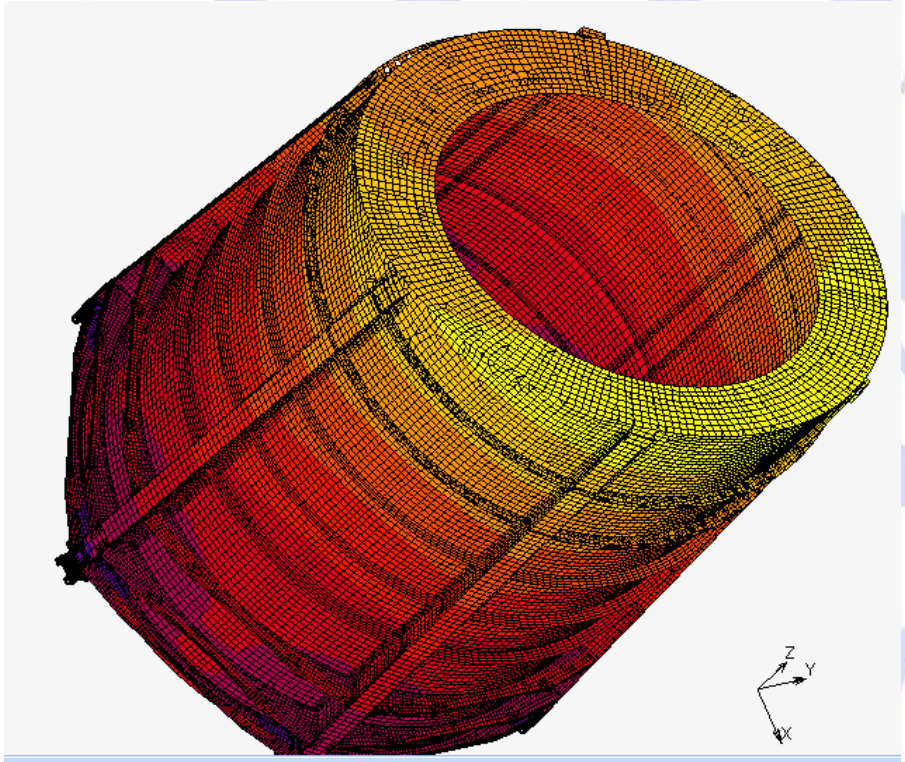
Project description:

- Bass-reflex loudspeaker box is usually designed in the frequency domain using analogous electrical circuits
- Customer wants to optimize loudspeaker box w.r.t. bass attack, decay and non-linearity's from motor and speaker suspensions. This is not possible in the usual way

Project deliverables:

- Finite element bass-reflex loudspeaker box model with all parameters (also voice coil and amplifier) converted to mechanical values
- Works both in the frequency and the time domain. Bass-reflex port can be substituted by passive (slave) speaker
- Attack, decay and all non-linearity's studied in time domain and optimized to obtain cleanest bass response

Euclid satellite hull?



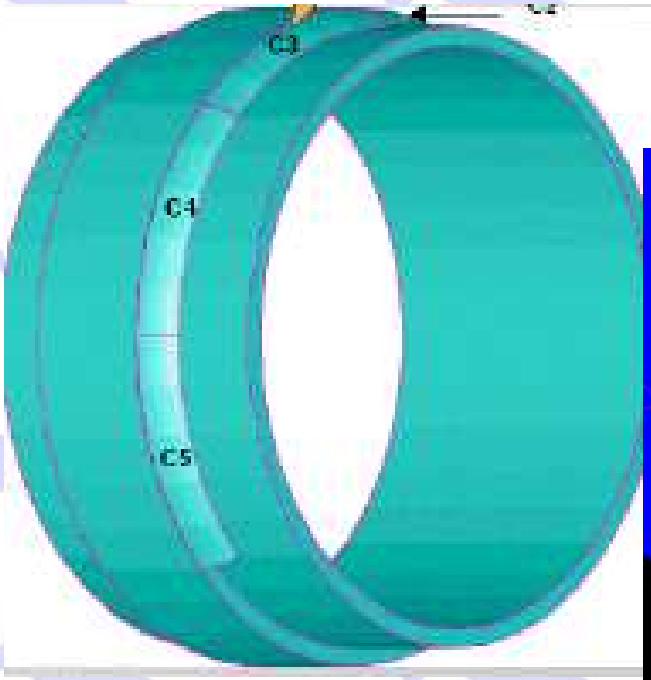
Project description:

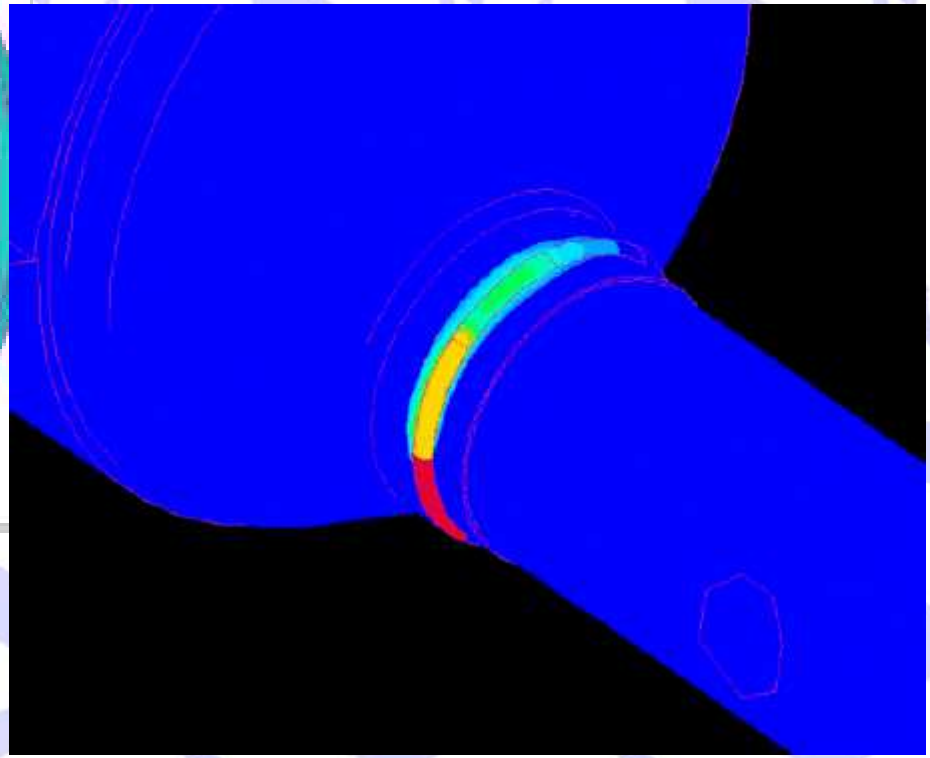
- Zie map incub voor beschrijving

Project deliverables:

- Wave interaction

Pipe welding





Loopwerk Oce

Project description:

- Switch must withstand shortcut at 15kV

Project deliverables:

- 3D fully coupled Multi-physics model

De Nul, incl hijsogen

Project description:

- Switch must withstand shortcut at 15kV

Project deliverables:

- 3D fully coupled Multi-physics model

Michel vd Wiele

Project description:

- Switch must withstand shortcut at 15kV

Project deliverables:

- 3D fully coupled Multi-physics model

Delamination Cohesive zone

Project description:

- Switch must withstand shortcut at 15kV

Project deliverables:

- 3D fully coupled Multi-physics model

Sequential welding

vvv

v

Determination of Narayamswami glass relaxation parameters

vvv

v

Titanium welding

Project description:

- Dit eerst eens 3D uitrekenen en half model filmen zodat het inwendige sichbaar is

Project deliverables:

- 3D model

Mooring cable mantle abrasion

Project description:

- Offshore mooring cables are subjected to accidental scouring interactions with vessels
- This causes abrasion and premature wear of outer cable mantle

Project deliverables:

- Tensioned mooring cable interacts with approaching vessel (different approaching velocities
- Shearing contact forces from global model transferred on detailed local model containing sub-ropes and mantle ropes
- Wear index model developed and validated
- Different fiber materials and combinations investigated

Rope reel (un)winding

Project description:

- Rope is composed of inter-twisted “subropes”
- During winding small subrope tension differences cause residual deformatoin and stress in rope
- This leads to winding and unwinding problems

Project deliverables:

- Global

Offshore projects

Mooring cable interaction with swell sea

- Offshore oil rig is subjected to varying loads (from choppy to swell sea) which cause its mooring cables to wobble
- This results in varying tensions and stress/strains in the mooring cables and decreased lifetime

Mooring cable scouring

- Mooring cables are subjected to accidental scouring interactions with approaching vessels
- This causes abrasion and premature wear of outer cable mantle

Sound reduction of pile sinking in ocean floor

- Sinking of monopile can cause serious disturbance of sea animal habitat due to high sound levels

Wind load

Trolley wire for High Speed Train

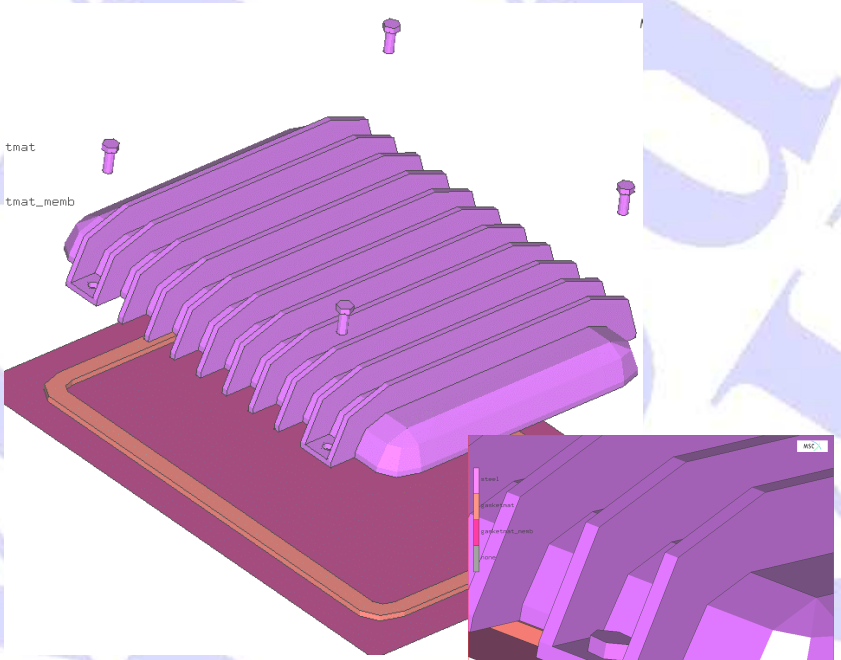
Project description:

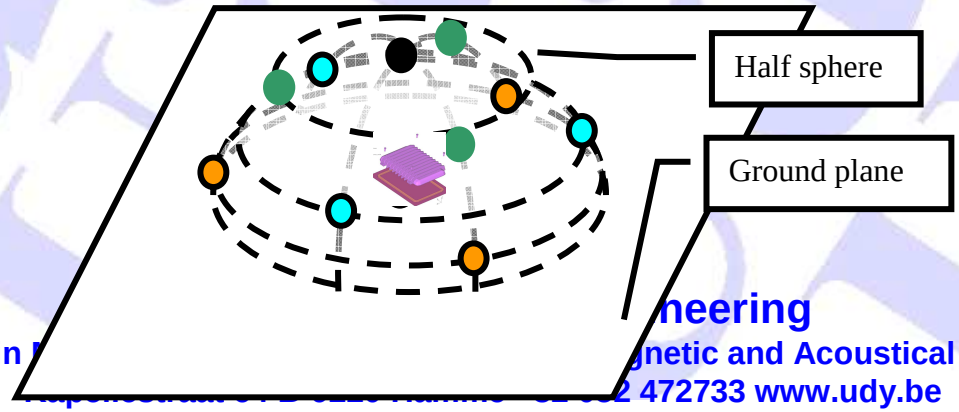
- Rope is composed of inter-twisted “subropes”
- During winding small subrope tension differences cause residual deformatoin and stress in rope
- This leads to winding and unwinding problems

Project deliverables:

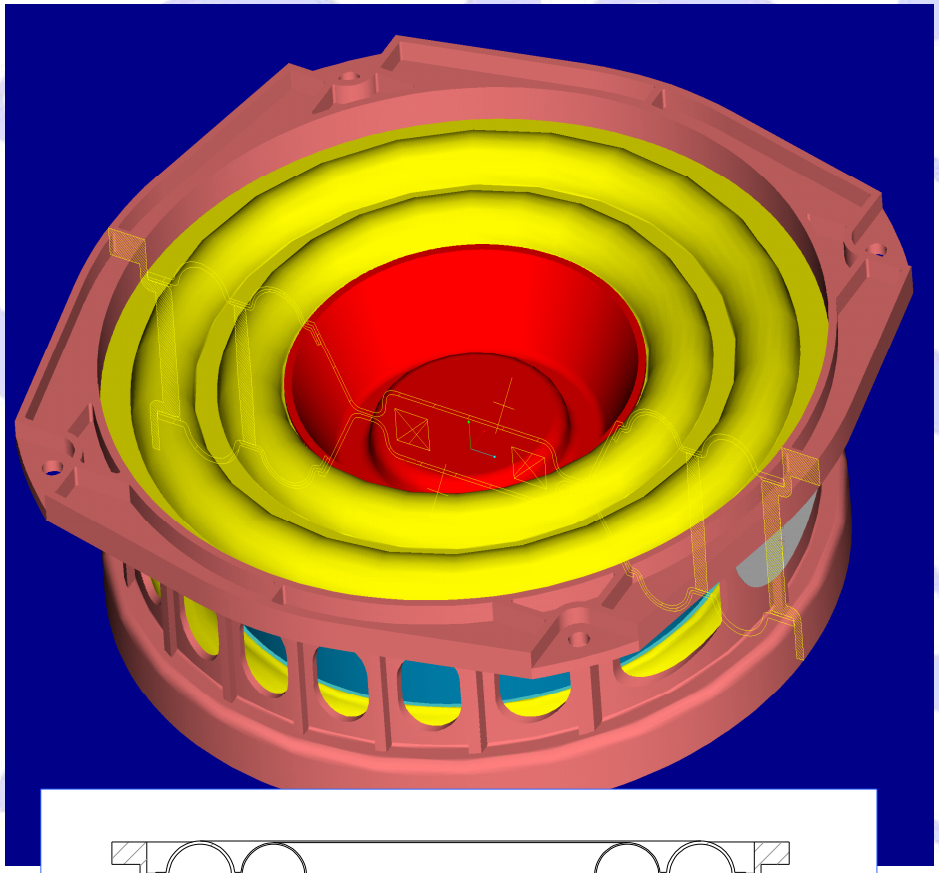
- Global

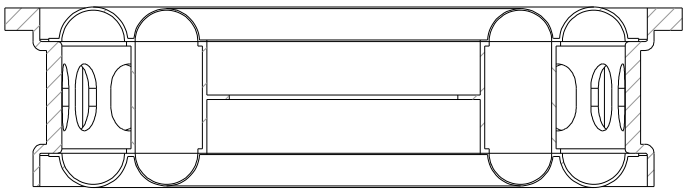
Acoustic projects





Acoustics





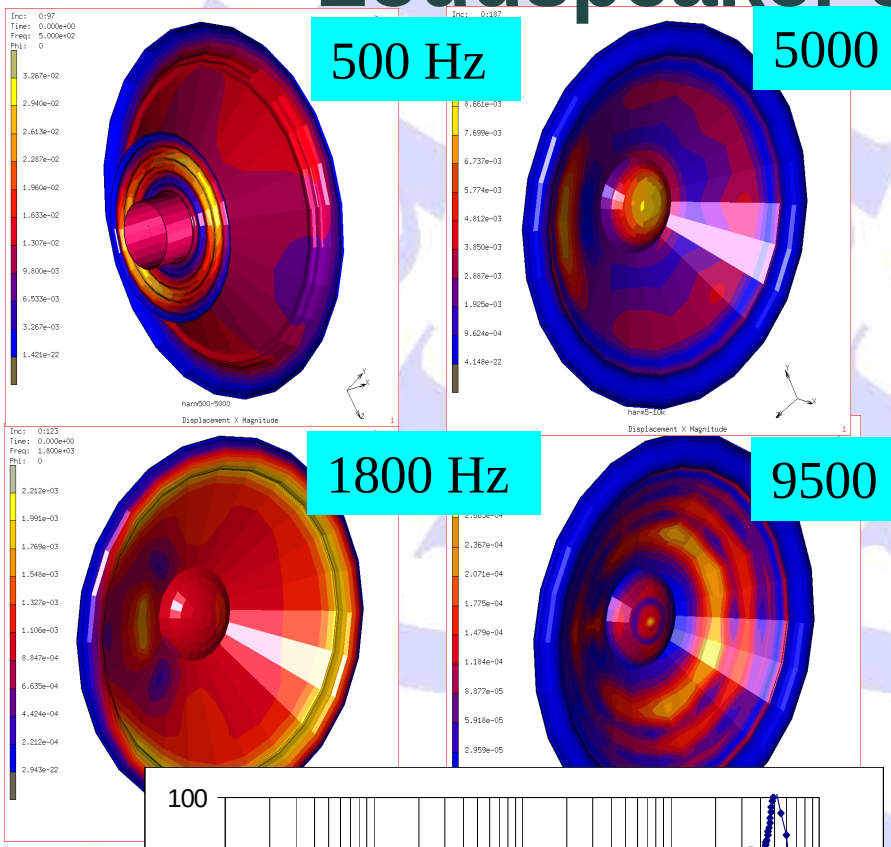
Project description:

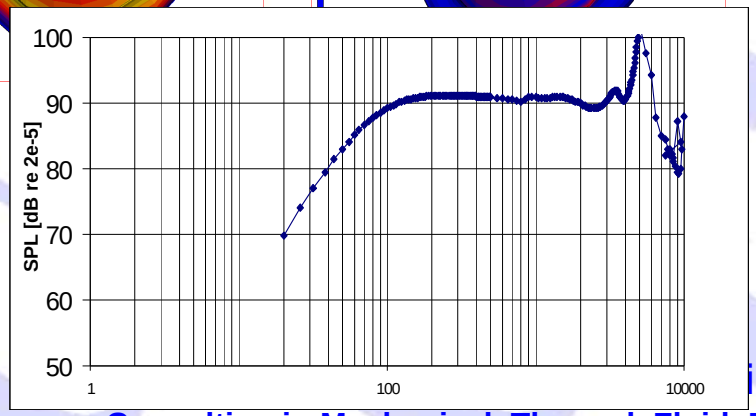
- Low frequency loudspeaker must be able to work under extreme high excursions.
- Design double outer rubber rim.

Project deliverables:

- Parametric model.
- Static and dynamic rubber behavior under large deformations.
- Sound radiation.

Loudspeaker sound radiation





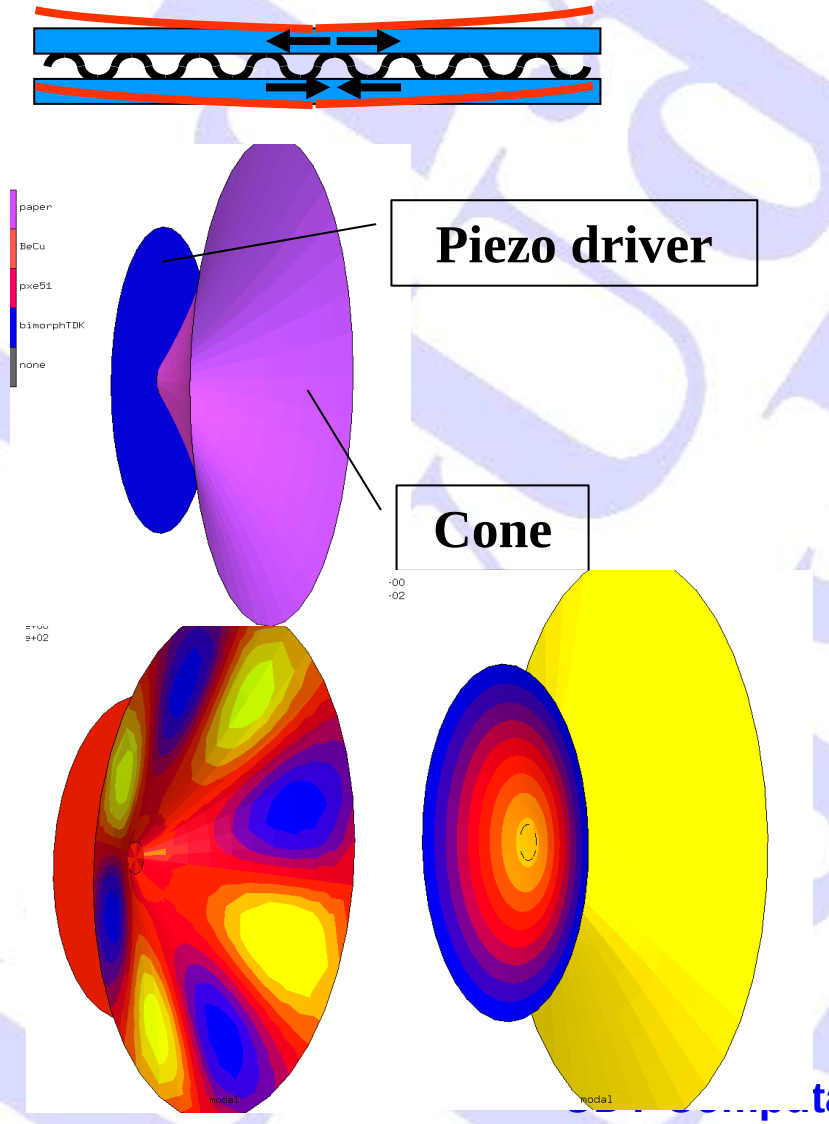
Project description:

- Complete virtual prototyping of loudspeaker.
- Characterization of loudspeaker specific materials, including their frequency dependency.

Project deliverables:

- Full 3D mechanical cone break-up calculation.
- Effect of material anisotropy.
- Sound radiation with acoustic program URAY.
- Thiele-Small parameters included.
- Accuracy within ±0.2 dB.

Piezo actuator



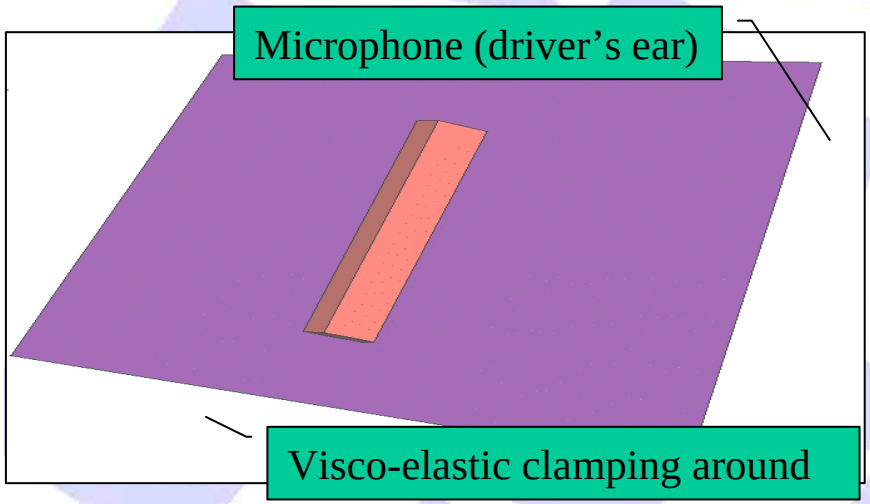
Project description:

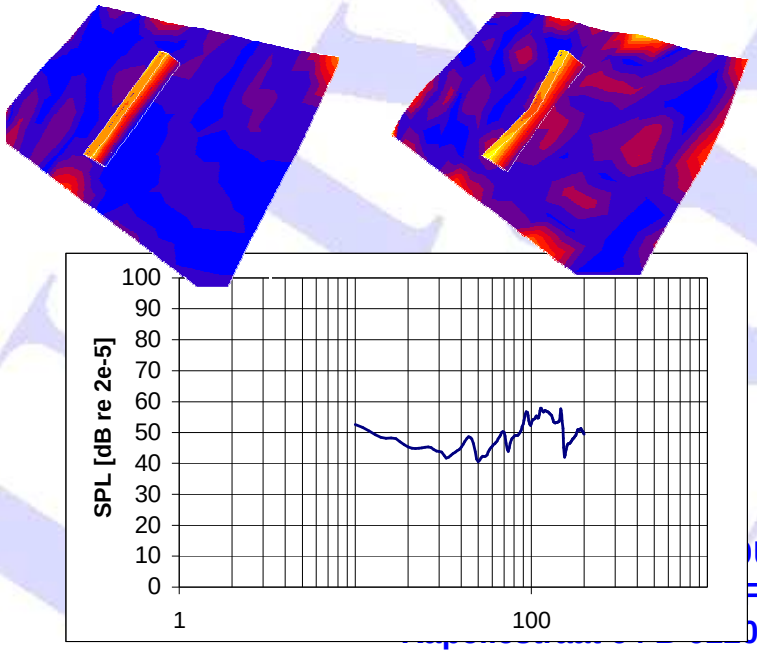
- Operates through piezo driver.
- Optimizing coupling efficiency between driver and cone experimentally would require many experiments without really understanding physics behind.

Project deliverables:

- Vibrational behavior of cone-driver-coupling studied parametrically.
- Piezo driver tri-laminar structure modeled with continuum and shell elements.
- Optimized geometry and suspension as to obtain flat frequency response and high coupling efficiency.

Noise from automotive wiper





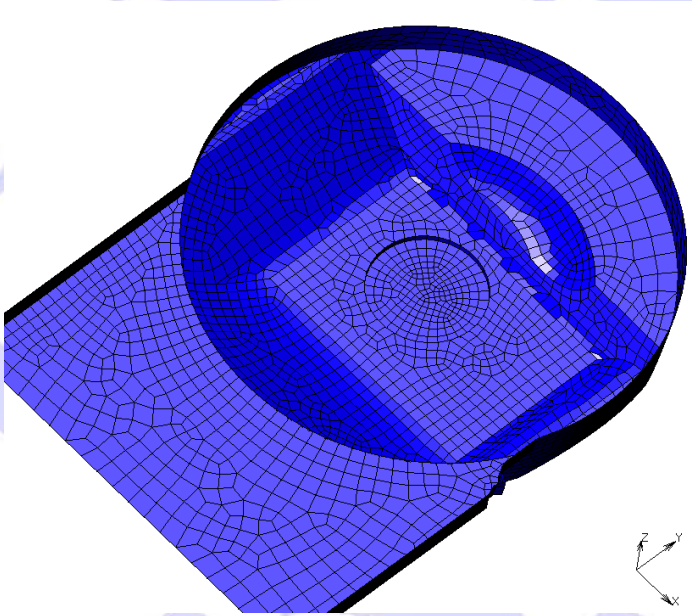
Project description:

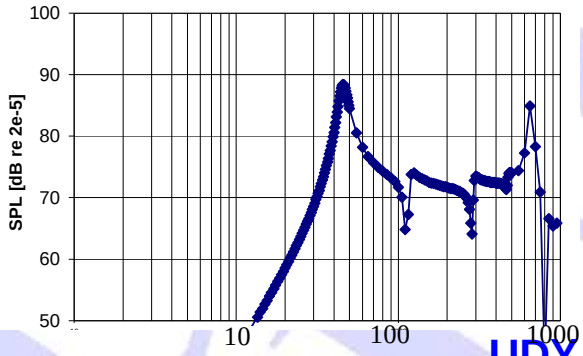
- Wiper vibrations are transmitted to windscreen, amplifying the noise emitted by it.
- How can this noise be reduced at driver's ear position?

Project deliverables:

- Full 3D mechano-acoustical model .
- Effect of rubber wiper material, spring pre-load and pre-stressed visco-elastic side clamping included.
- Composite windshield with damping layer between.
- Vibration patterns at critical frequencies visualized.
- Sound pressure at driver's ear calculated.
- All these parameters are varied until minimum sound pressure is obtained.

Noise reduction from automotive cover





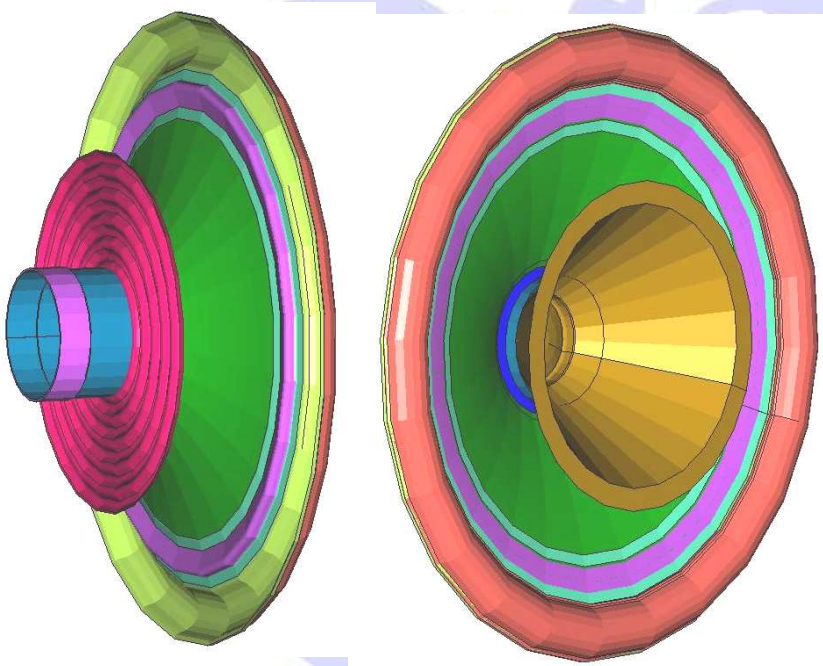
Project description:

- Plastic cover with complex geometry for automotive application emits annoying sound due to frequency dependent pressure excitation in plenum.
- “Cut and try” experiments and time schedule supplier exhausted.
- Urgent problem!

Project deliverables:

- Import form CAD.
- Vibrational behavior of cover studied.
- Sound radiation calculated.
- Cause of noise identified.
- Optimized thickness distribution and fixation as to flatten frequency response and reducing harmful resonance's.
- “First-time-right” solution.

Double cone loudspeaker

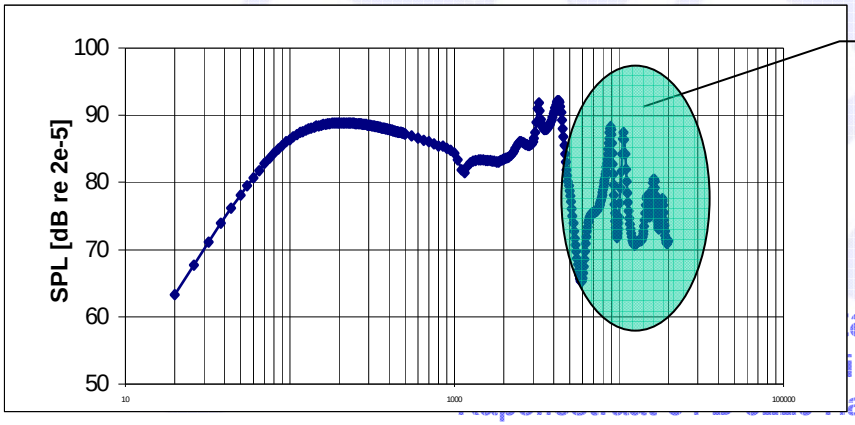


Project description:

- Double cone loudspeakers are used for extended bandwidth.
- Problem: how to match small to large cone for optimal sound radiation?

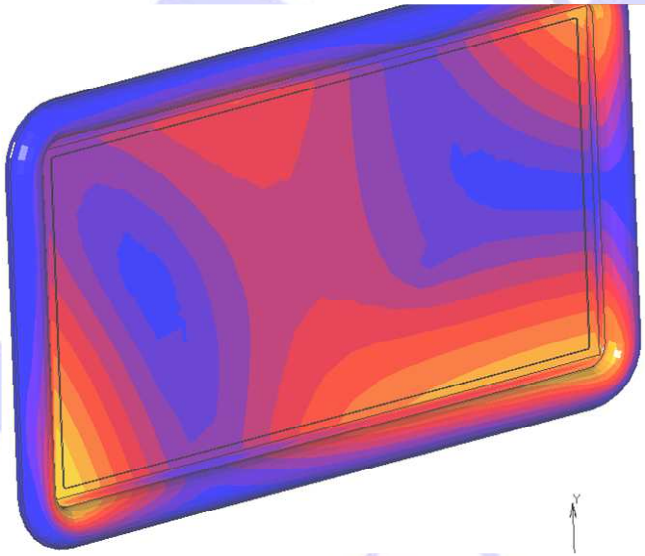
Project deliverables:

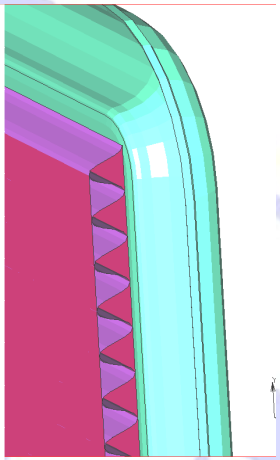
- Vibrational behavior of combined cone-driver-suspension studied parametrically.
- Optimal match determined.

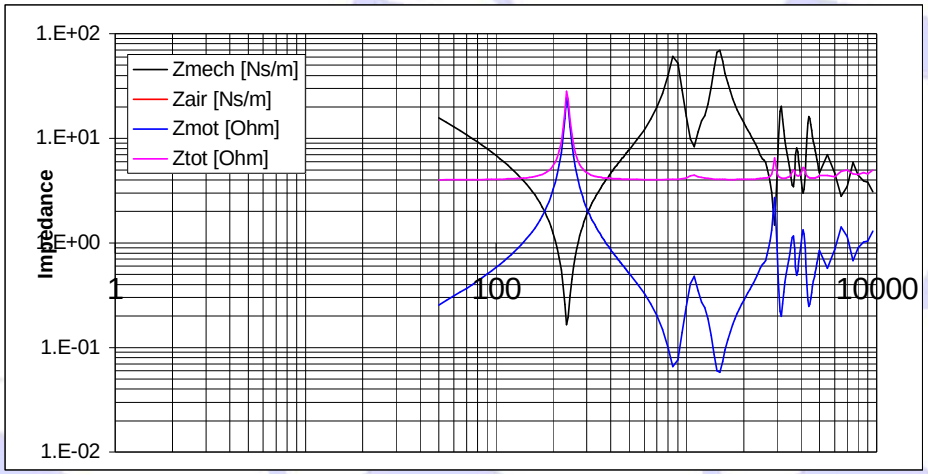


Small cone radiation

Sound radiation from composite panel







Project description:

- Flat composite panel radiates sound
- Determine acoustical impedance of different combinations of composite layer stack

Project deliverables:

- Composite flat panel in combination with rubber rim band simulated and realized.
- Vibrational behavior of flat panel studied parametrically.
- Sound pressure calculated.
- Acoustical impedance (complex) calculated.

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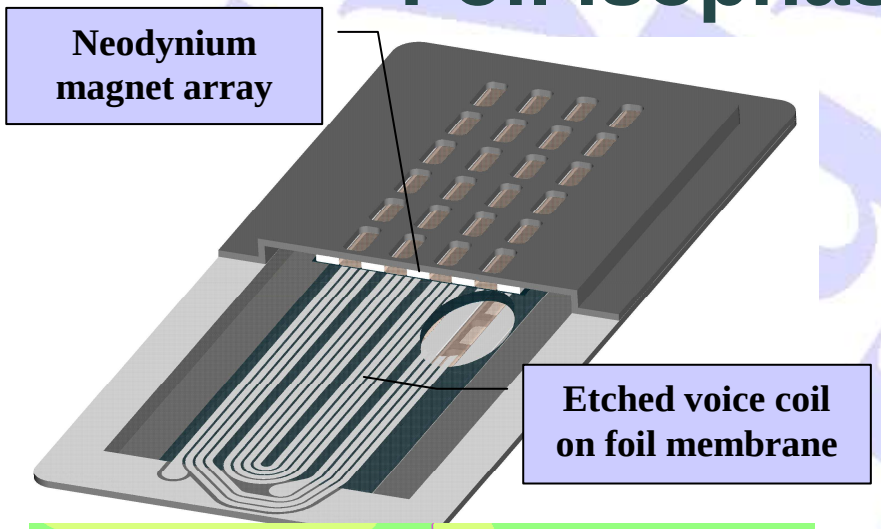
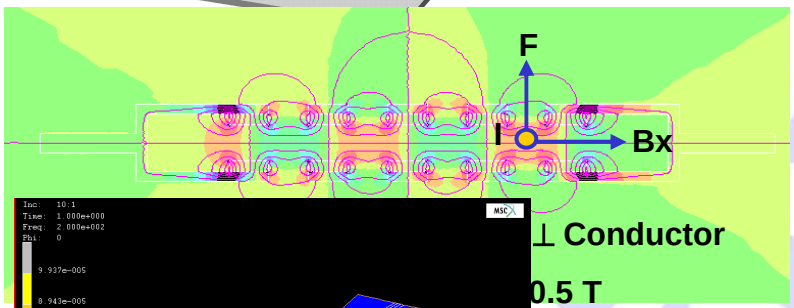
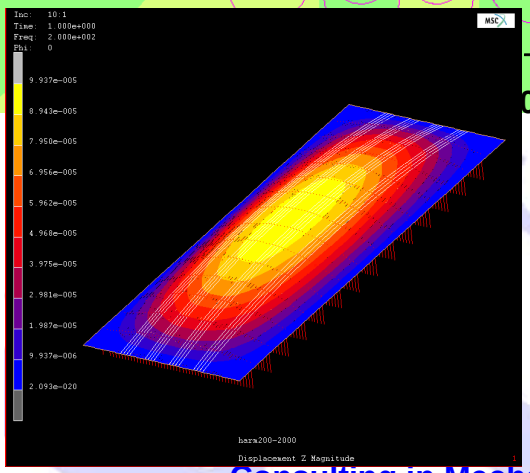
Foil isophase loudspeaker





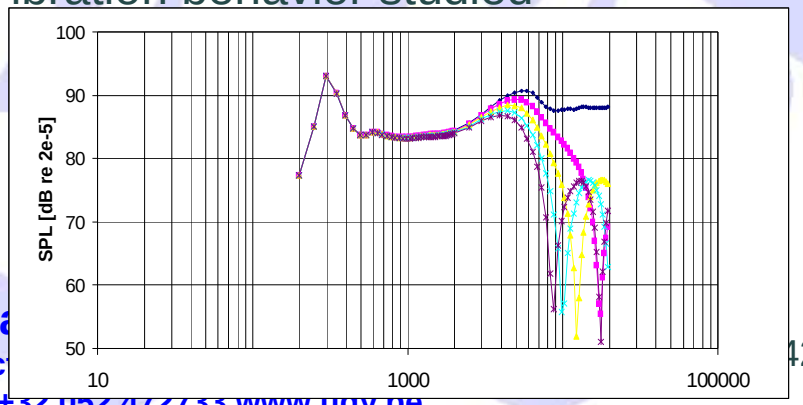


Project description:

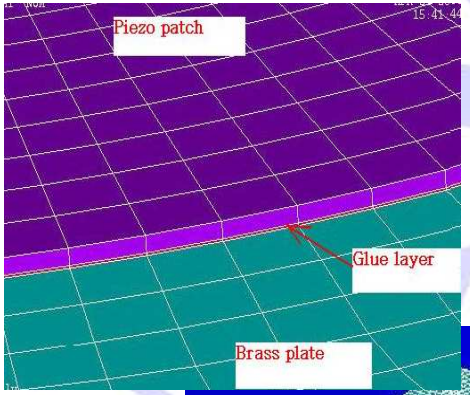
- New type of loudspeaker consists of thin foil with etched voice coil operating in magnetic field from array of Neodynium magnets.
- Determine design parameters for optimal sound quality.

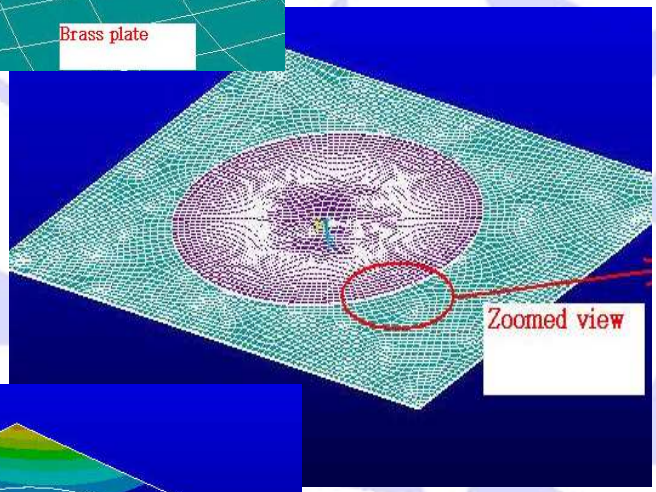
Project deliverables:

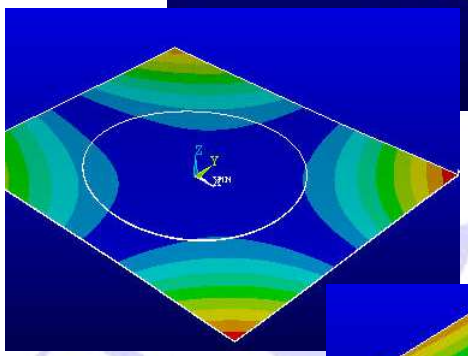
- Magnet field of magnet array calculated.
- Sound pressure at different microphone angles calculated.
- Air load accounted for via subroutine
- Vibration behavior studied

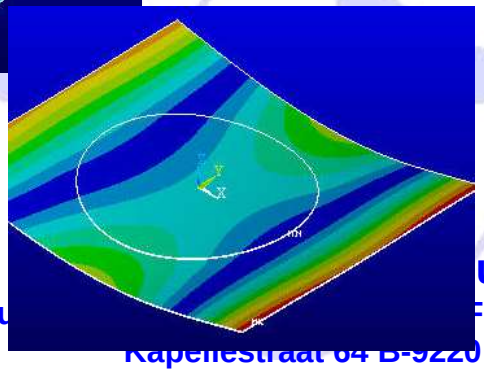


LCD loudspeaker







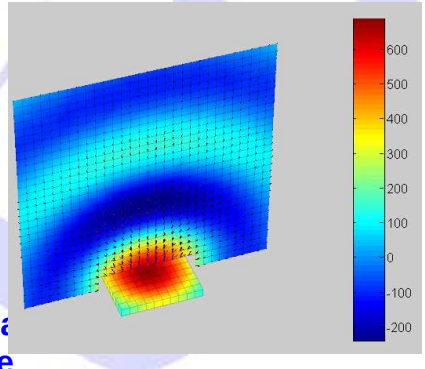


Project description:

- Liquid Crystal Display (LCD) screen is operated also as loudspeaker by gluing a piezo-ceramic disc to its back.

Project deliverables:

- Vibrational behavior and sound pressure calculated.
- Parameter variation :
  - •piezo-electric constants.
  - •Disc diameter.
  - •LCD dimensions.
  - •Glue layer thickness.
  - •Etc.



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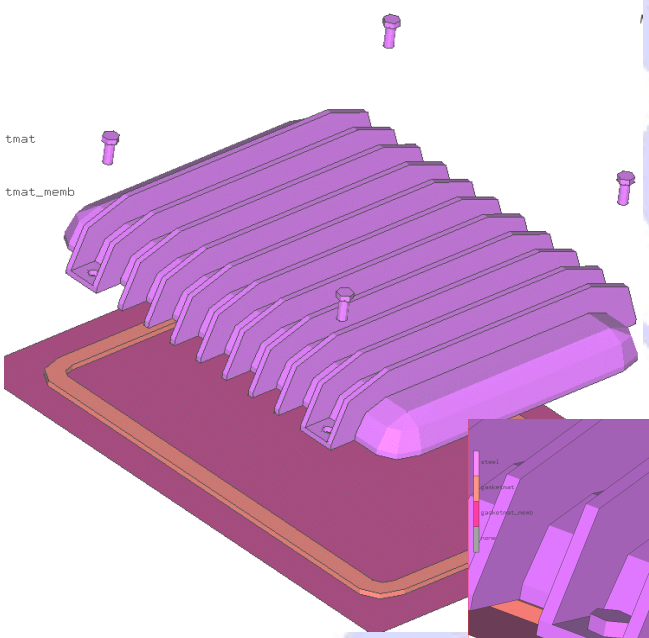
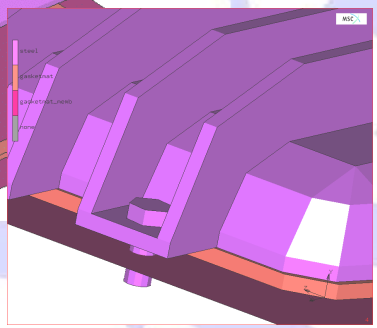
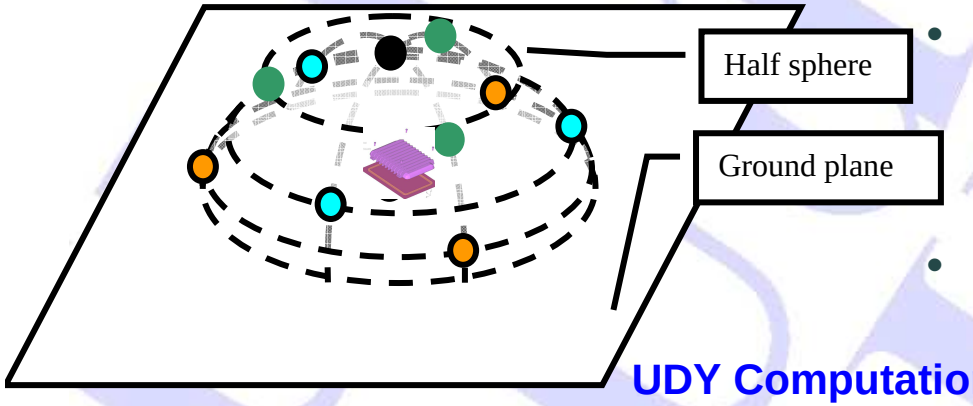
Sound from pre-stressed compressor cover







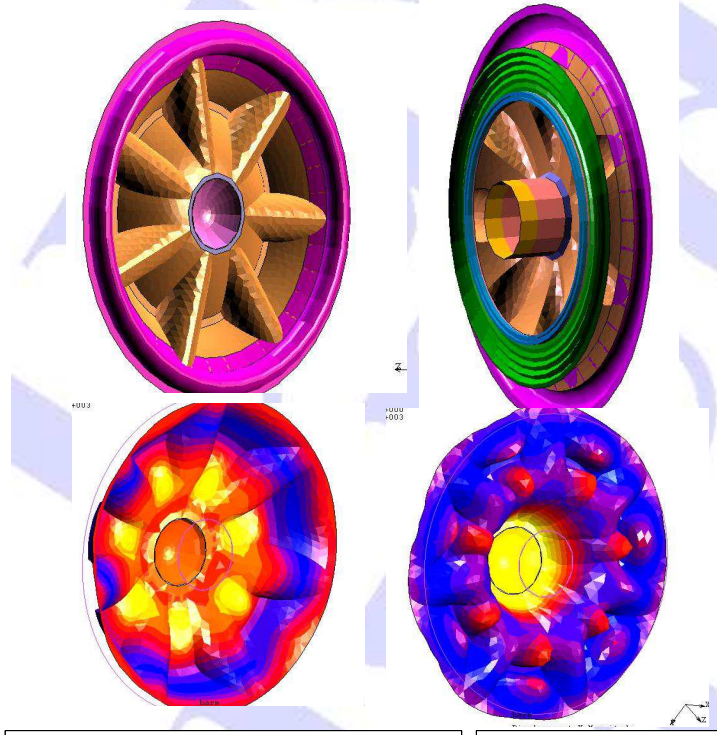
Project description:

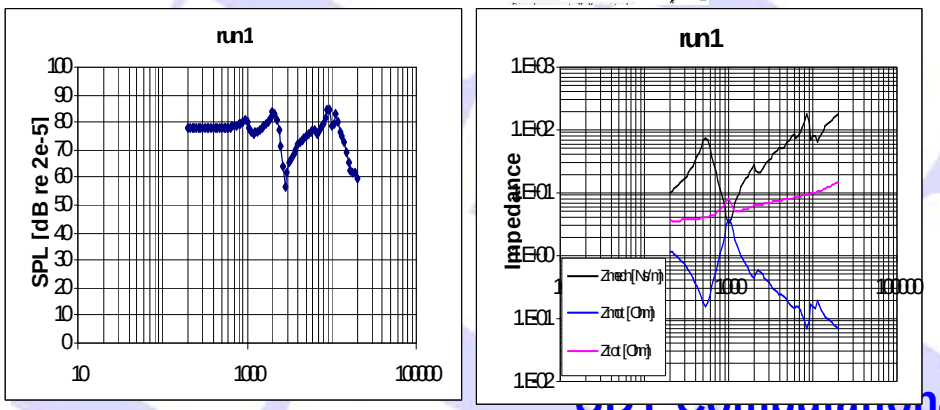
- Compressor cover is bolted to rigid base structure, with gasket in between.
- Four bolts are given pre-stress, then varying pressure applied at inside.

Project deliverables:

- Each bolt individually pre-stressed
- Gasket has realistic properties: thickness direction different from planar.
- Free field Sound pressure at 1 m distance calculated.
- Sound Power calculated with 10 microphones according to ISO 3745 standard (in half-space)→No reverberant room needed
- Damping characteristics of gasket and cover ribs modified to reduce emitted noise.

Advanced Loudspeaker Design





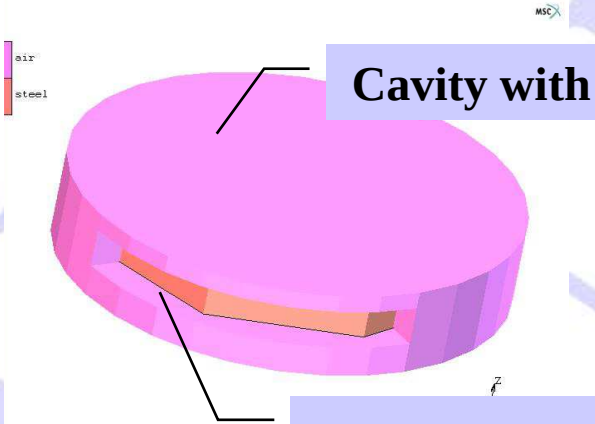
Project description:

- Loudspeaker design requires specialized skills based on experience
- Novel concepts take a long time to prototype and test
- Virtual prototyping required

Project deliverables:

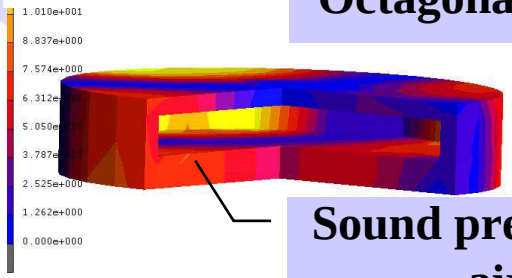
- Parametric model built:
  - Inner cone
  - Outer cone
  - Radial ribs
  - Etc. all relevant parameters
- On-axis and off-axis sound pressure curves calculated
- Mechanical and electrical impedance calculated.
- Optimized virtual prototype built

Combined internal/external acoustics

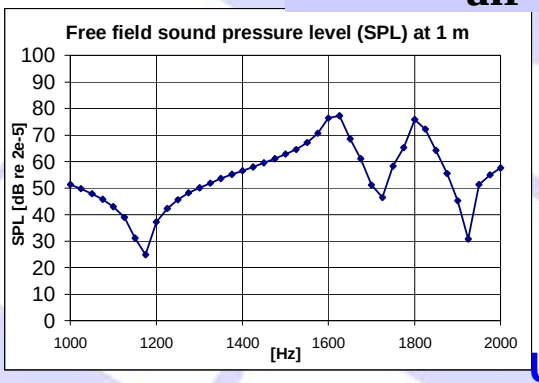


Cavity with slot

Octagonal mirror



Sound pressure in air



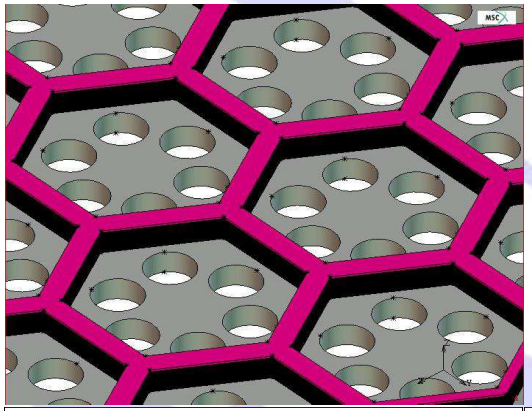
Project description:

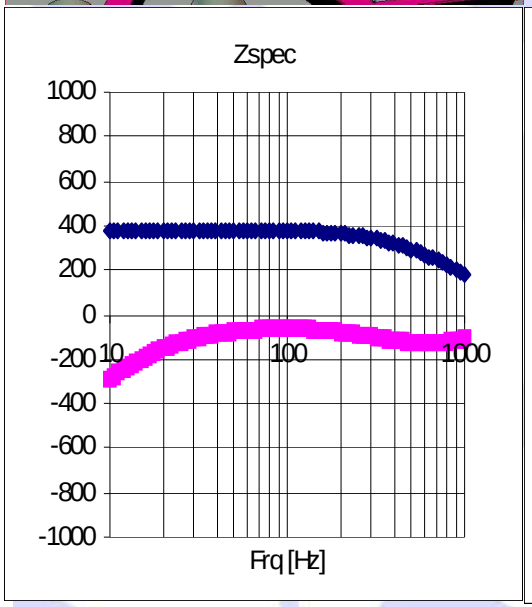
- Octagonal mirror rotates in cavity with slot
- The passage of the octagonal corners over the slot causes irritating noise for workers
- What are the factors influencing the sound level and what can be done to decrease it

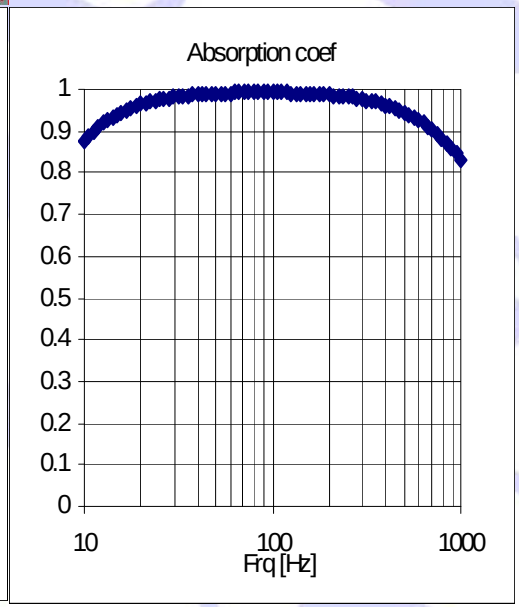
Project deliverables:

- Full 3D coupled acoustical/structural model
- Internal and external sound calculated
- Geometry and construction details changed
- Overall sound level decreased by 10 dB

Wideband sound absorber







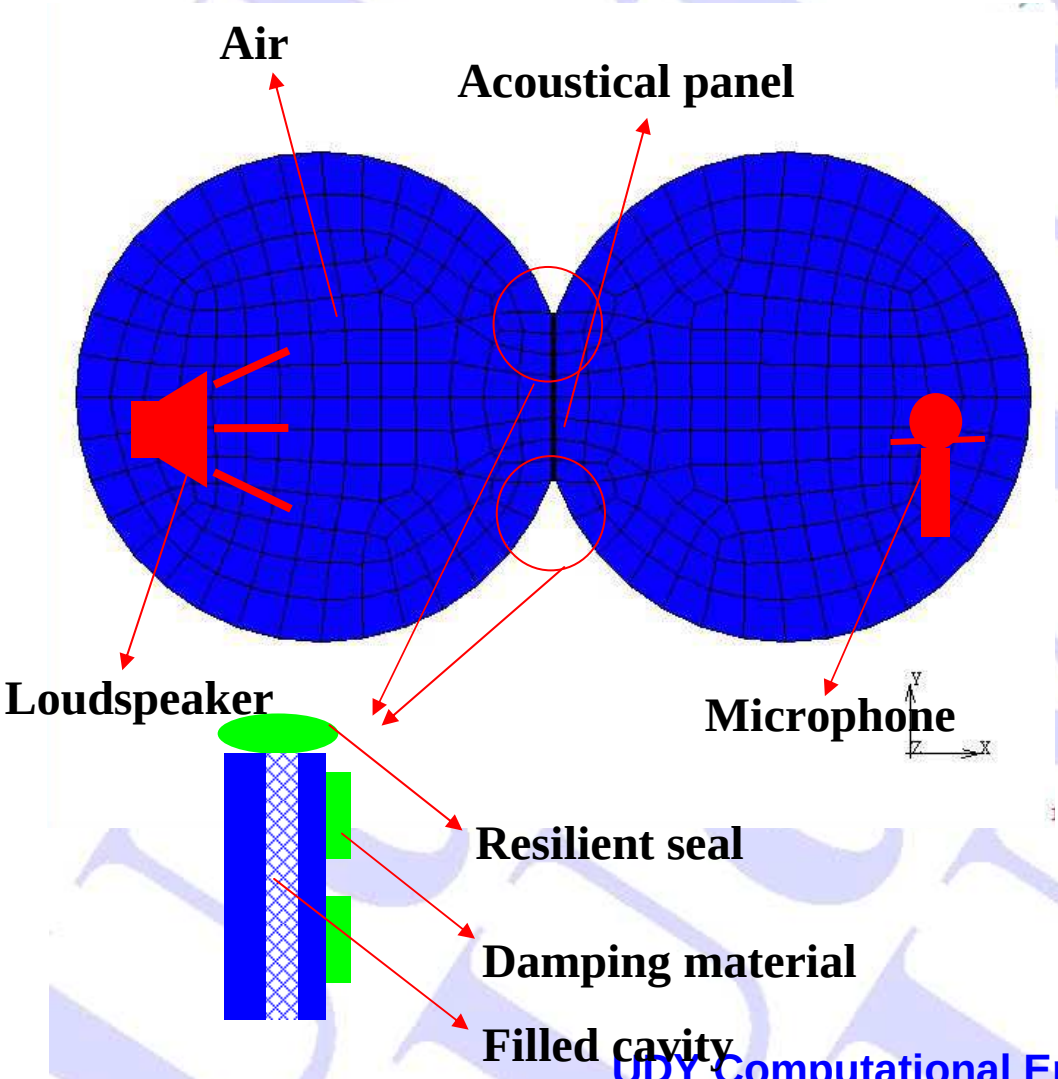
Project description:

- New sound absorbing panel designed specifically to absorb low frequencies
- Sound wave interaction with the panel
- Calculate complex acoustical impedance, absorption and reflection as function of design variables

Project deliverables:

- Full 3D coupled acoustical/structural model
- Impedance and absorption calculated
- Optimized for maximum values

Acoustic transmission



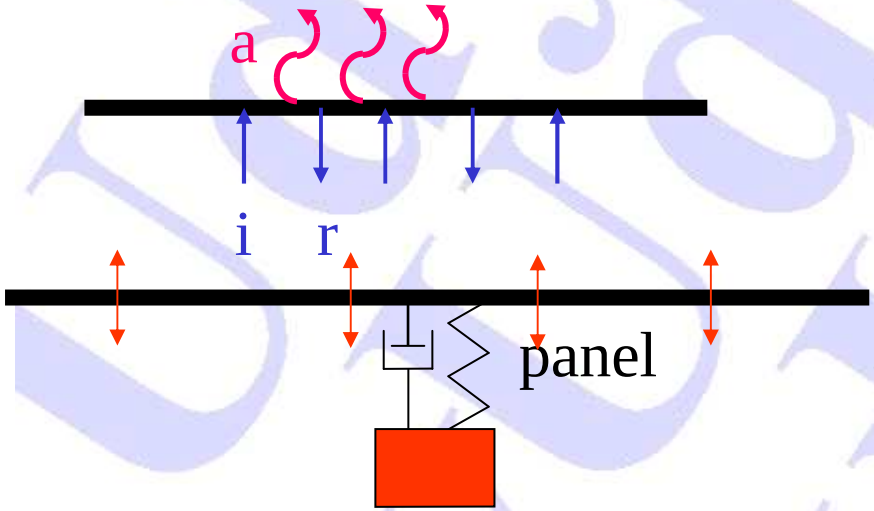
Project description:

- Two chambers are separated by acoustical panel
- Sound is produced in left chamber
- What is sound level in right channel
- Change construction details of panel to reduce transmission

Project deliverables:

- Coupled acoustical/structural calculation
- Transmission loss (absorption) determined
- Optimized for minimal value in specified frequency band

Selective noise reduction panel

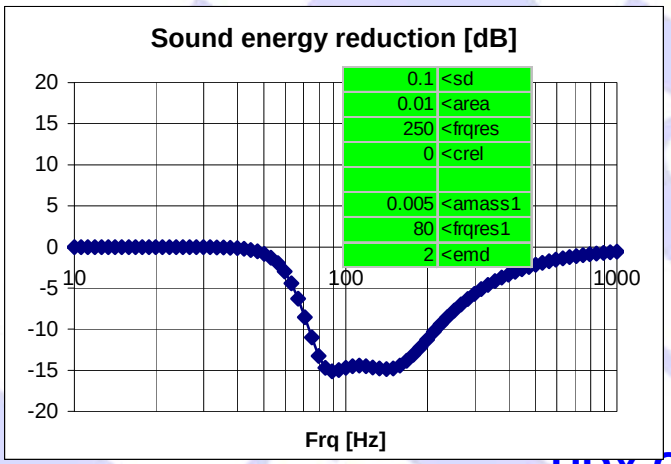


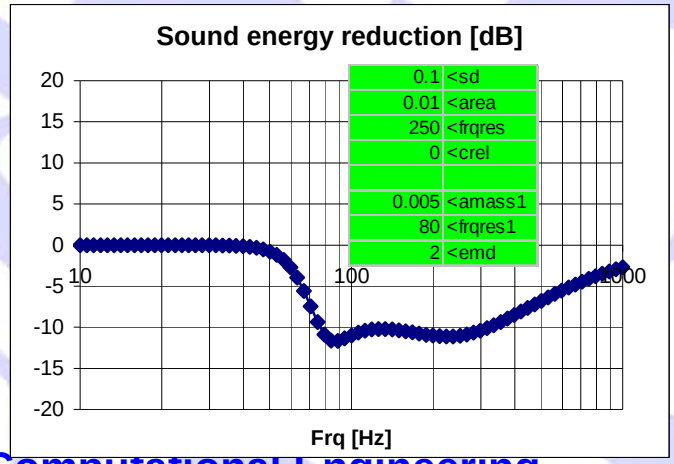
Project description:

- Noise reduction or control below 500 Hz is difficult to achieve with classical absorbers or panels.

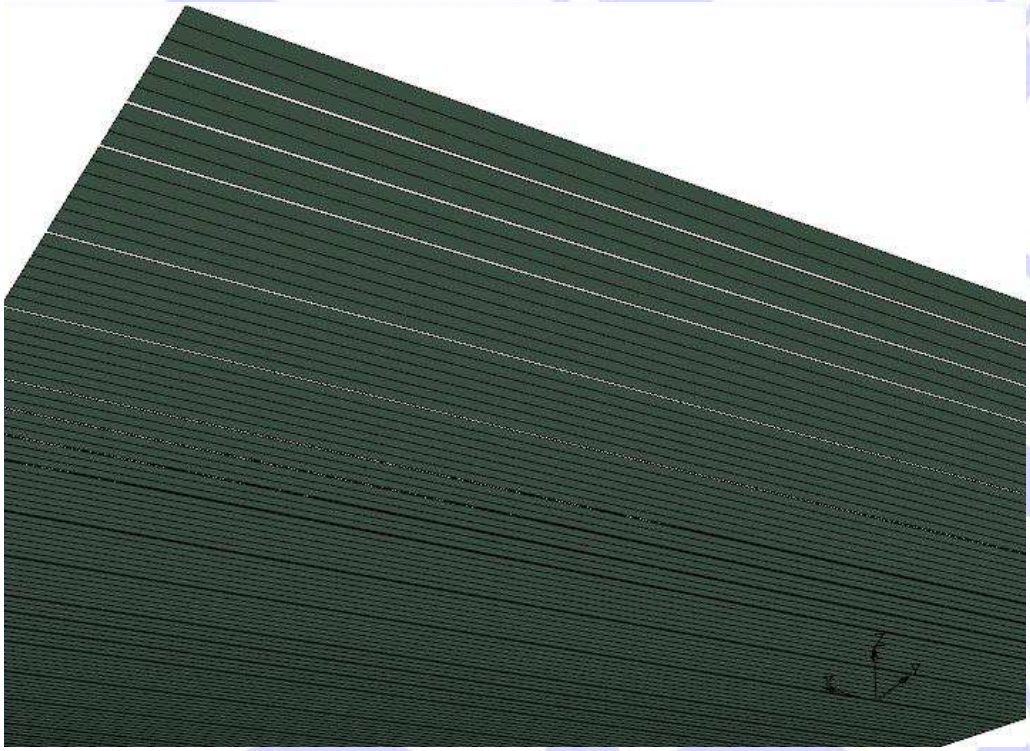
Project deliverables:

- New panel with electromagnetic damping means is able to damp or control adequately sound below 500 Hz.





Acoustic ceiling U-Ceiling®



Reverb. time t60 [s]	0.9	0.7	0.7	0.7	0.6	0.5	0.4
Clarity C80 [dB]	−2	−4	−3	−2	0	0	0
STI [−] (1)	0.5	0.5	0.6	0.6	0.7	0.8	0.7
RASTI [%] (2)			25		30		
Frequency [Hz]	100	200	500	1K	2K	5K	10

Project description:

- Room has bad acoustics characterized by high reverberation time, noisy and non-ergonomic environment and low speech intelligibility

Project deliverables:

- Patented U-Ceiling® applied under existing ceiling
- U-Ceiling® consists of tunable broadband Helmholtz resonators and panel resonators combined with MLS (Maximum Length Sequence) dispersing slits
- Excellent room acoustics, see table

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Music studio or Home Theatre design

Detail floor

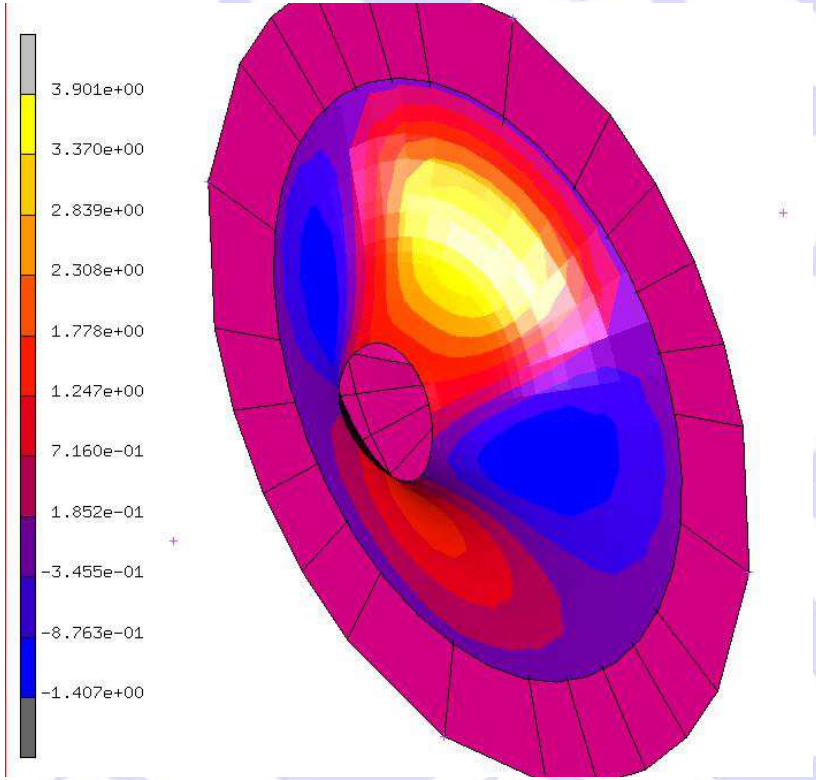
Project description:

- Music performance in existing classical town mansion provokes complaints from neighbors

Project deliverables:

- The studio is installed in the attic and consists of floating flex-limp walls, ceilings and floor
- Floor resonance frequency 19 Hz
- Transmission loss increased by 35dB at 500 Hz
- Excellent reduction of outdoors town noise
- Excellent interior acoustics for enjoyable musical performance and perception
- Peace with neighbors

Stiffness test during



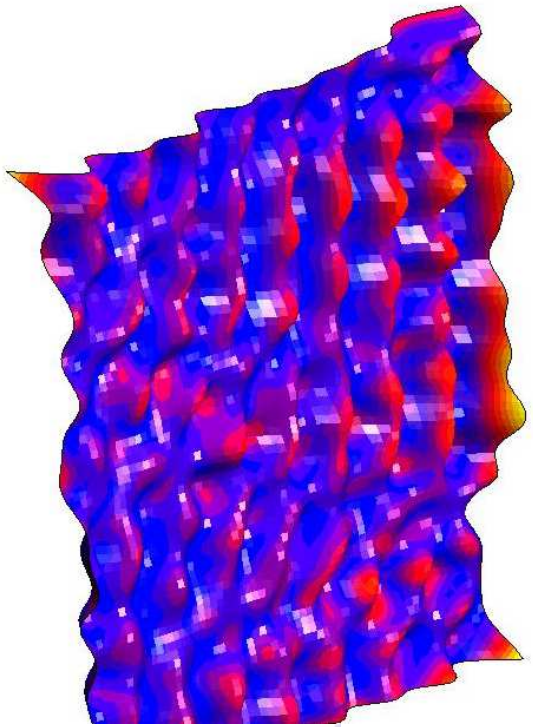
Project description:

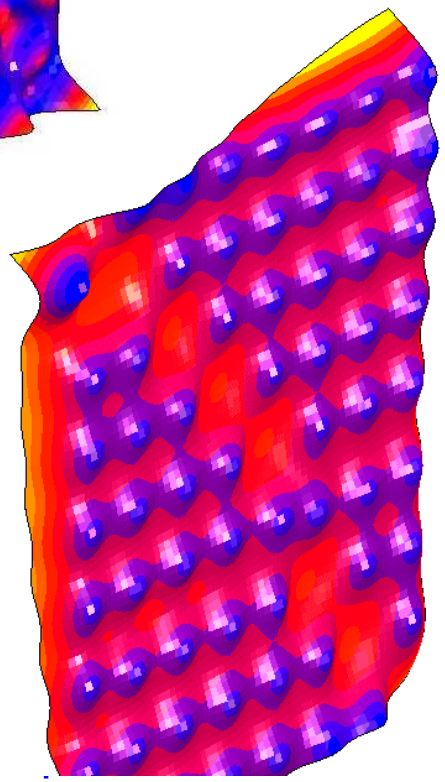
- Customer wants to establish relationship between (simple) in-line stiffness measurement and acoustical quality of the product.

Project deliverables:

- In-line measurement set-up simulated.
- Position of exciter and sensor optimized to find the optimum correlation with laboratory acoustical measurements.

Panel vibration





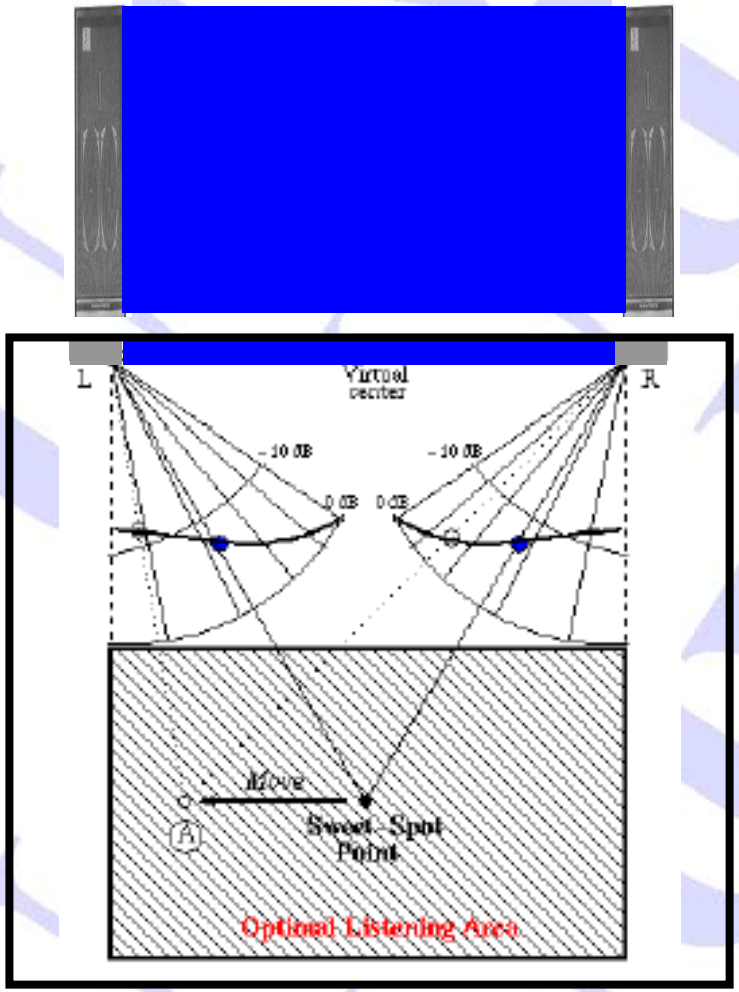
Project description:

- Sound absorbing panel.
- Interaction with sound waves

Project deliverables:

- Coupled field analysis: mechanical and acoustical.
- Influence studied:
  - Composition of panel
  - Damping.
  - Distance to wall.
  - Etc.
- Panel optimized for maximum damping in specified frequency range.

Sound field reconstruction (π Stereo)



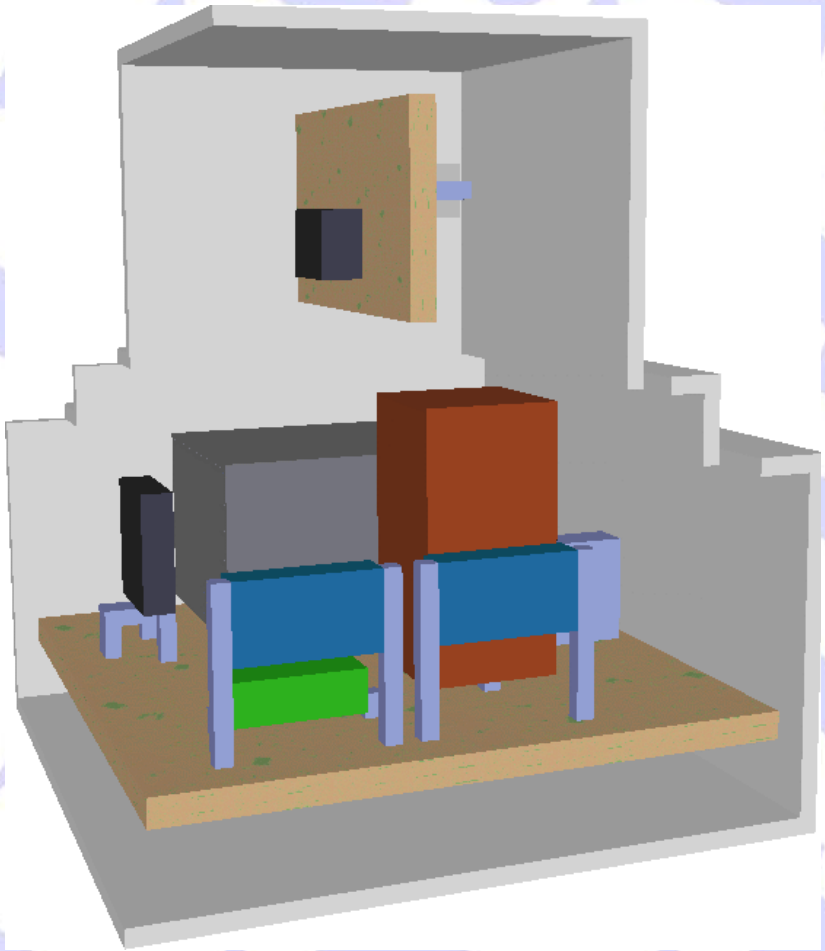
Project description:

- Normal stereo and Dolby sound reproducing systems are unable to reconstruct the localizing sound field for more than one listener.
- Even if a central listener moves his head slightly lateral, the stereo impression gets lost.

Project deliverables:

- Using loudspeaker array and filtering, a special radiation pattern is constructed, which accounts for the time/intensity trading mechanism of the human hearing system.
- Listening tests reveal a true localizing of sound sources on large screens and in a wide listening (larger than the hatched one in picture left) area.
- A central loudspeaker is not needed.

Noise reduction from cooling airflow



Project description:

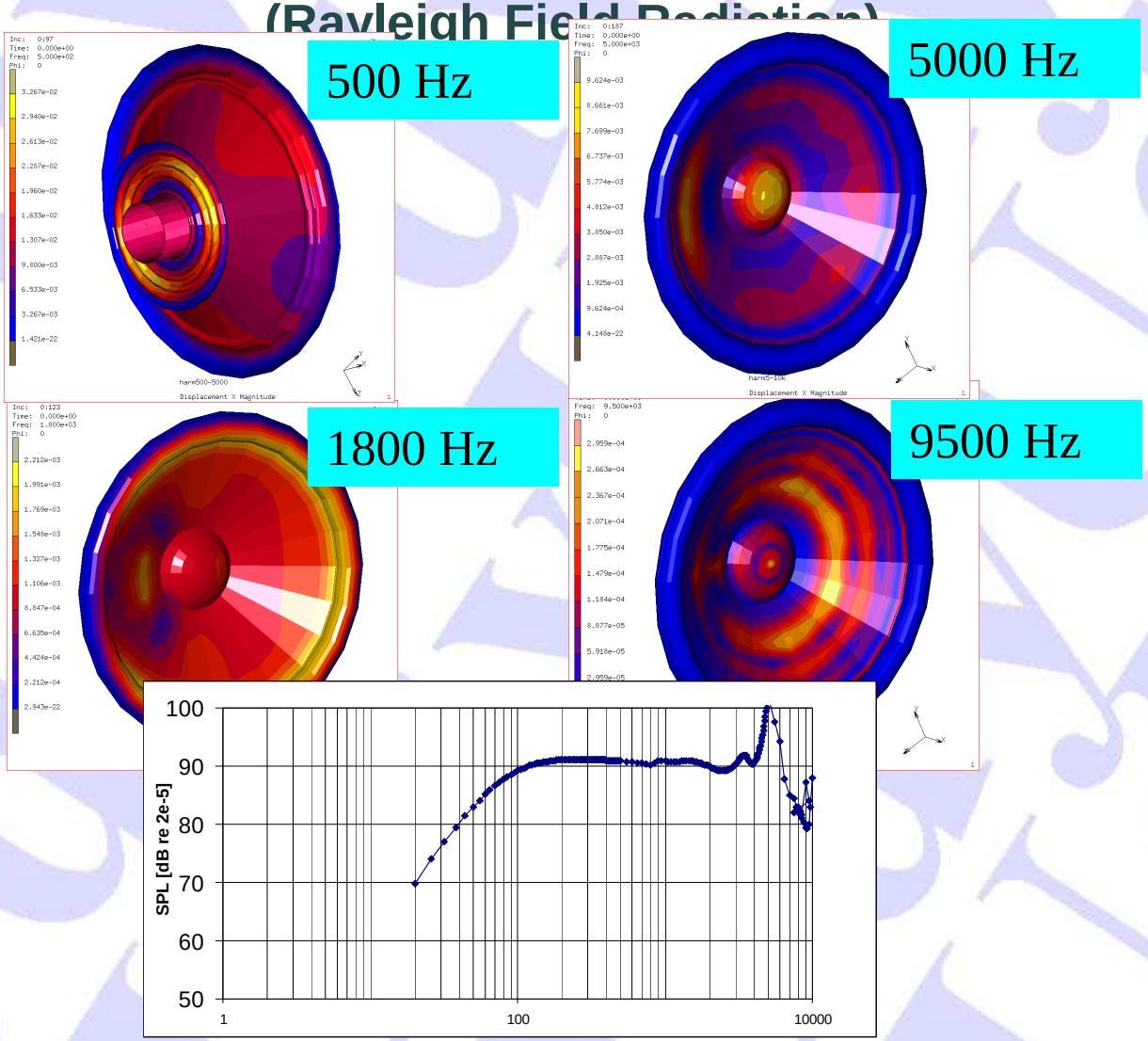
- Forced air flows through ducts and cabinet.
- Causes components and panels to vibrate.
- Noise emission.

Project deliverables:

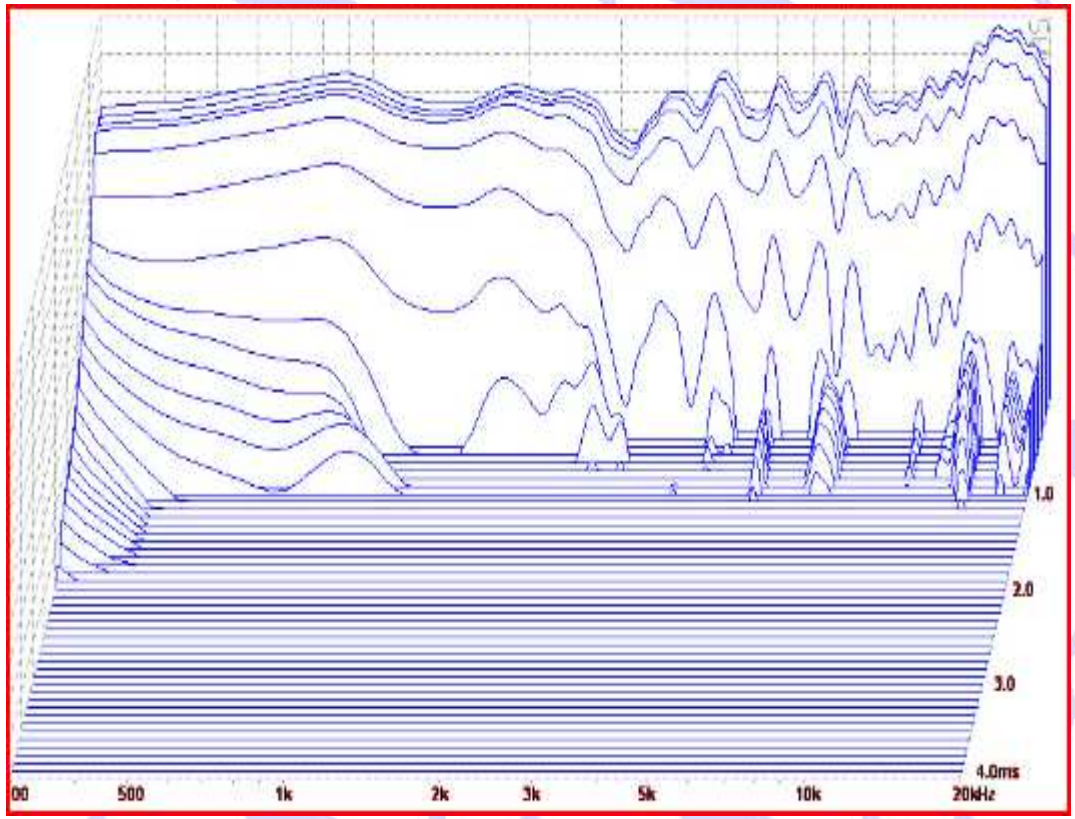
- Air flow (also turbulent) is calculated in CFD.
- Alternating pressure is imported in FEM and vibration on structure is determined.
- Can be transient or random vibration.

URAY

(Rayleigh Field Radiation)



Waterfall decay characteristic



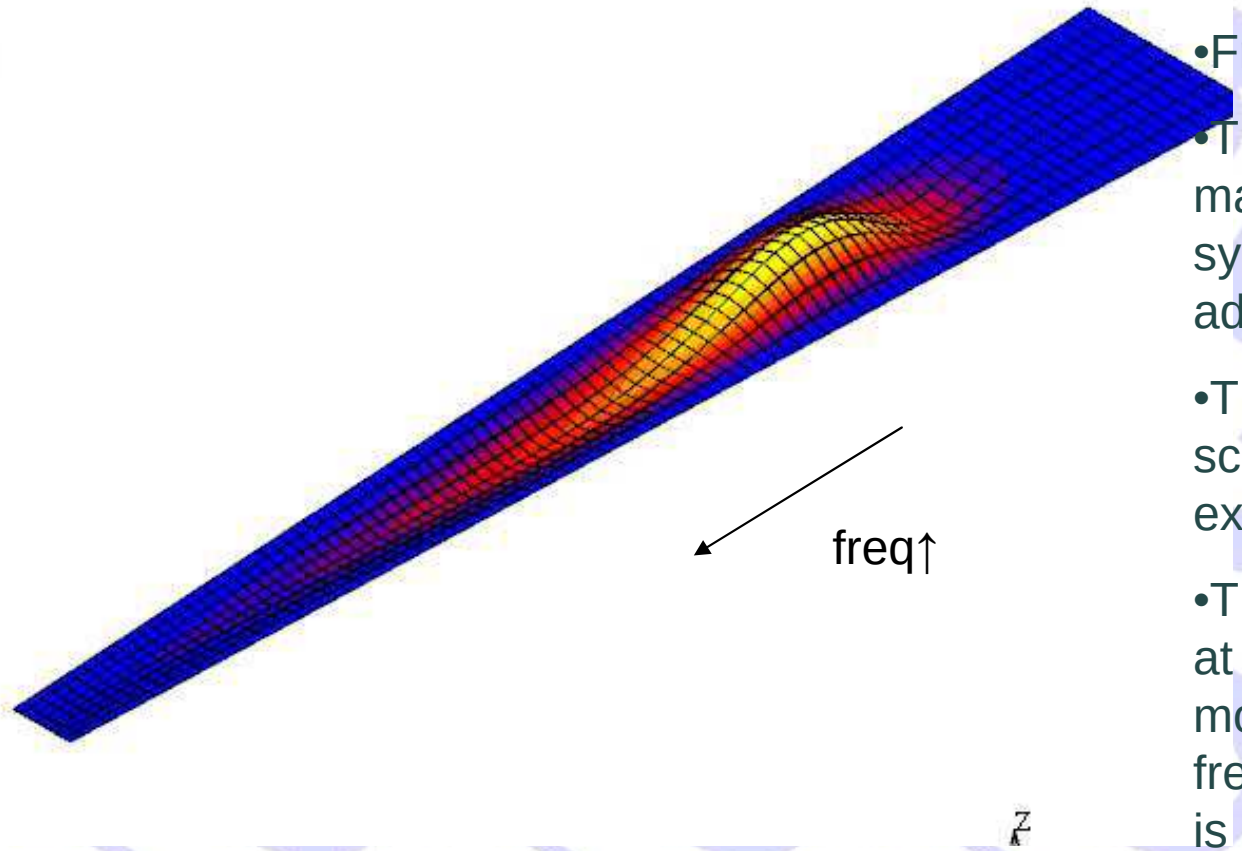
Project description:

- Loudspeaker has “colored” sound due to unwanted cone vibrations (cone “break-up”).

Project deliverables:

- From the measured or calculated impulse response, the waterfall decay characteristic is determined. This gives the decay of the individual frequencies as function of time

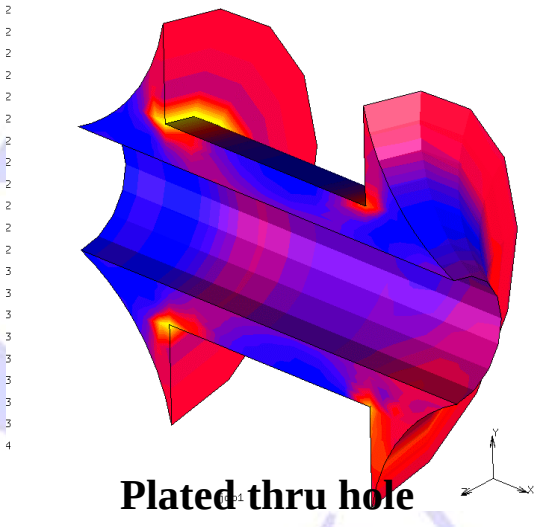
Traveling wave basilar membrane



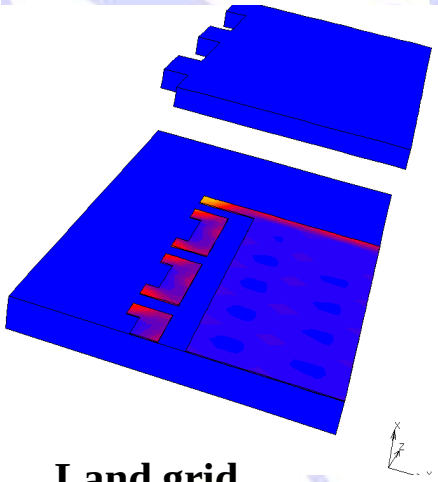
- Freq is about 1052 Hz
- The y dimension is magnified 10X and the symmetric elements added for visibility
- The deflection at the left scale is in [m] for an excitation of 1 μN at TM
- The traveling wave starts at the right at 200 Hz and moves to the left at higher frequencies. At 10000 Hz is arrives at the left side

Solder interconnections

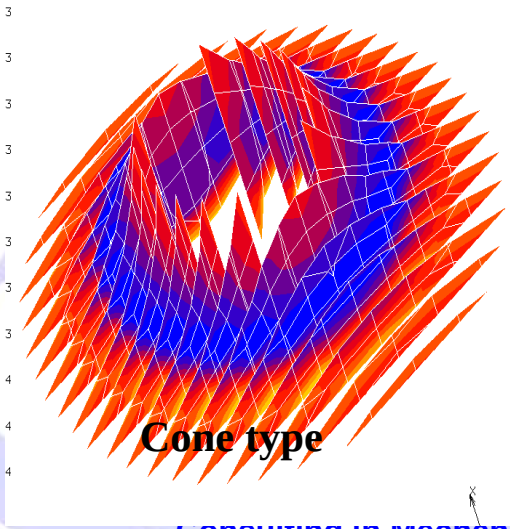
Thermal cycling fatigue of interconnections



Plated thru hole



Land grid



Cone type

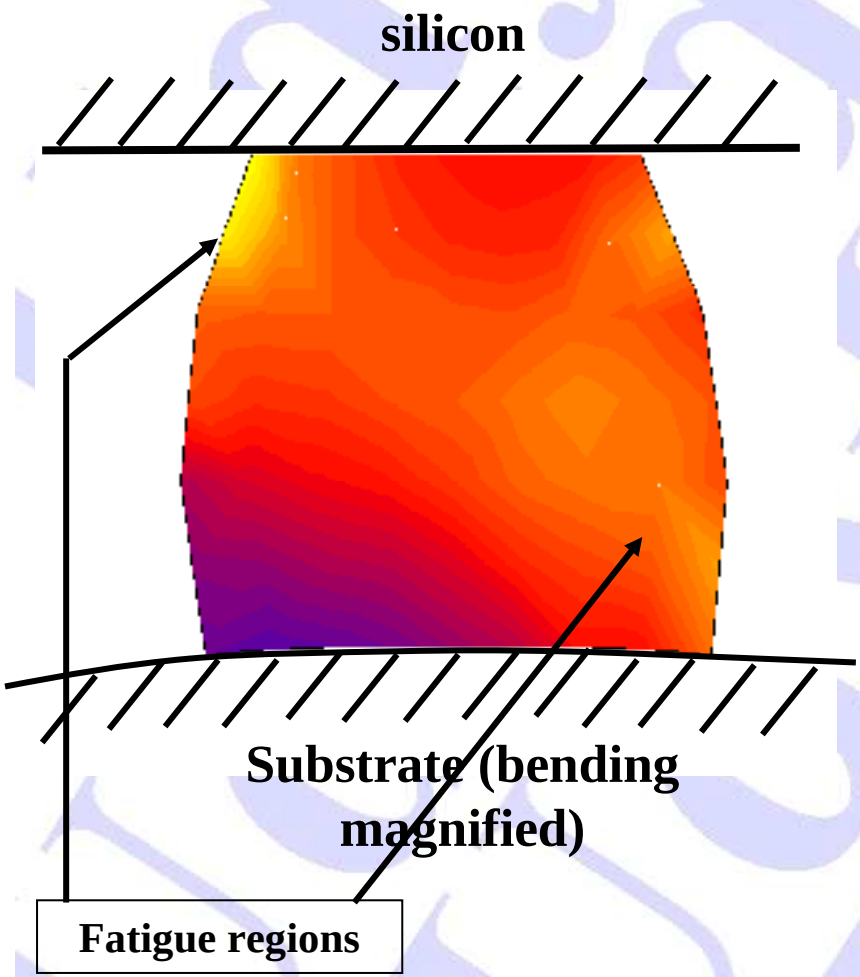
Project description:

- Metal piece or layer is subjected to external load combined with temperature cycling.
- Because of differences in thermal expansion coefficients, plastic straining causes fatigue and premature failing of service.
- Lifetime calculated according to Coffin-Manson relation.

Project deliverables:

- Geometry and material choice optimized as to reach required service lifetime.
- Inspection of development of damage inside the material.

Interconnections in BGA chips



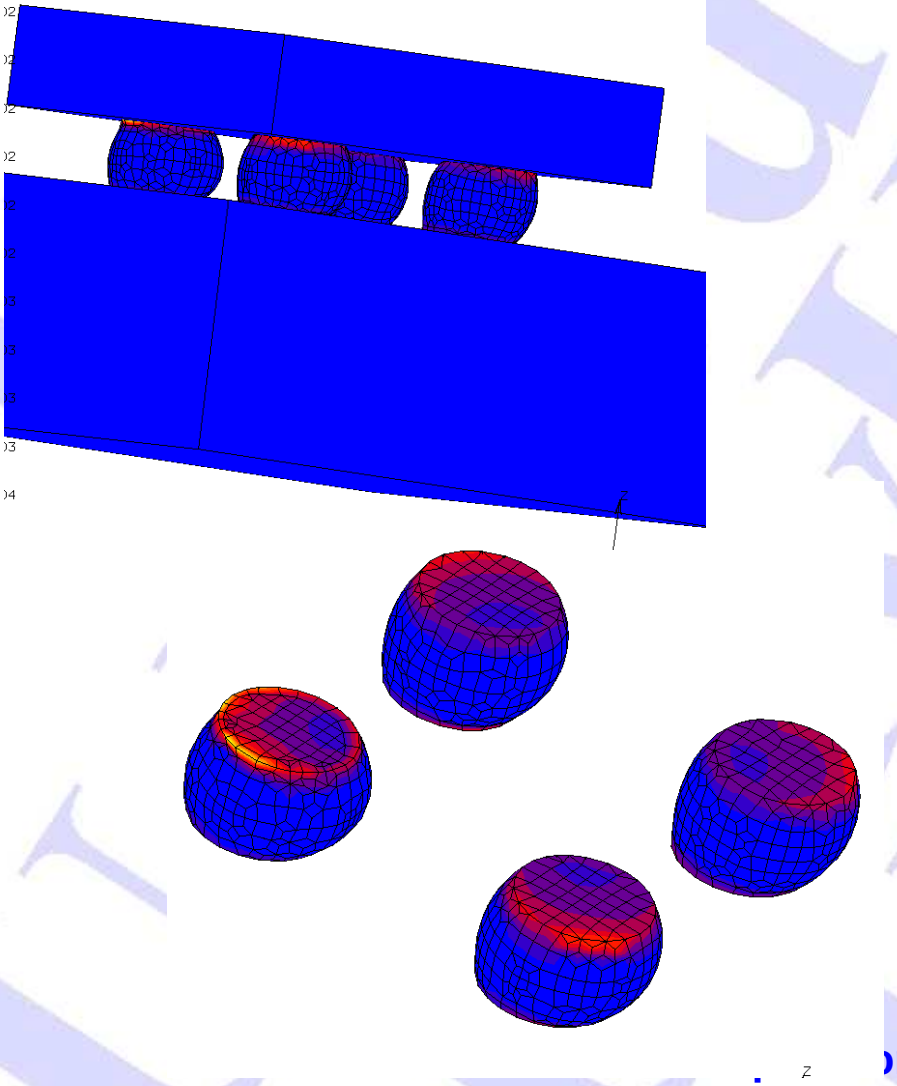
Project description:

- Solder micro interconnections in Ball Grid Array (BGA) chips have shape of small ball and are very vulnerable to mismatch in thermal expansion between silicon and substrate.

Project deliverables:

- BGA with its substrate subjected to temperature cycling.
- This causes plastic and creep strain in solder balls.
- This total inelastic strain is measure for cycle fatigue lifetime (Coffin-Manson rule).

Misalignment of micro-device



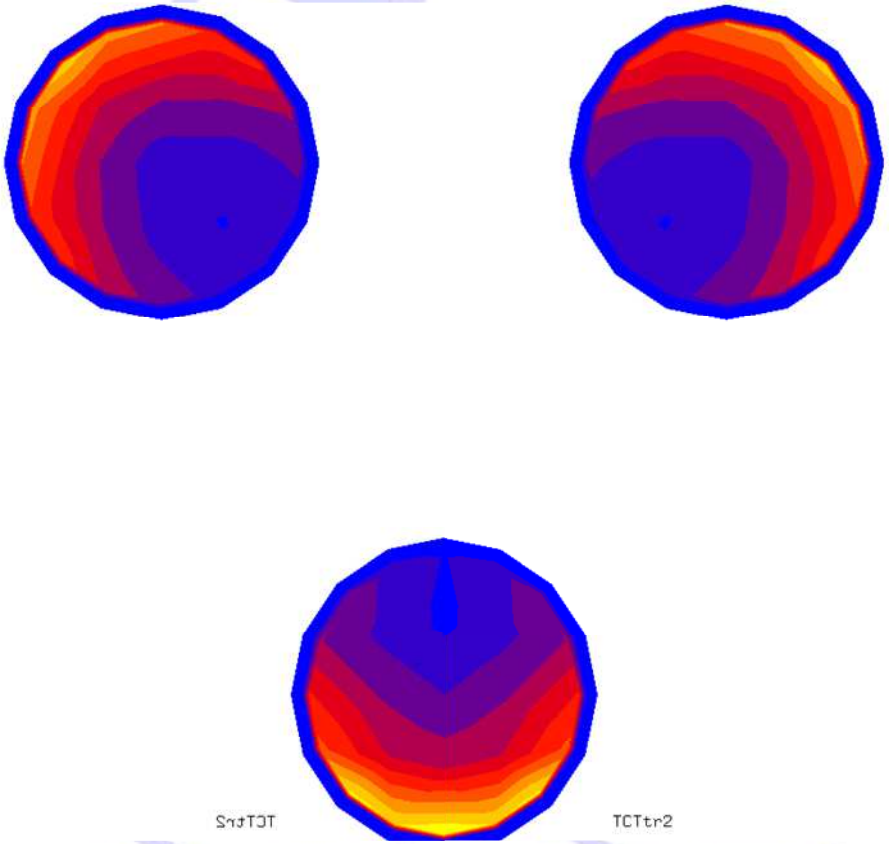
Project description:

- Due to differences in solder volumes, misalignment etc. of CSP (Chip Sized Package) is not parallel to substrate.
- Residual stress and (plastic) strain in solder balls of Chip Sized Package (CSP) during cooling down.

Project deliverables:

- Liquid solder balls formation of CSP is simulated by Surface Evolver.
- This model is imported in FEM solver.
- The residual stress and plastic strain accumulated during cooling down is calculated.
- The cause of CSP misalignment is investigated and remedied.

Separation local and global CTE mismatch



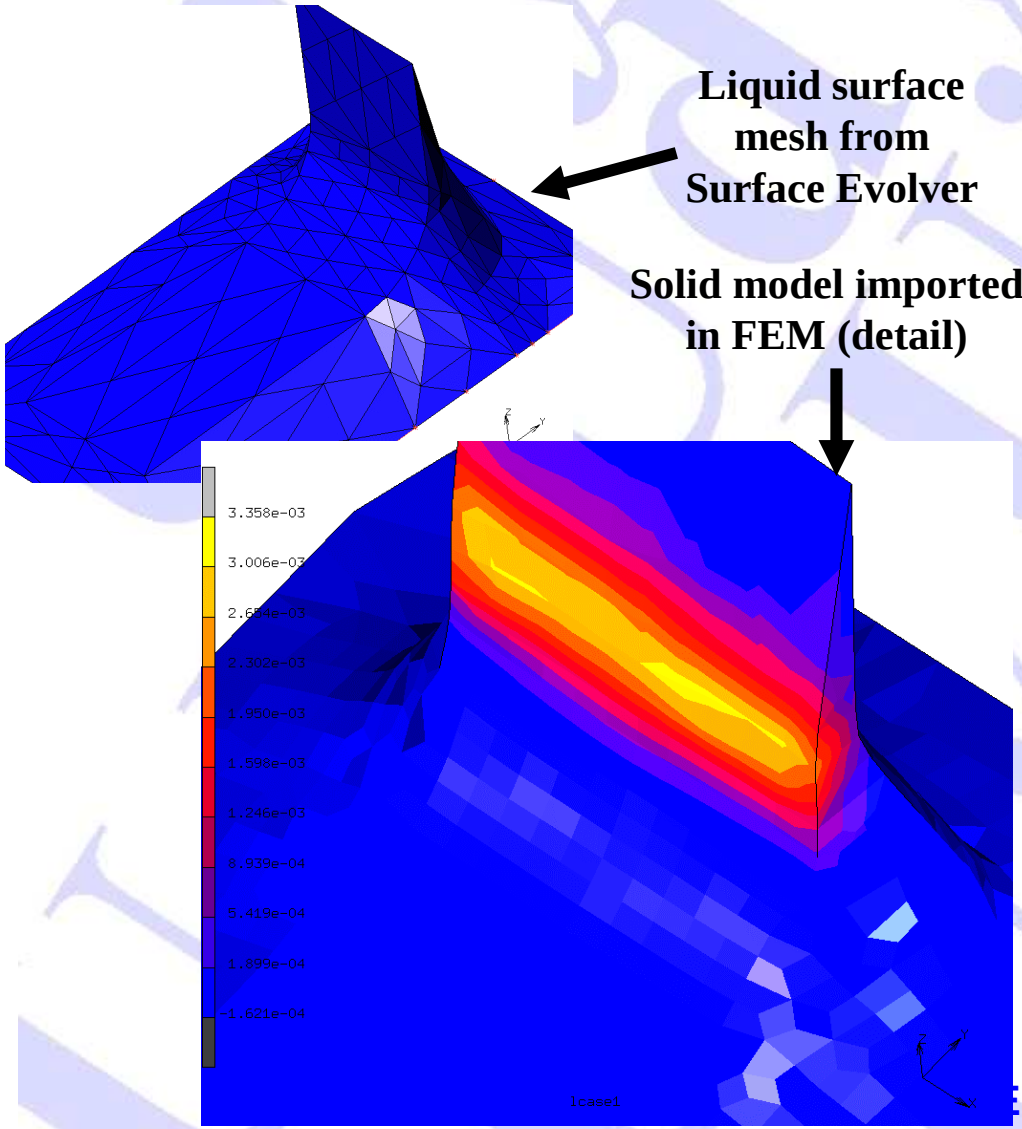
Project description:

- Local CTE mismatch can be an important device killer when short-time transient internal heating occurs frequently.

Project deliverables:

- Local deformations separated from global ones in high power light emitting CSP (only topview of 3D balls visible in picture left).
- Interface layers between solder and die and substrate optimized (both material choice and thickness).

Solidification shrink, residual stress



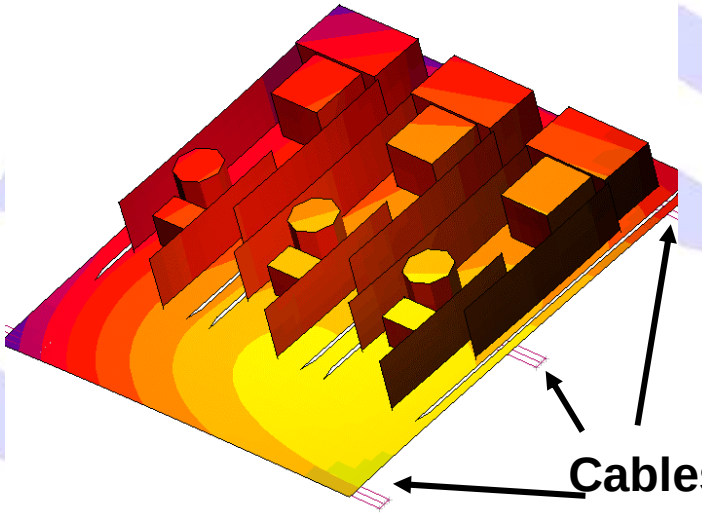
Project description:

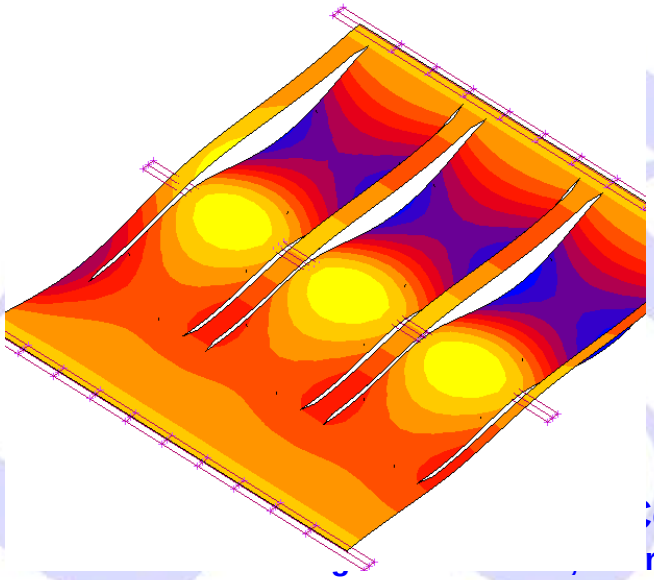
- Liquid solder develops shape under influence of gravity, surface tension and wetting angles by using the free Internet "Surface Evolver" program.
- The droplet is cooled down and solidifies, hence residual shrink and stress.

Project deliverables:

- Liquid shape determined exactly and imported in FEM without resorting to higher order B-surfaces.
- Full hexahedral solid mesh for advanced non linear thermo-mechanical analysis taking into account cooling effects.

Printed circuit board warp age





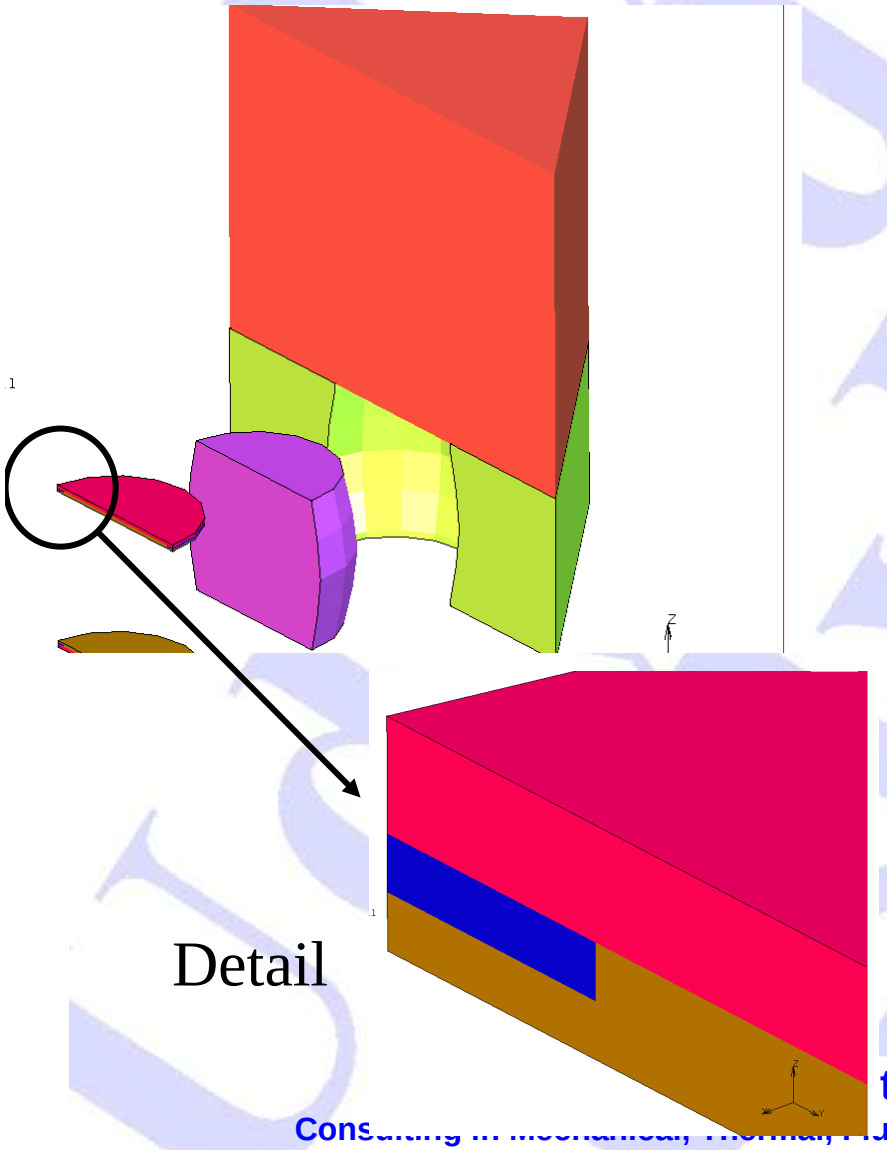
Project description:

- **Printed circuit board (PCB) with components passes through wave soldering oven supported by cables.**
- **The PCB consists of built-up copper and pre-preg layers. These have anisotropic and temperature dependent material properties.**

Project deliverables:

- **PCB modeled as built-up composite with all necessary anisotropic and temperature dependent properties.**
- **If needed, moisture influence can be included.**
- **True contact between board and cables.**
- **Extra boundary condition is temperature profile of oven.**
- **Deformation of board simulated as function of material and process parameters.**

Bump interface layer damage



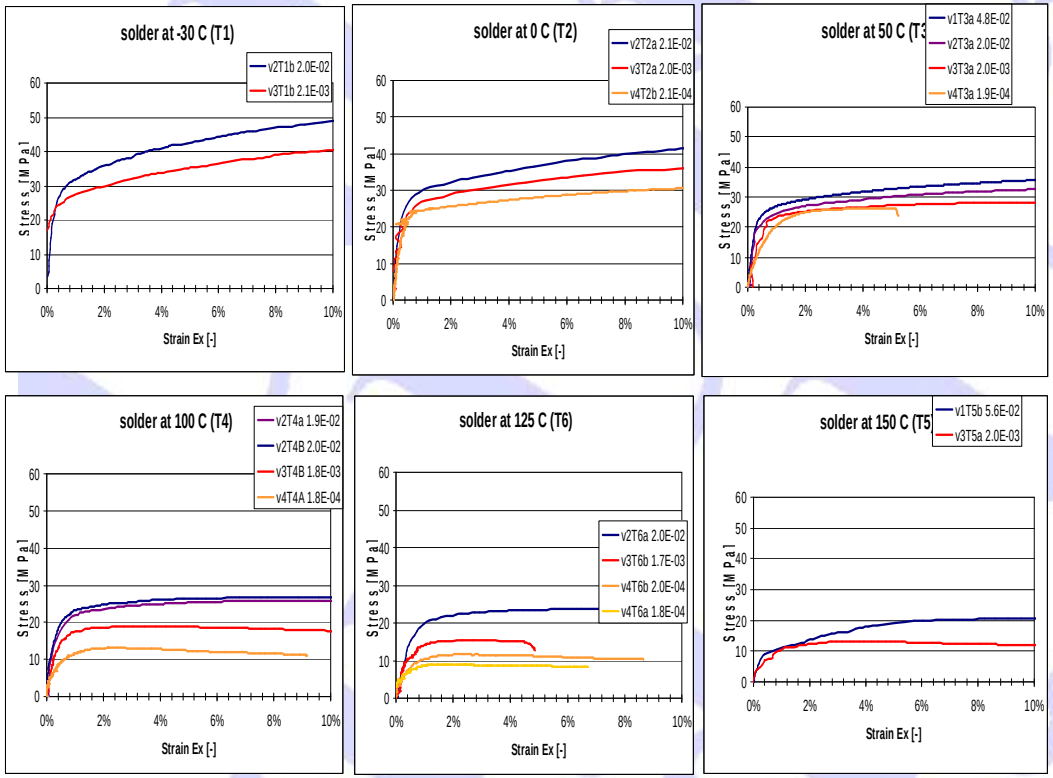
Project description:

- During TCT of Chip Sized Package (CSP), interface layers between solder balls and silicon and/or substrate exhibit large stress and consequently damage is initiated frequently there.

Project deliverables:

- 1 cell of Chip Sized Package (CSP) modeled in detail, including the interface layer pack (UBM, resist).

Solder material constitutive modeling



Project description:

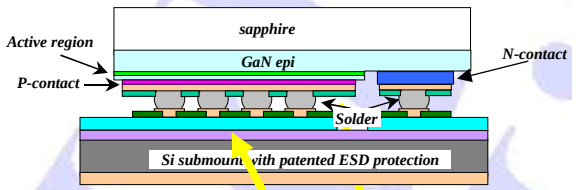
- There are hundreds of possible solder materials, amongst which Pb-free solders are becoming mandatory.
- Avoid tedious thermo-mechanical testing of devices for all possible solders requires comprehensive material testing and constitutive modeling capabilities

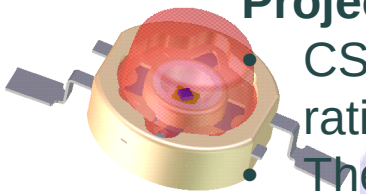
Project deliverables

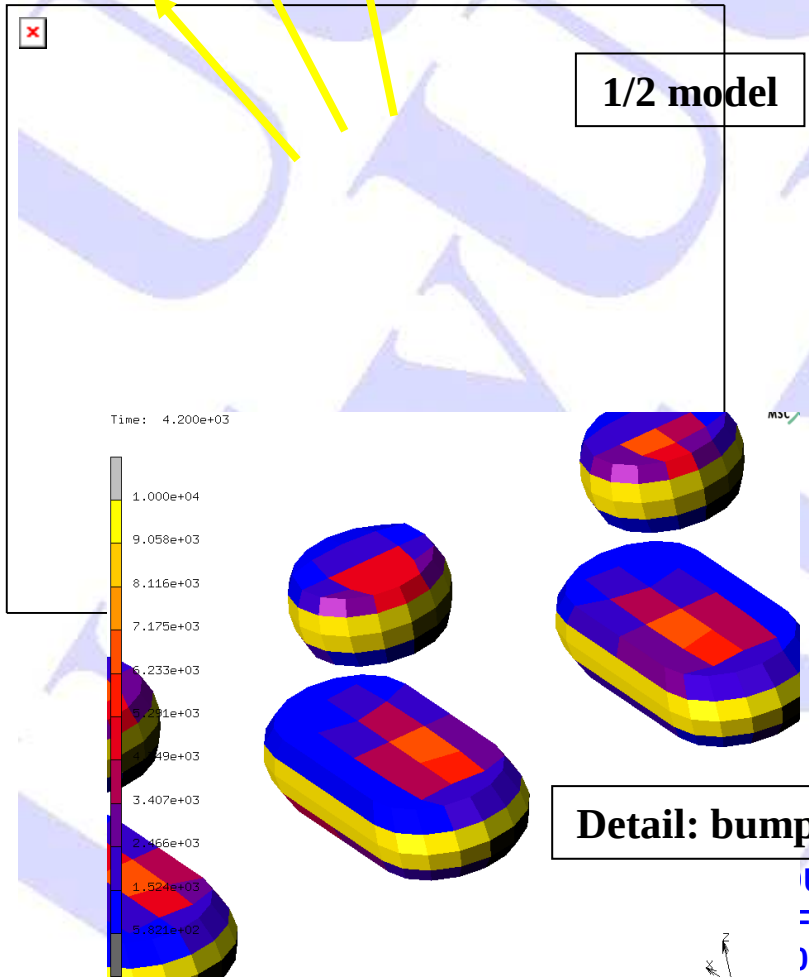
- Complete characterization of exotic solder material, including temperature dependency and fatigue data

Thermo-mechanics of packages, dies and leadframes

High Power Chip Size Package (CSP)







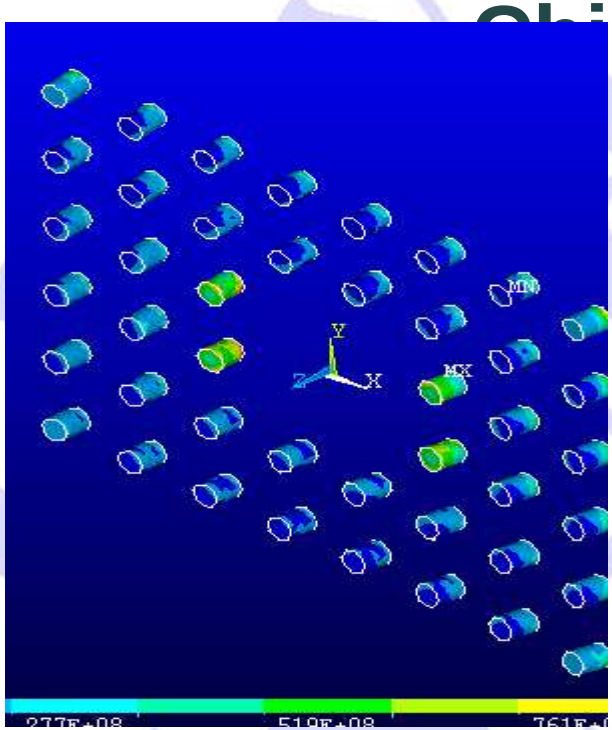
Project description:

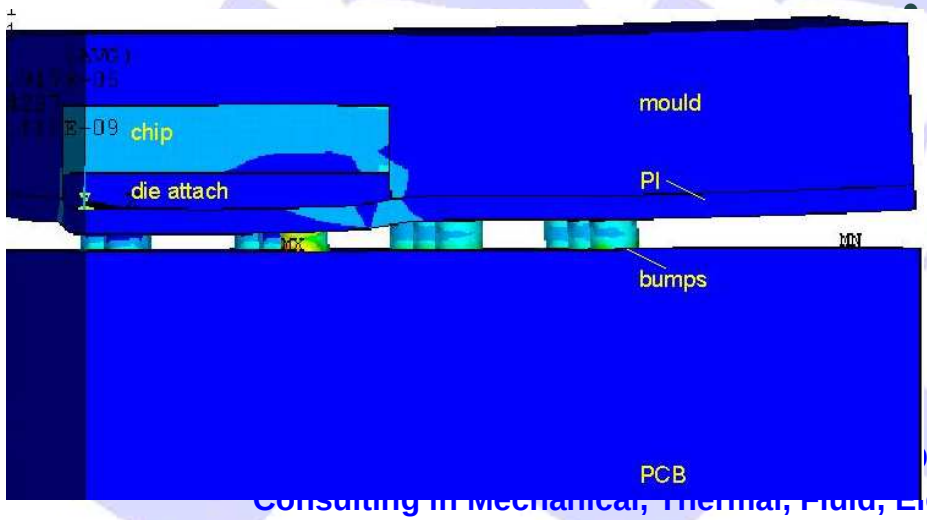
- CSP is operated at high surface power ratings (up to 1 W/mm^2).
- The design is heavily supported by numerical low cycling fatigue (LCF) simulations of deposited layers and solder bumps.

Project deliverables:

- Insight in factors affecting solder bump lifetime
  - –Geometry of LEDs and bumps, including oval shape
  - –UBM stack (Under Bump Metallization)
- Virtual, customer tailored, testing:
  - –Different power cycling test programs according to automotive specs, resulting in huge savings in ‘real’ testing: TCT, P-TCT, TST
- Material models include plasticity and creep to capture time effects.
- Special LCF visual postprocessor.

Chip size package





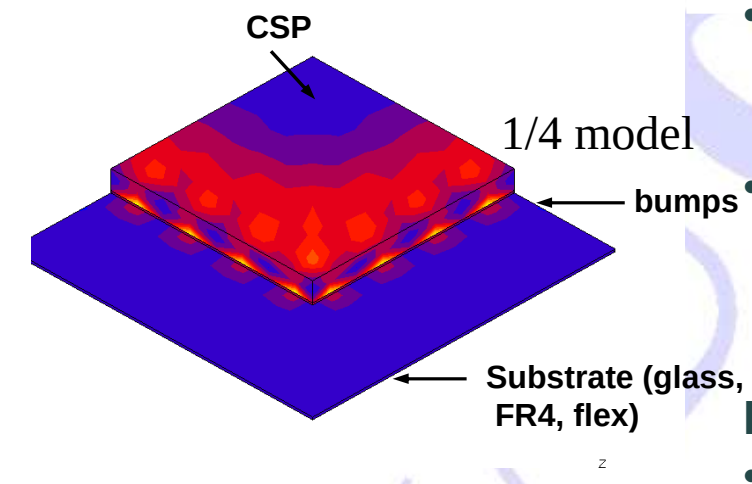
Project description:

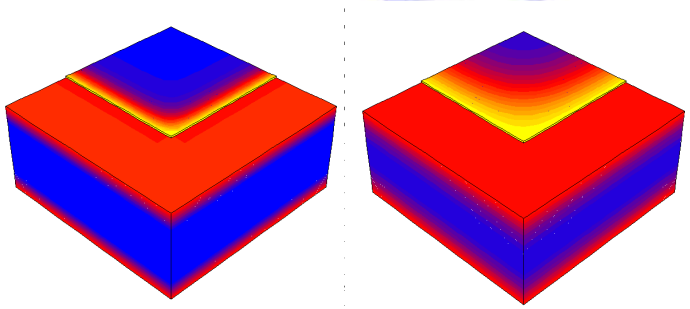
- CSP solder beads are vulnerable to thermal stress.
- Underfill used to relief stress.

Project deliverables:

- Complete CSP modeled, including the substrate and underfill.
- Thermal stress determined during TCT.
- New underfill specified.

Chip sized package (CSP)





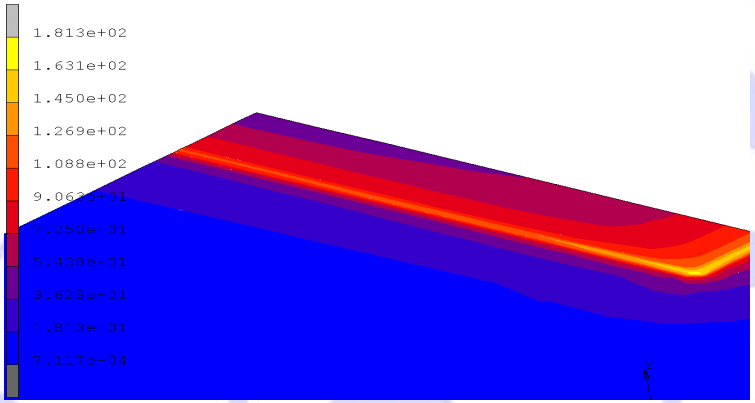
Project description:

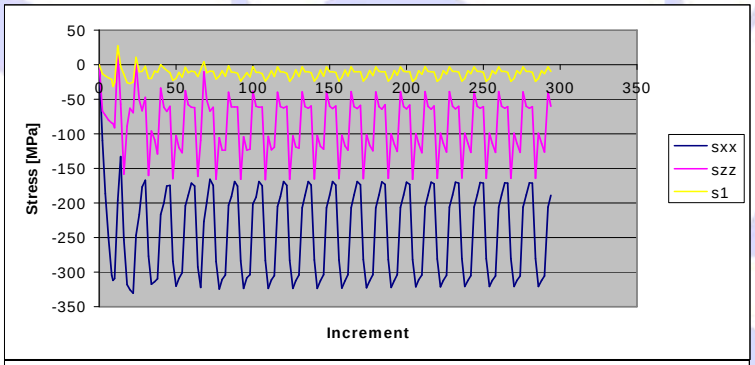
- We support state-of-the-art advice in the field of thermo-mechanical issues of microelectronics, packages and interconnections.
- As an example, we take an Array Chip Sized Package (CSP), which is glued by means of a conducting adhesive to a flexible substrate

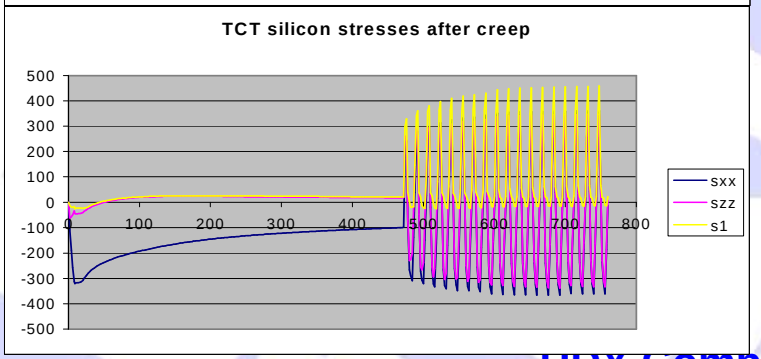
Project deliverables:

- Complete chip is modelled in 3D and all phases during manufacturing and different environmental conditions are simulated. These are:
  - curing of the adhesive
  - power/temperature cycling of the cured CSP
  - moisture penetration as function of time
- At each time, the internal forces, deformations and stresses are calculated.
- Construction details are modified to optimize performance.

RF base module







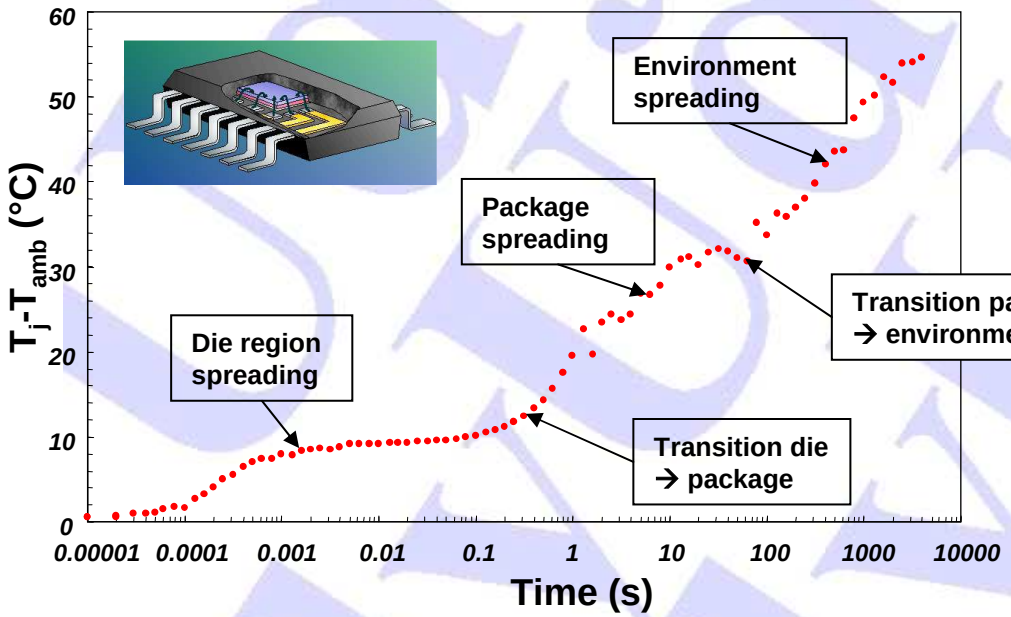
Project description:

- **During production and use, the RF base module is subjected to thermal and mechanical loading, causing failure and reliability problems.**

Project deliverables:

- **Complete module with manufacturing and test conditions modelled.**
- **The simulations indicate that the most critical process is the temperature cycling test. Stress levels reaching critical values are predicted after a limited number of cycles. This increase is caused by the hardening effect of the leadframe copper.**

Internal thermal behaviour packages



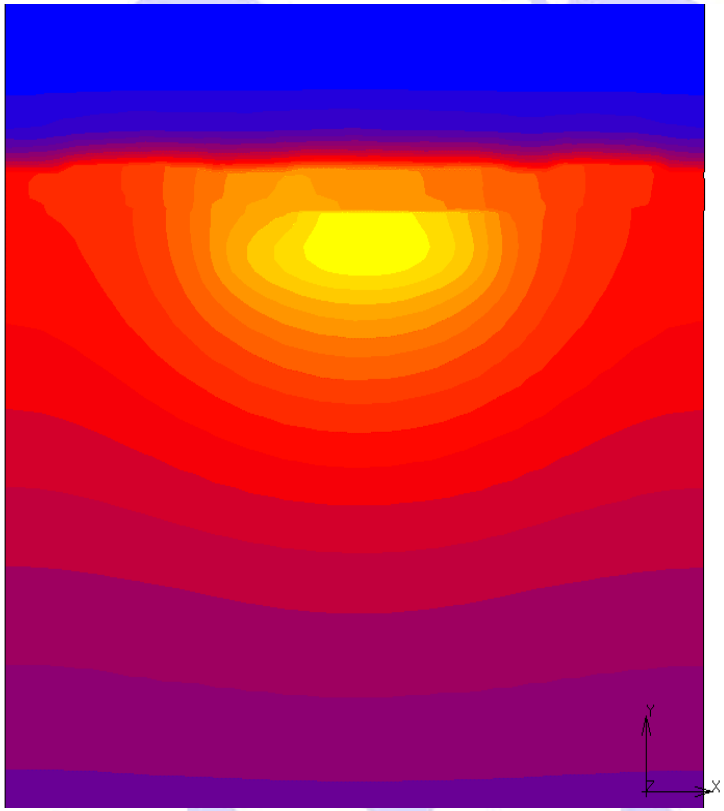
Project description:

- Package has various time constants.
- Slope change marks an interface → new "part" of package takes part in heat transfer.

Project deliverables:

- Transient, non-destructive, analysis method.
- Detect failures: die-attach, de-lamination ….
- Characterisation of thermal behaviour (Rth_{j-a}).
- Verification of die-level package models.

Pn-junction simulation

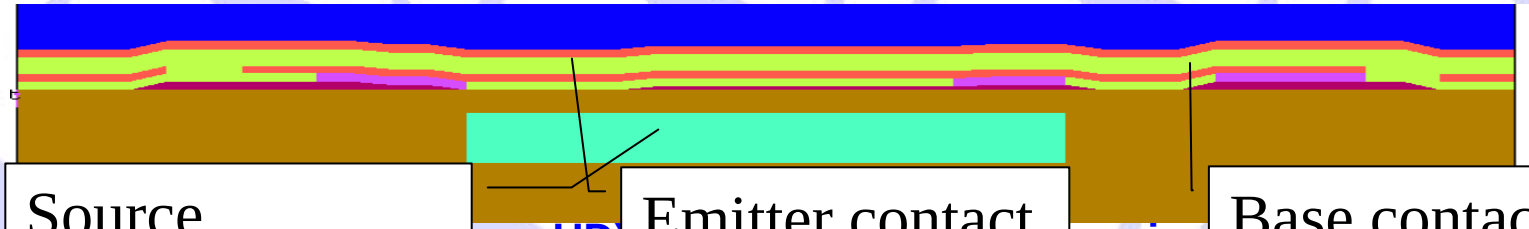


Project description:

- The deposition of layers is simulated, including non linear material behavior.
- The device is simulated during its operating.
- Thermal and mechanical parameters are determined.

Project deliverables:

- Coupled field analysis.
- The process conditions during layer deposition are optimized.
- The influence of geometrical and material parameters upon performance is determined.
- Transistor parameters can be tuned.
- Lifetime of device increased.

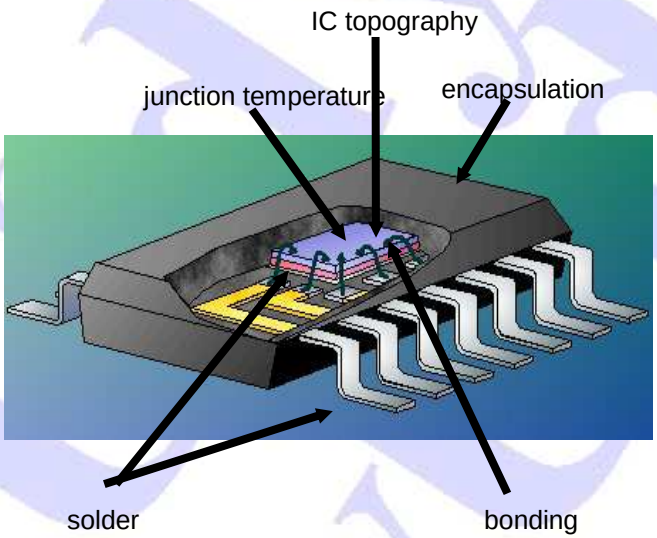


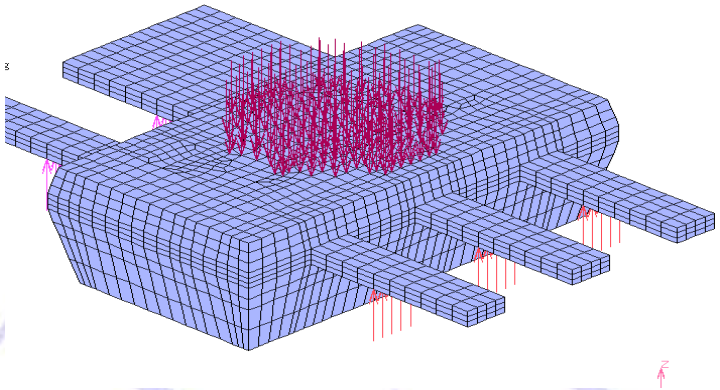
Source

Emitter contact

Base contact

Virtual package design





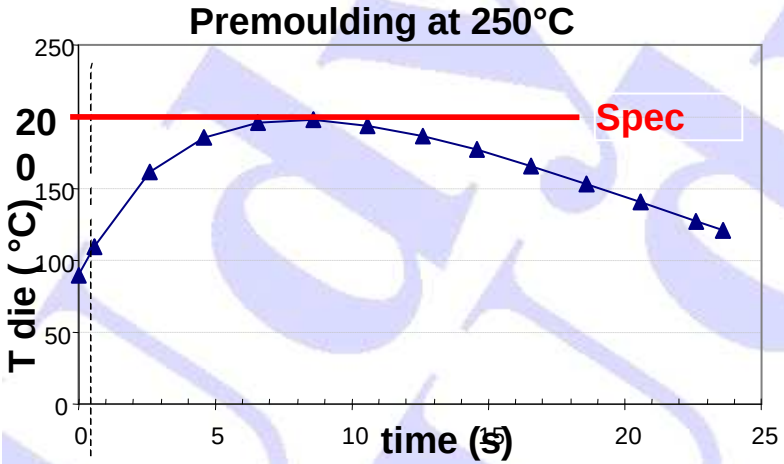
Project description:

- Given: die, leadframe, pin count and package dimensions, material specification and thermal and/or mechanical loads.

Project deliverables:

- We are able to simulate the stress distribution, temperature profile, solder interconnection forces, the solder fatigue lifetime etc.
- Without tooling or testing, optimization of dimensions and material choice is possible.
- This results in considerable time and money savings in testing and time-to-market.

Sensor package redesign for higher application temperatures



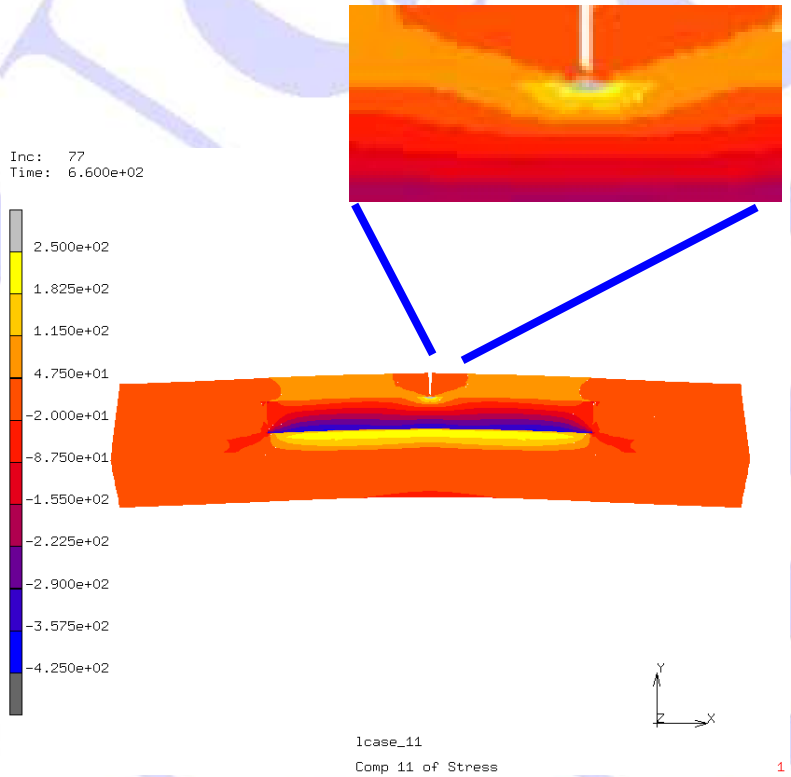
Project description:

- Customer wants to re-design existing sensor ASIC for higher temperatures applications.
- Without modification, this results in die crack.

Project deliverables:

- Mechanical simulations: investigation of influence of different encapsulation materials on die stress in comparison to stress resulting from the connection to PCB.
- Thermal simulations: to ensure that die temperature remains below pre-mould process at 250°C.
- Also electrical signal offset simulated.

Package crack and die stress



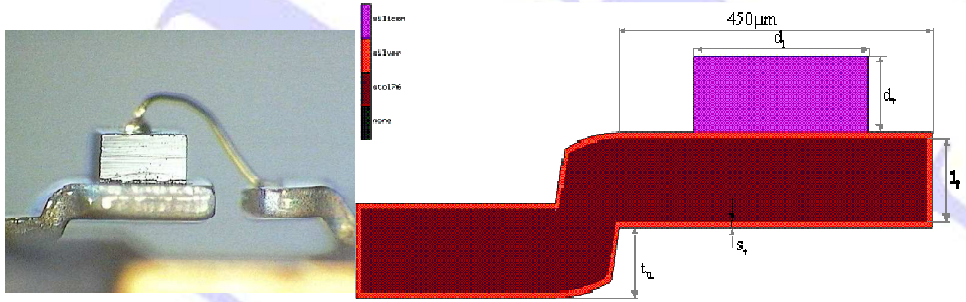
Project description:

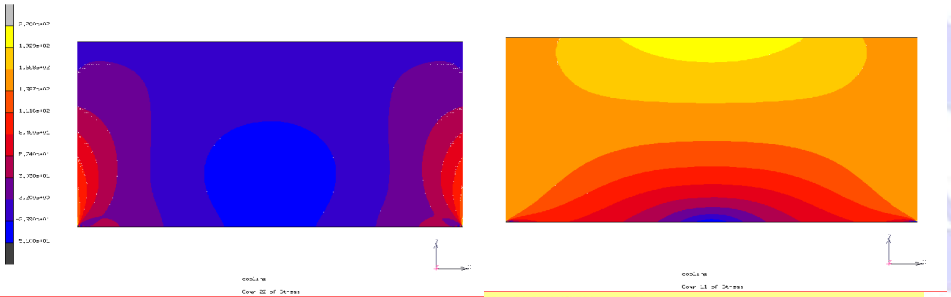
- Initial crack in package.
- Can this be the cause of die breakage?

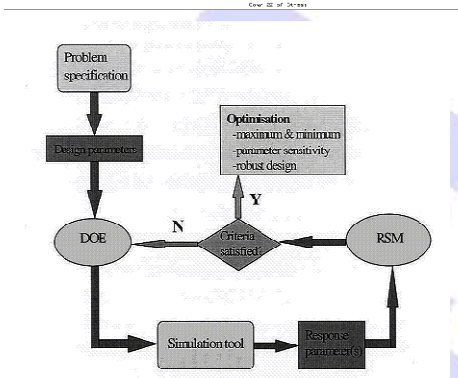
Project deliverables:

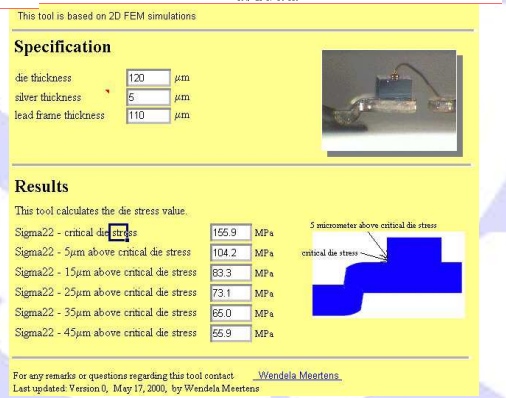
- S11 is about 250 MPa in a large area near the crack (see magnification: gray part is even >250MPa) which causes silicon to crack.

Die crack with up-bent leadframe









Project description:

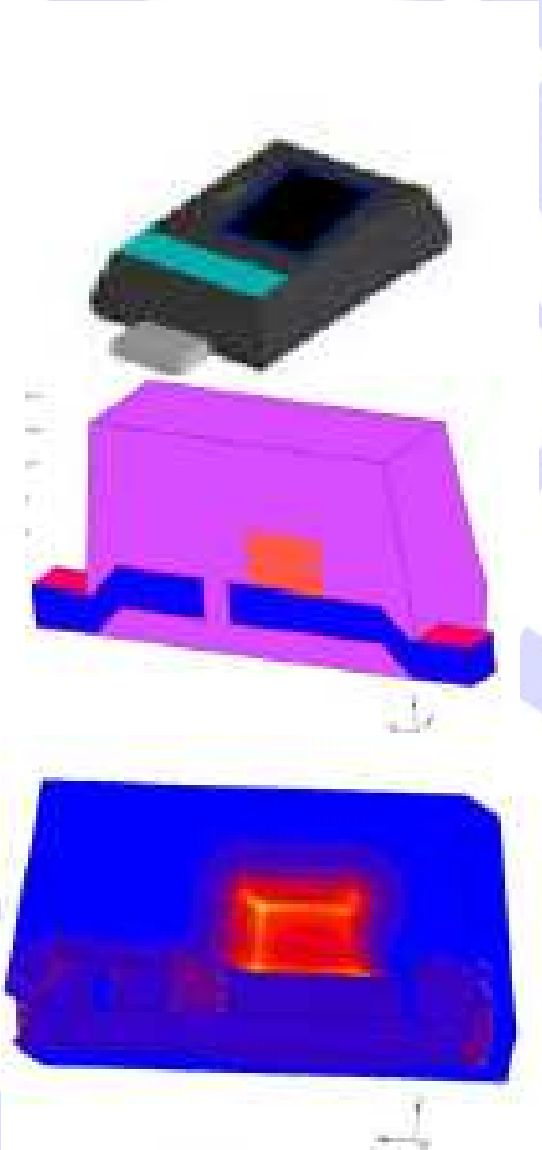
- **SOD523 has die soldered or glued on “up-bent” leadframe.**
- **Determine combination of die dimensions and thickness of solder and plating layer, so that no die cracks occur during thermo-mechanical testing.**

Project deliverables:

- **Stress in x- and y-direction determined after soldering die to leadframe.**
- **Response surface modeling (RSM) using “Latin Hypercube” method to capture all possible combinations adequately.**
- **Tool for black-box users.**

Molding and Overmolding

Plastic body stress & failure analysis



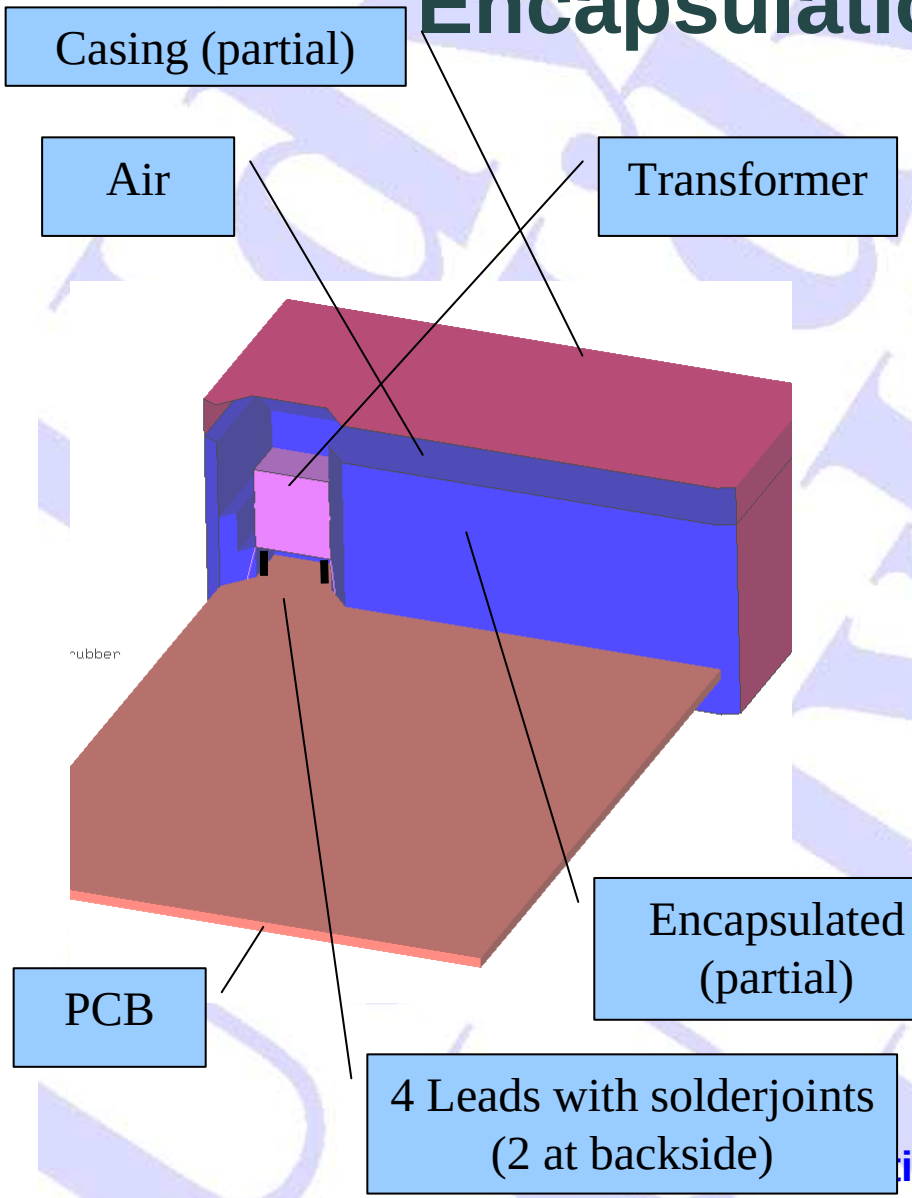
Project description:

- Plastic cracks were observed during over-molding process.
- What is the influence of material parameters, process conditions and curing effects on global reliability?

Project deliverables:

- Critical locations for plastic body cracks due to processing are detected.
- Dominant production steps and failure mechanisms for body cracks are found: molding plays dominant role due to its visco-elasticity nature.
- Improved reliability, less failures**.**

Encapsulation (“potting”)



Project description:

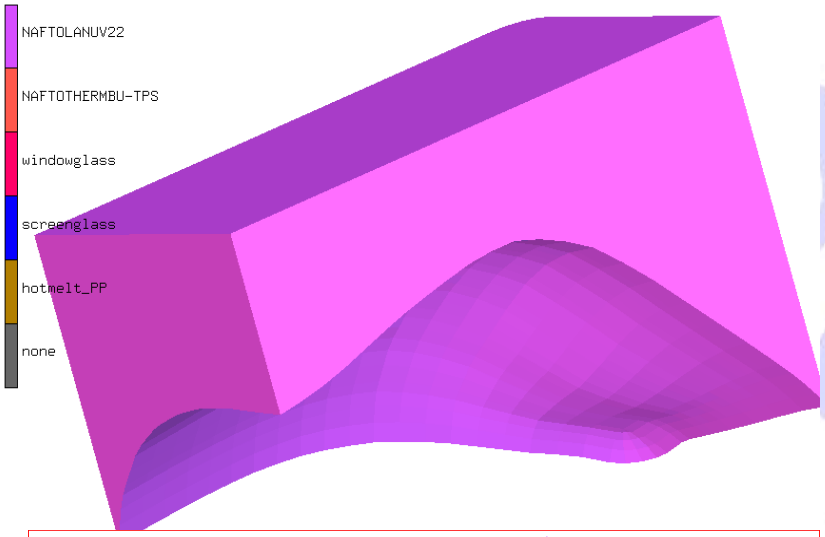
- PCB with transformer soldered with its 4 leads to the PCB, partially or completely encapsulated in outer ballast casing.
- Question: what are forces on solderjoints during temperature cycling (-40/125 degC) with different encapsulation materials if there is (not) release coating and if filling is partial?
- Picture shows Finite Element Analysis model. For visibility, the casing, and the encapsulation are partly omitted.

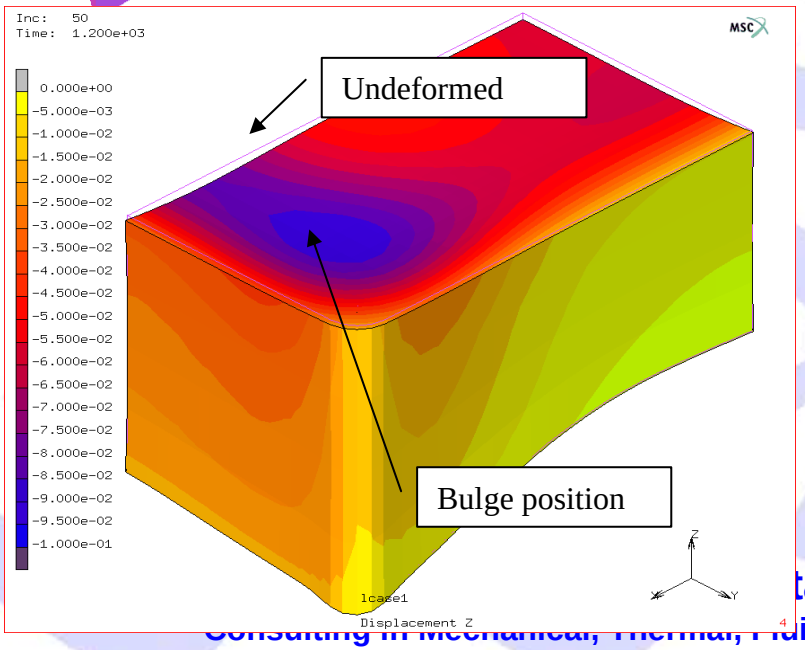
Project deliverables:

- The encapsulation is cured at 60 deg C. No stress nor forces at this temperature.
- The program calculates the forces at the 4 solderjoints at 3 temperatures: 125, -40 and 20 deg C.

Board Level

Underfills





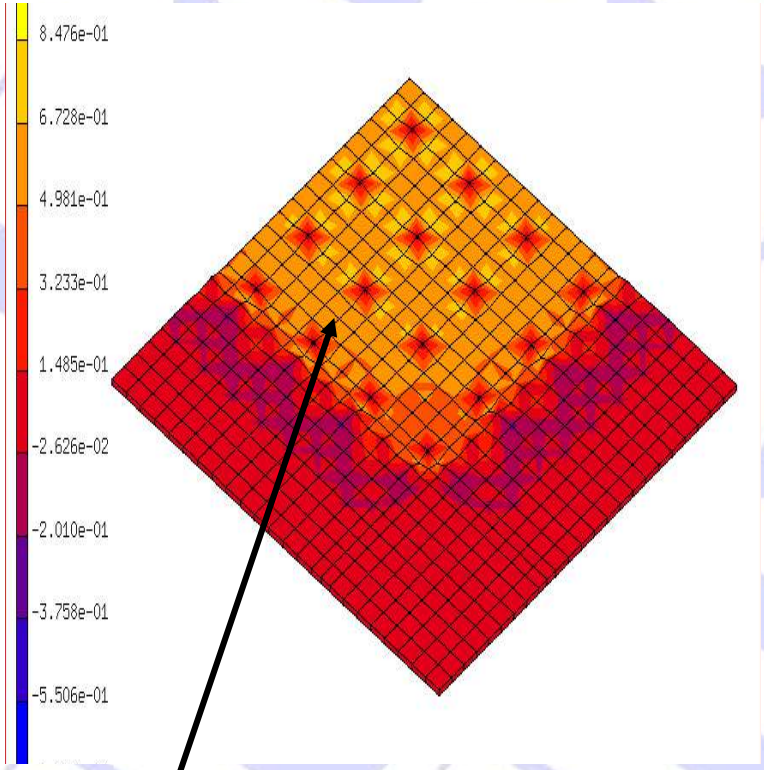
Project description:

- Silicon die and substrate are connected to each other by pouring adhesive between them.
- Curing shrink of adhesive causes deformations (strongly magnified in vertical direction in picture left).
- In some cases e.g. under influence of hygroscopic effects, underfill delaminates.

Project deliverables:

- Curing of adhesive simulated numerically.
- Deformation mechanism simulated.
- Criterion for delamination established (Rankine stress).
- Guidelines and design rules to prevent delamination.

Flip Chip underfill adhesive curing



Backside of substrate shows hillocks under bumps

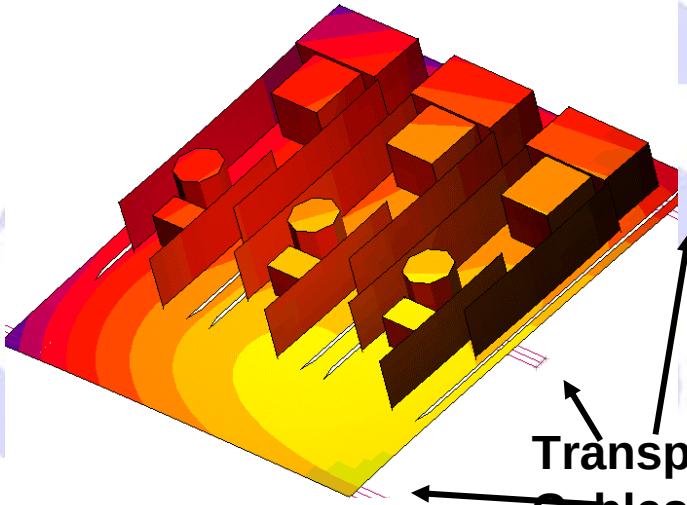
Project description:

- Flip Chip and Chip Sized Packages (CSP) are underfilled (sort of adhesive) between die and substrate to enhance mechanical reliability of interconnections (bumps) with respect to thermal mismatch.
- Exhibit shrink during curing.
- This deforms the substrate (in this case polyimide flex).

Project deliverables:

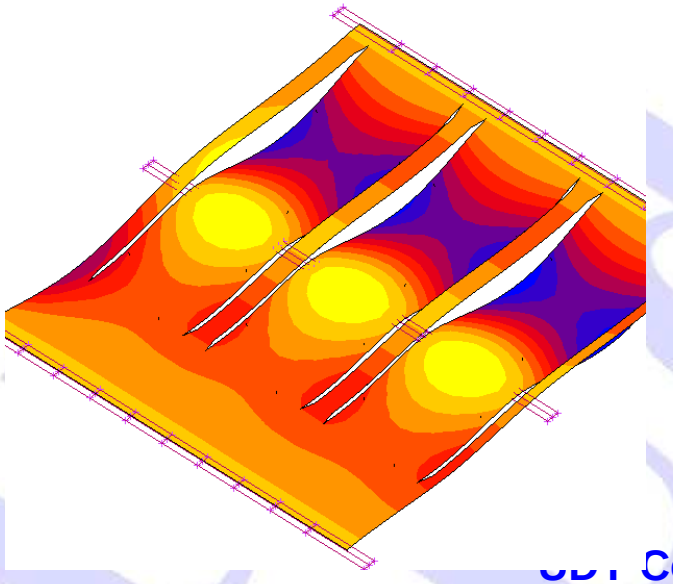
- Curing shrink is simulated.
- Effect on bump forces investigated.
- Calculated substrate deformation and hillock heights matches exactly the measured one.

Printed circuit board warpage



Project description:

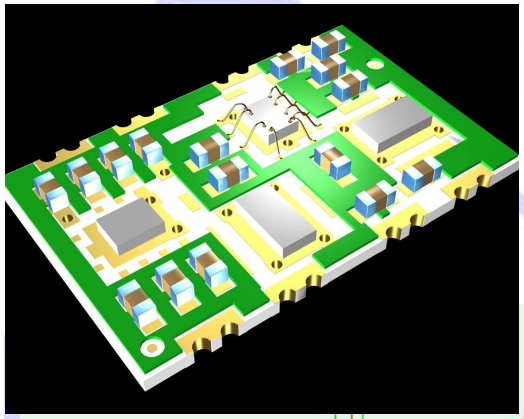
- **Printed circuit board (PCB) with components passes through wave soldering oven supported by transport cables.**
- **The PCB consists of built-up copper and pre-preg layers. These have anisotropic and temperature dependent material properties.**

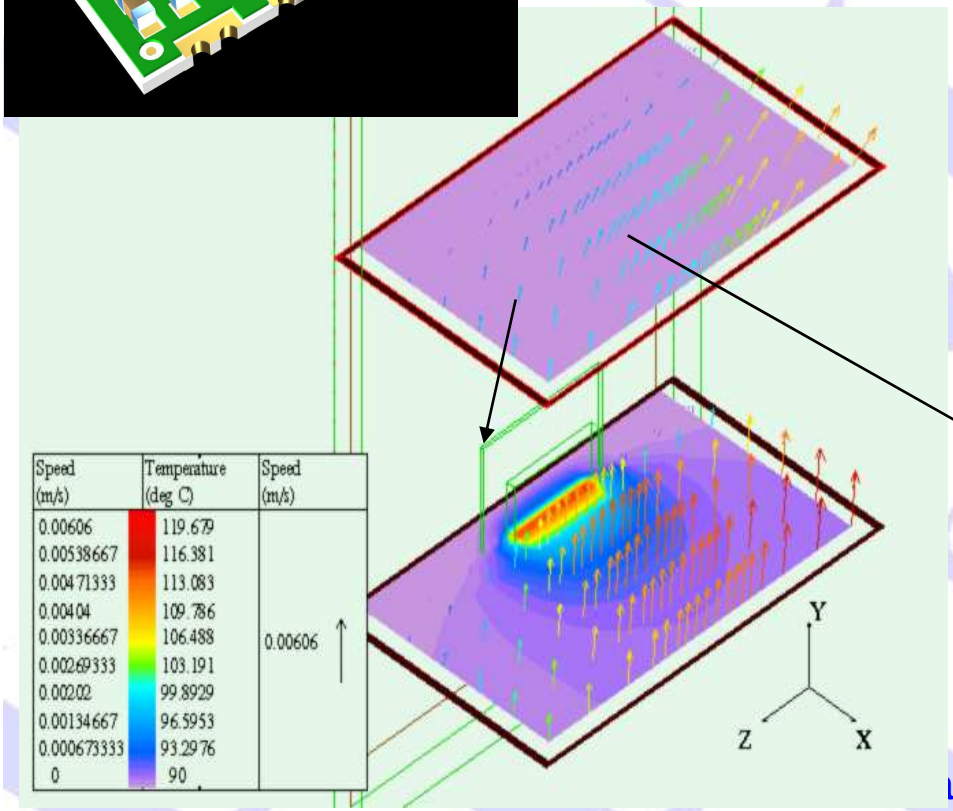


Project deliverables:

- **PCB modeled as built-up composite with all necessary anisotropic and temperature dependent properties.**
- **If needed, moisture influence can be included.**
- **True contact between board and cables.**
- **Extra boundary condition is temperature profile of oven.**
- **Deformation of board simulated as function**

Air flow cooling





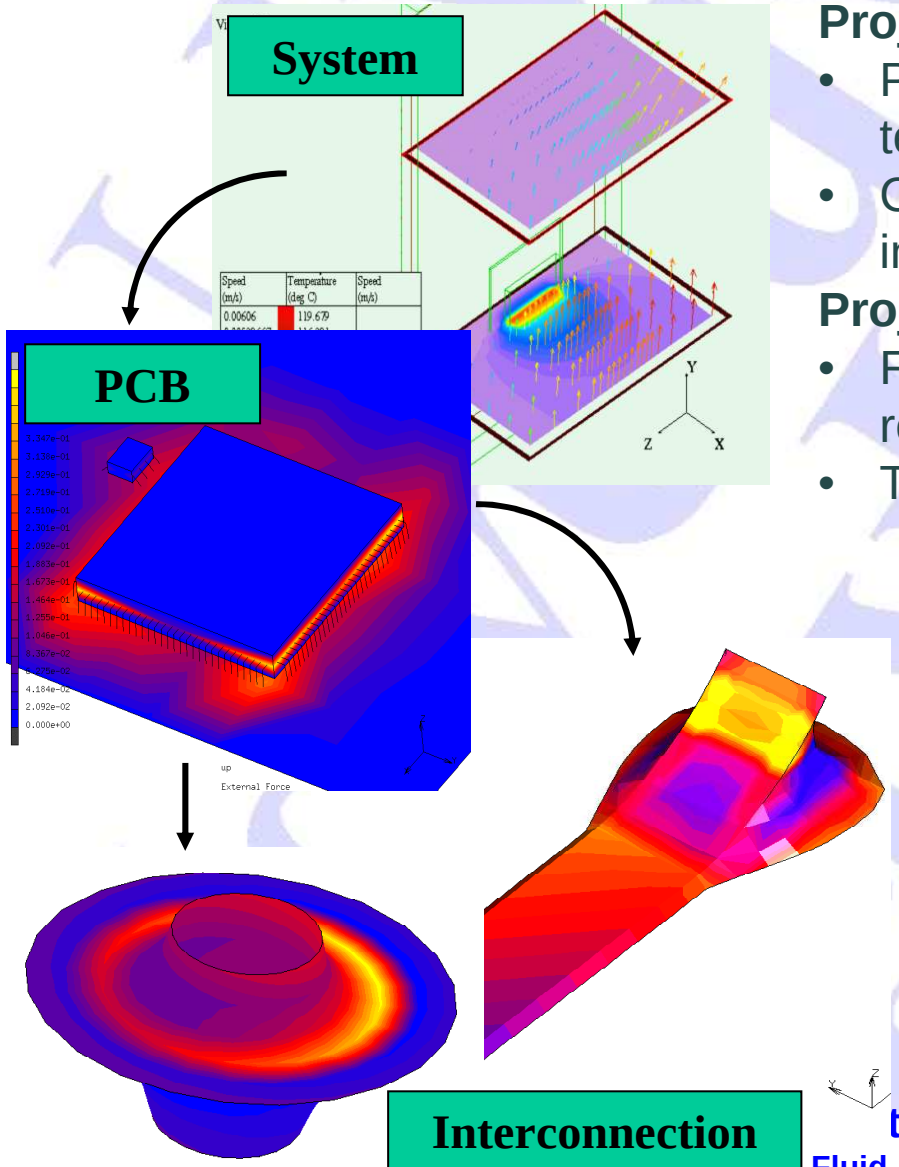
Project description:

- **Printed board with loose components passes through wave soldering equipment and is not wetted at some regions due to a.o. warping.**

Project deliverables:

- **Board transport over chains in oven modeled by contact analysis.**
- **Thermally induced deformations during wave soldering.**
- **Vibration analysis.**

EBIRA: PCB lifetime analysis



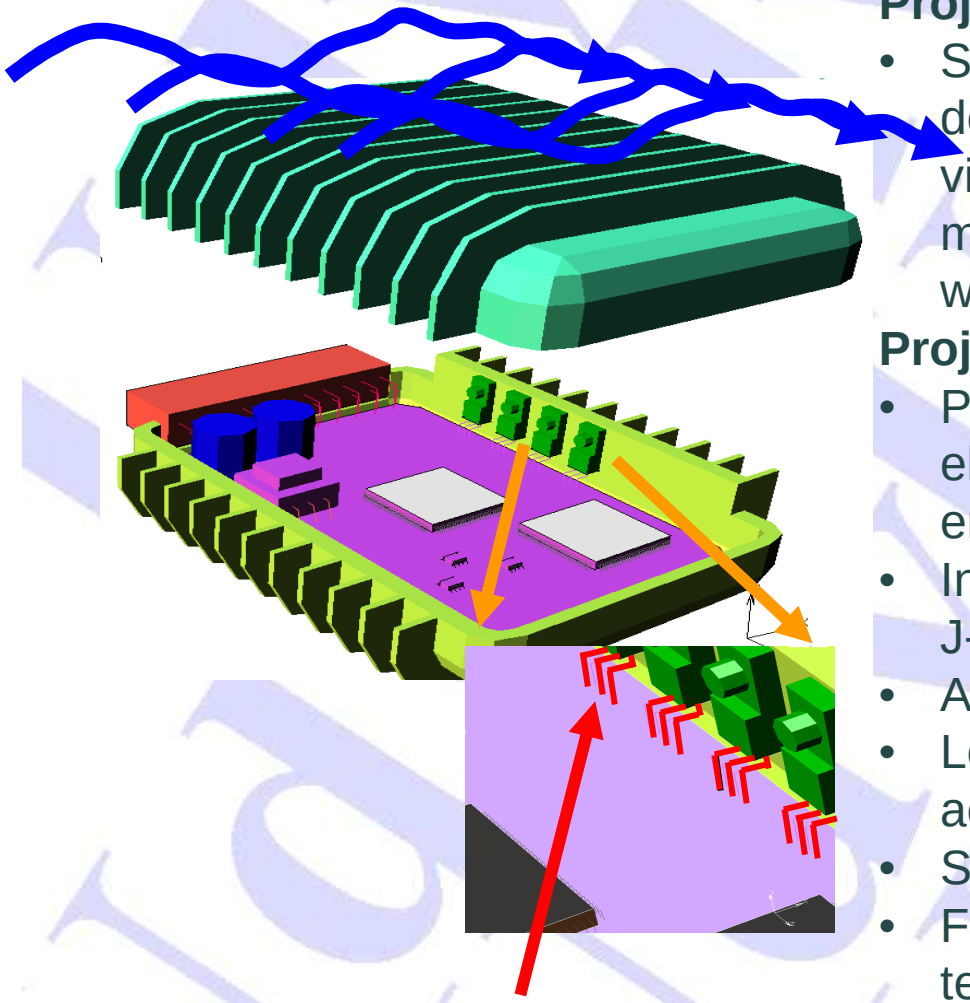
Project description:

- PCB is subjected to power and ambient temperature cycling, shock and vibration.
- Causes fatigue (plasticity, creep) in solder interconnections.

Project deliverables:

- Fatigue lifetime of complete PCB under realistic operating conditions is determined.
- Three “tier” sub-modeling approach:
  - •System: air flow (forced/natural) in cabinet gives steady state or transient temperature field.
  - •PCB: this field, together with the mechanical boundary conditions and loads (e.g. shock) are applied to the PCB, from which temperature and loads on individual solder joints are determined.
  - •Interconnection: finally, fatigue lifetime of interconnection is calculated (from extensive geometric and material library, including Pb-free solders).

EBIRA Example



Project description:

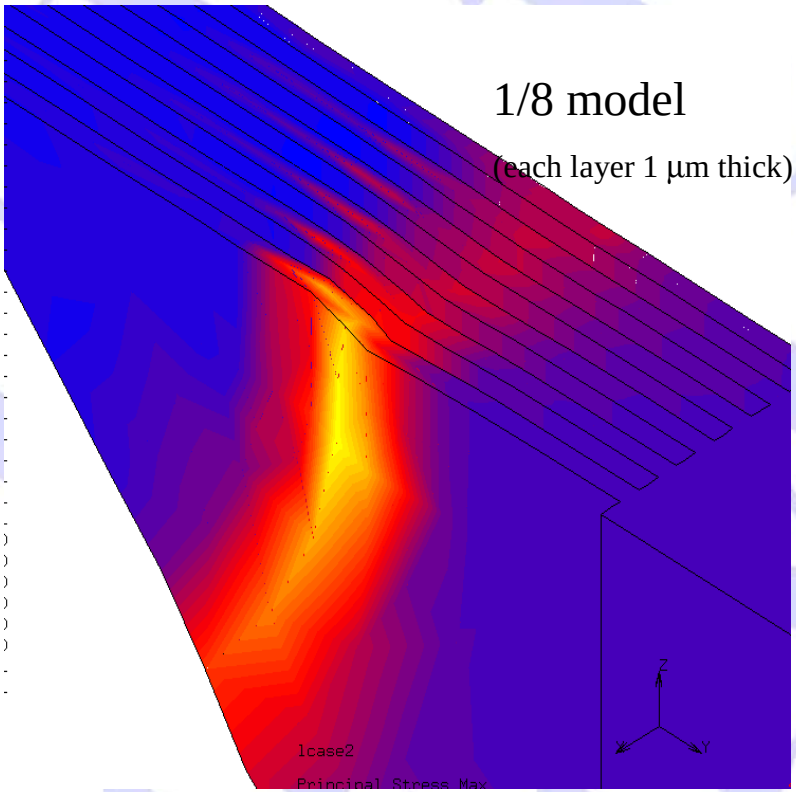
- Solder interconnections fatigue lifetime determination under combined TCT and vibration of complete electronic unit mounted in die cast aluminum enclosure which acts also as heatsink.

Project deliverables:

- PCB contains PQFP's, SOP's, transformer, elco's, FET's on heatsink, connector and enclosure.
- Interconnections types: pin-hole, gullwing, J-lead, smd.
- ALL interconnections modeled.
- Leads modeled with 3D beams for accurate bending behavior.
- Solder temp. dep. properties and creep.
- FR4 orthotropic material properties, temperature dependent.
- FET's screwed or spring loaded (see detail).
- Lifetime determined per interconnection type.

Wafer Level

Bond pad cracking



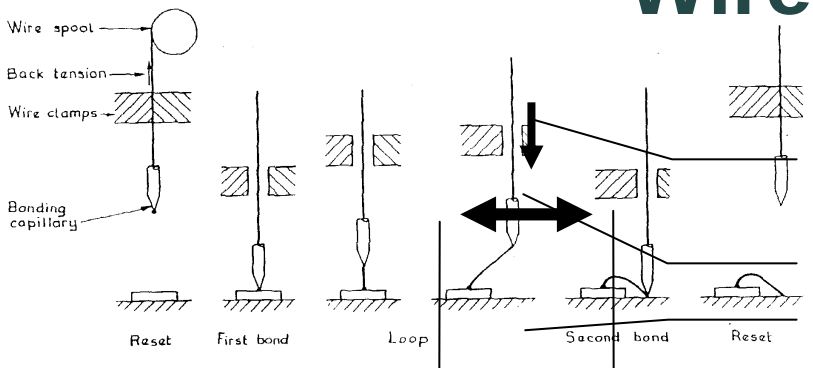
Project description:

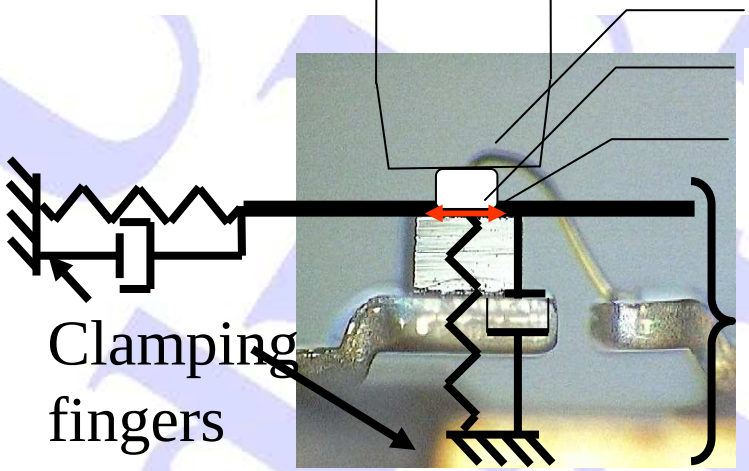
- Bond pad is a small island on chip circumference from which a connection to the outside world is made by means of a wirebond.
- Consists of conducting and isolating thin layers (thickness ≈ 1 μm) deposited on each other during CVD or sputtering process.
- How can cracks in bond pad during wire bonding be reduced?

Project deliverables:

- Damage mechanism simulated and identified
- Proposal for internal ”pillars”, which reduce the stress during bonding with a factor 2

Wirebonding





Bond force

Piezo

Capillary

Tip

Ball

Friction

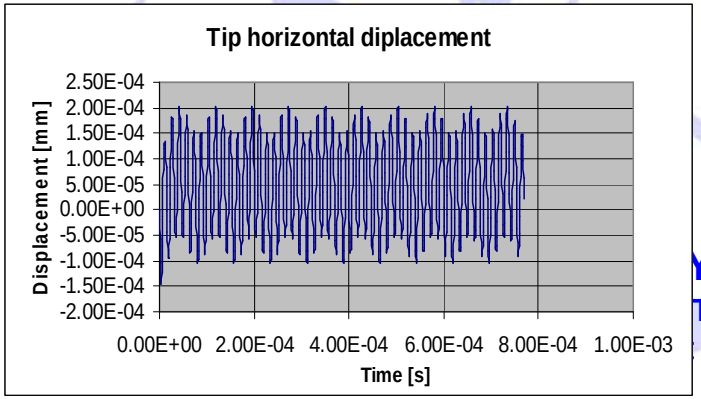
Die+leadframe+clamping

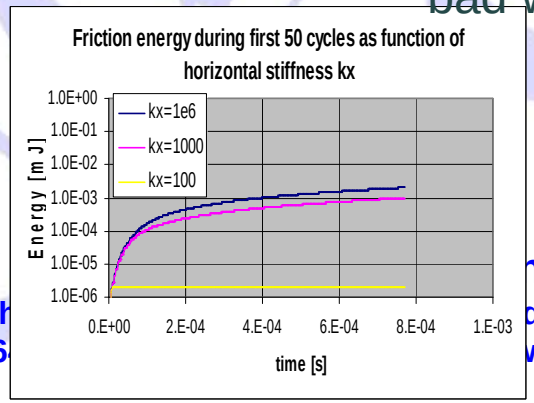
Project description:

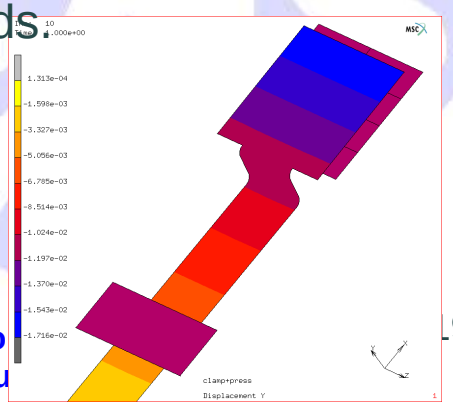
- Die is glued or soldered to its leadframe, which is clamped some distance away.
- Gold wire is bonded ultrasonically to top of die.
- Bad welds. Reason?

Project deliverables:

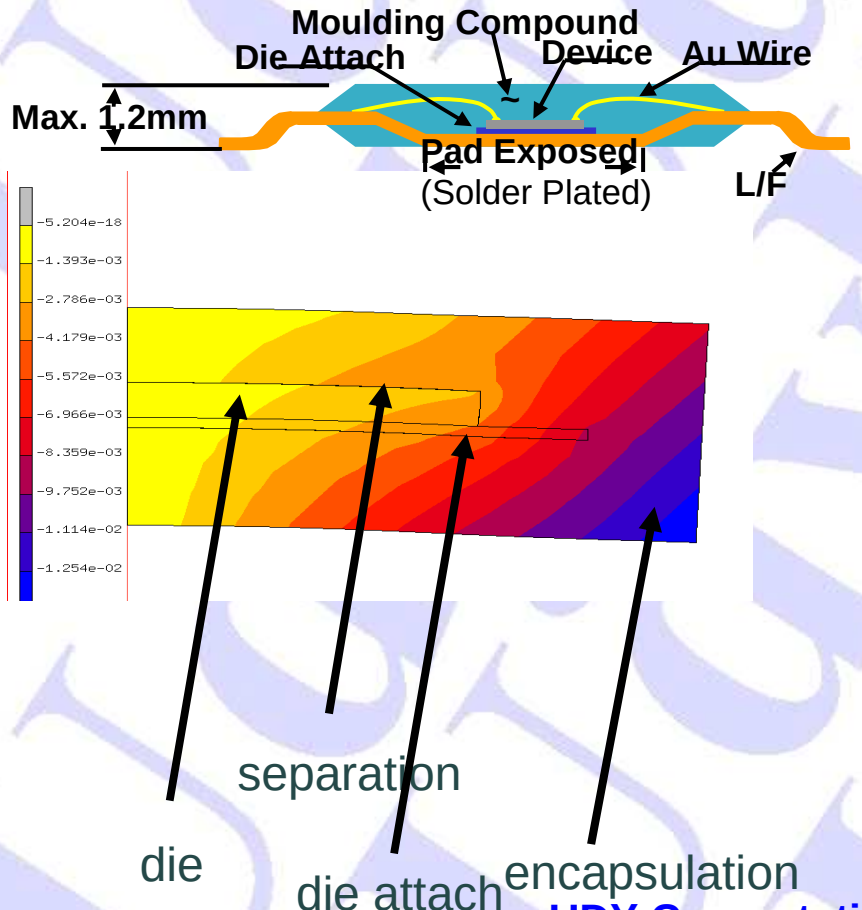
- Influence of leadframe and its clamping studied using transient dynamic calculation in combination with friction.
- Clamping optimized to eliminate bad welds.







Chip die passivation / encapsulation interaction



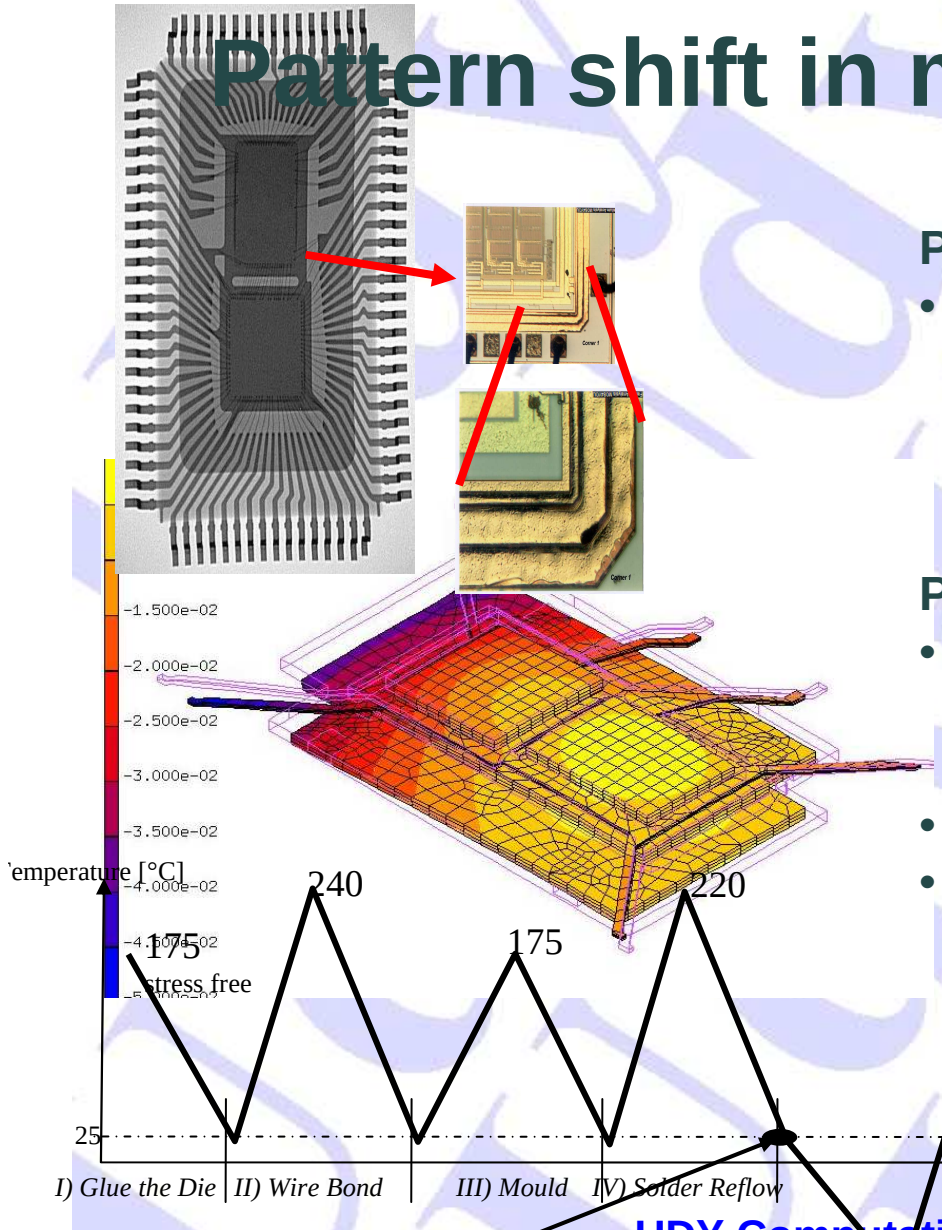
Project description:

- After some time, the top of the die separates from the encapsulation, causing degradation and even cracks at the top passivation layer of the die and in the underlying layers.

Project deliverables:

- Separation mechanism modeled.
- Degradation mechanism understood and design rules established for metal strain relief slots.

Pattern shift in multi module chip



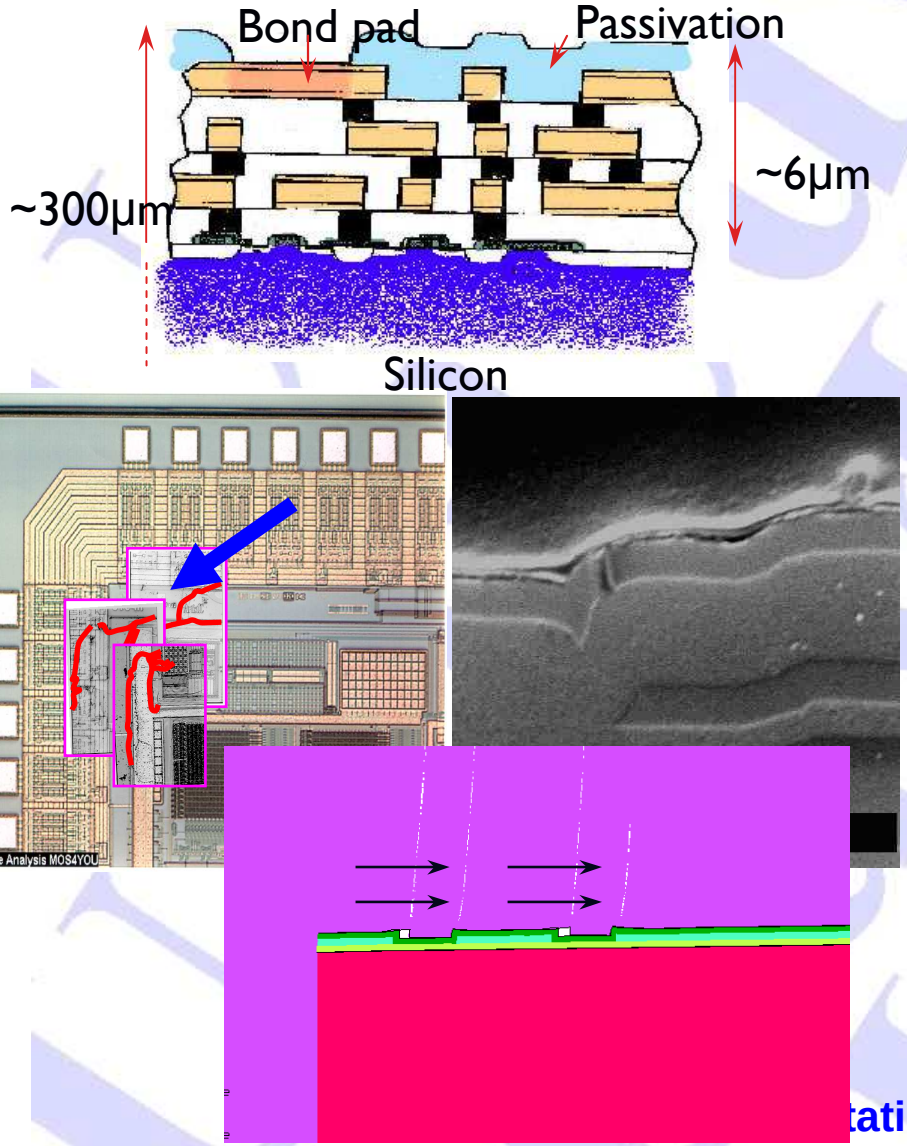
Project description:

- During production and use, the MMC is subjected to thermal and mechanical loading, causing failure due to pattern shift.

Project deliverables:

- Complete module with its manufacturing process, including reflow soldering, modelled.
- Critical stress at corner investigated.
- Definition, in co-operation with supplier, of low stress moulding compound.

Passivation crack investigation



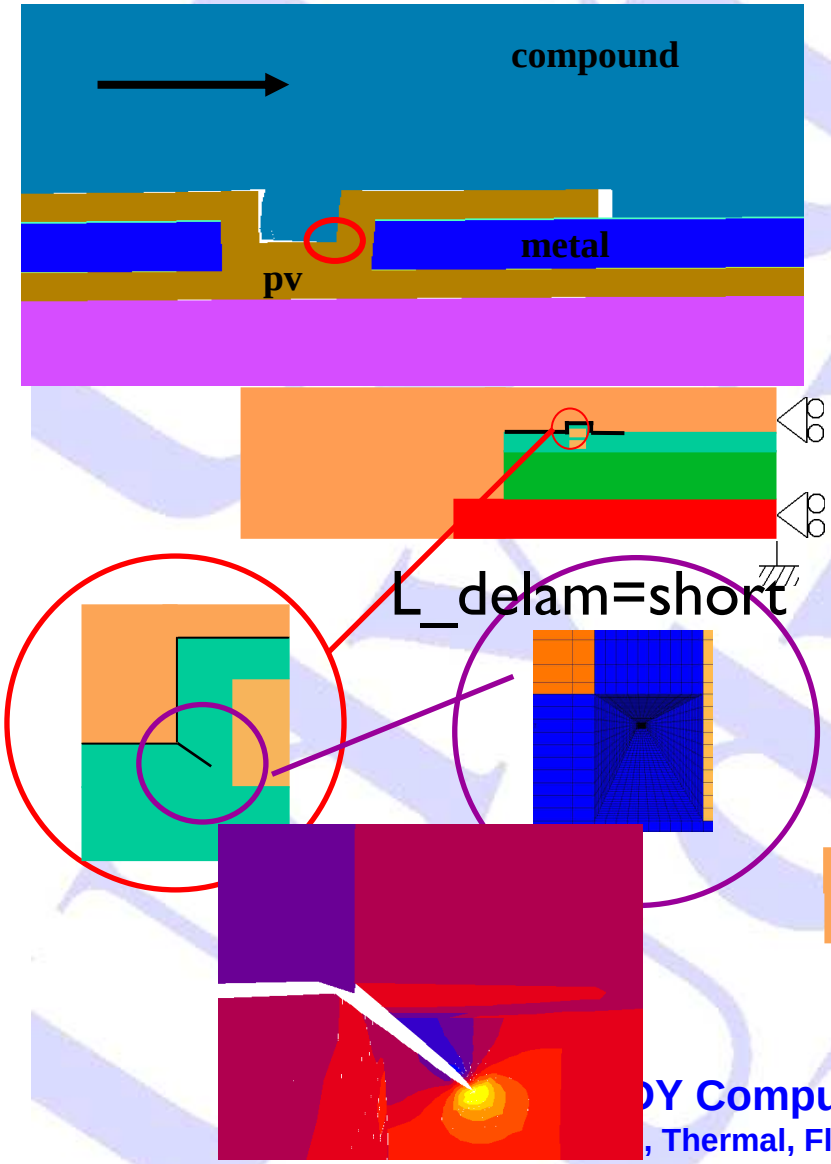
Project description:

- What is reason of cracks in SiN passivation layer?
- How to get rid of?

Project deliverables:

- Delamination of encapsulation after several thermal cycling tests cause high stress (up to 1000 MPa) in passivation layer, because it at interlock positions, it can can “push” against it.
- Influence of thickness and position of interlocks studied.
- Different wafer redistributing coatings simulated to decrease effect: BCB (Cyclotene), polyimides and silicones.
- Problem solved.

Passivation crack with J-integral

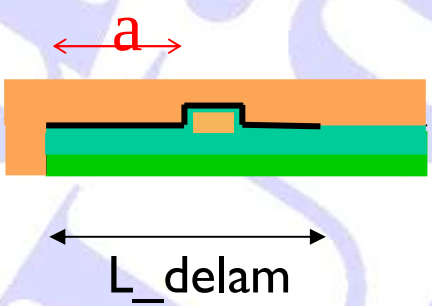


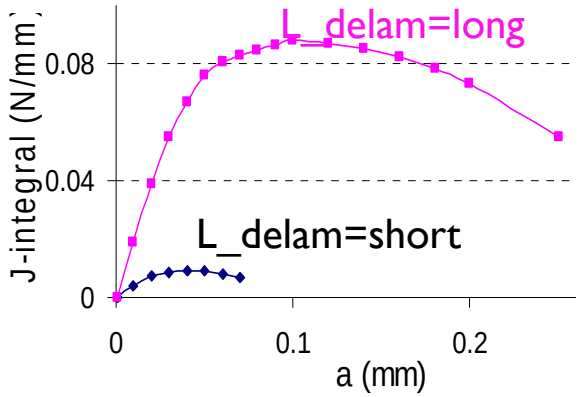
Project description:

- Investigate possibilities of J-integral to determine crack-energy

Project deliverables:

- 2D model with delamination and initial crack to predict J-integral values
- Delamination identified as the driving force for delamination cracking.
- ???There is a metal line position of maximum crack energy.





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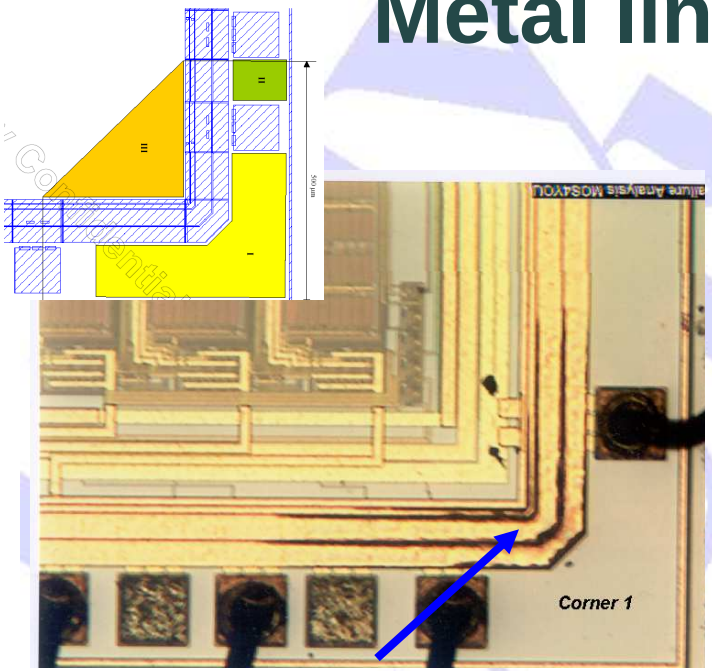
Metal line shift in “Painter”



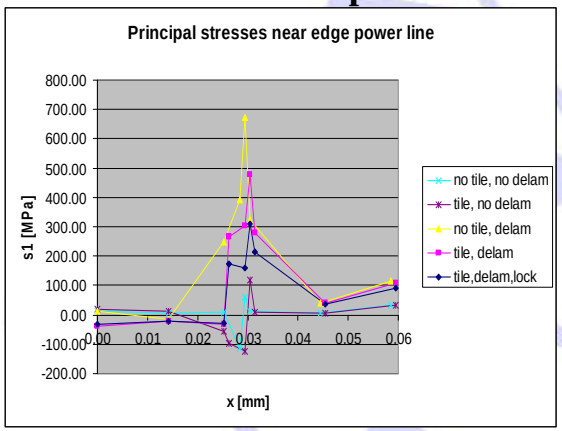
extreme pattern shift

Project description:

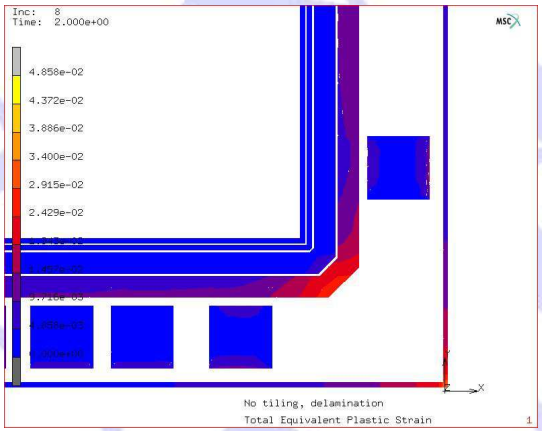
- Shifting of metal lines during qualification tests caused electrical short-circuiting.
- Can additional dummy metal patterns in the corner of the IC prevent the observed pattern shift?

Project deliverables:

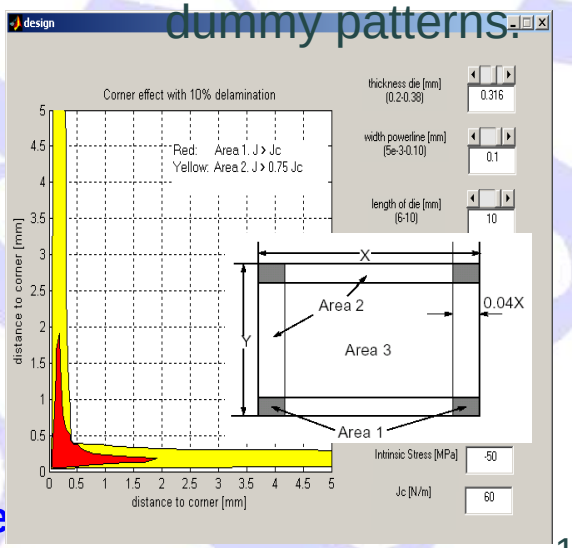
- Simulations were performed to investigate/quantify the influence of dummy metal patterns near the power line in the IC corner.
- Recommendations and tool were made for position and type of dummy patterns.



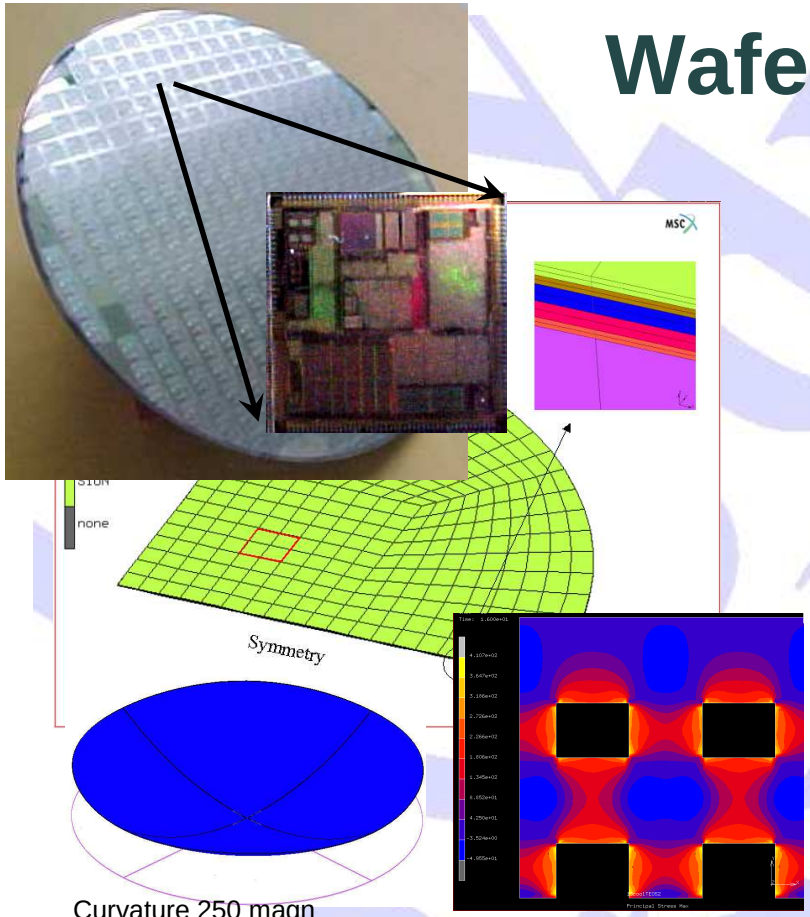
Influence tiling and delamination on maximum stress levels



Plastic deformation in metal



Wafer curvature



Curvature 250 magn

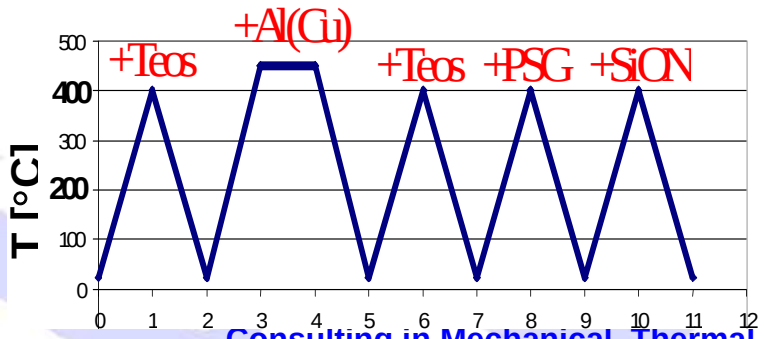
Predicted stress distribution between metal lines

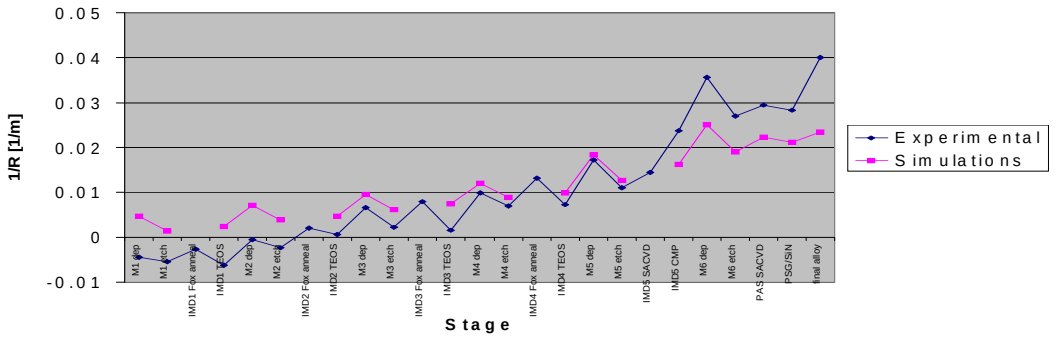
Project description:

- Wafer curvature must be kept in narrow tolerance, because it is measure of residual process stress.

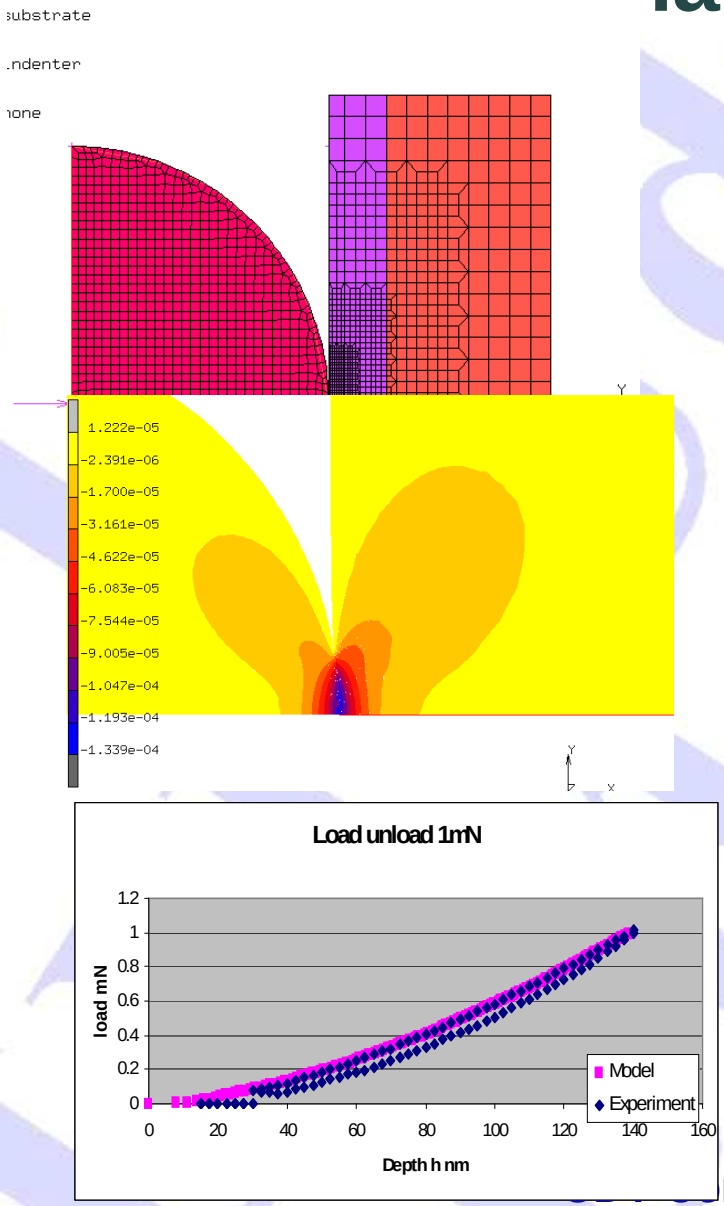
Project deliverables:

- Layer build-up modelled.
- Intrinsic stress in Teos, PSG, and SiON determined.
- Relation curvature change from applied layers and process conditions established.





Micro- and nano indentation of SiLK



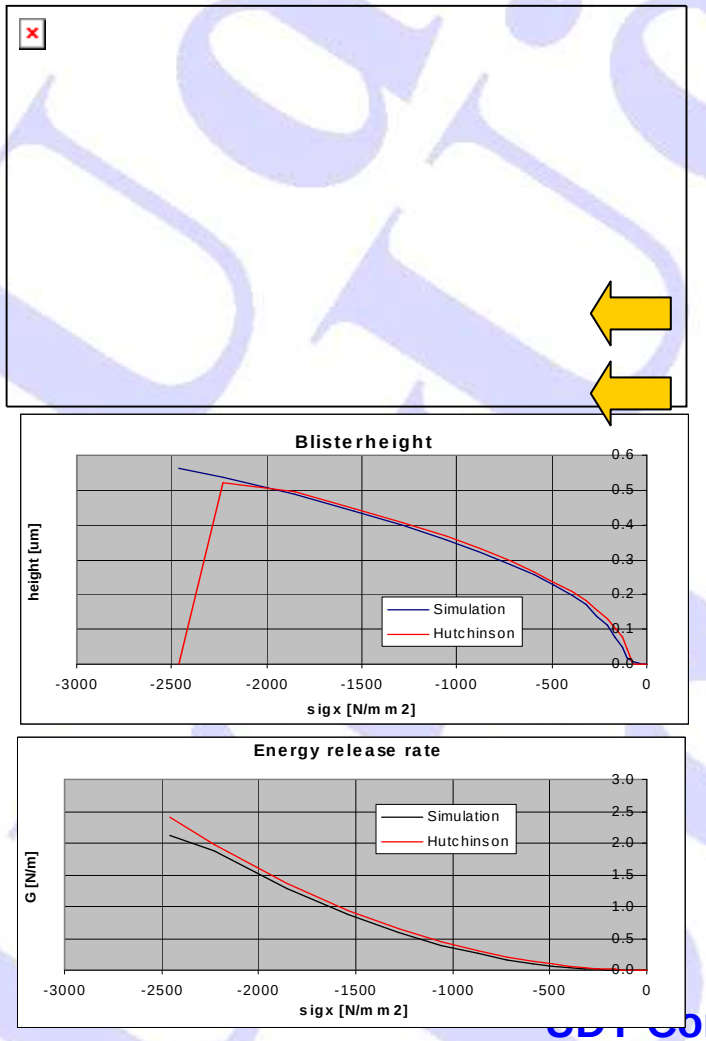
Project description:

- Micro- and nano indentation experiment are important for the characterization of micro-electronics materials, e.g. SiLK.
- The resulting material models (e.g. plastic, creeo, visco-elastic) are fitted using FEA analysis.

Project deliverables:

- The load/unload characteristic of SiLK is simulated and compared to experiment.
- Visco-elastic properties determined.

Micron layer buckling delamination



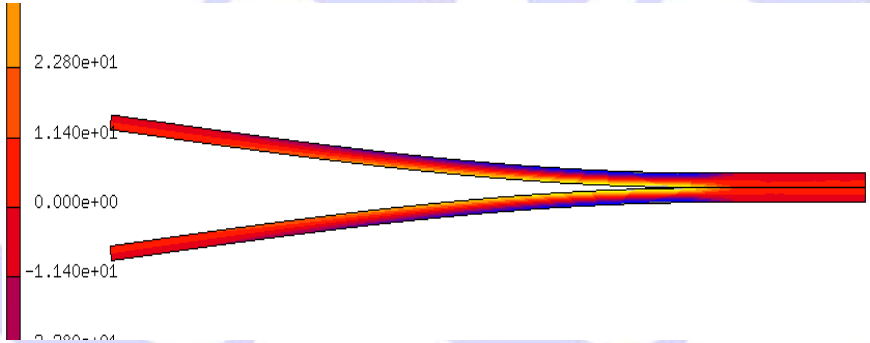
Project description:

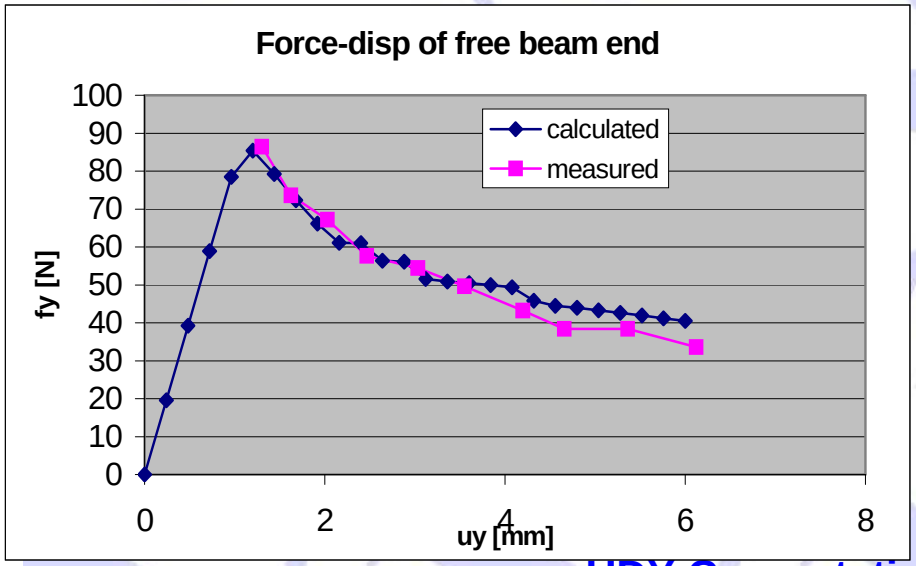
- Thin metallic layer on substrate e.g. ITO on KAPTON, or IC metal line on silicon .
- Can exhibit buckling delamination under severe bending.

Project deliverables:

- Buckling delamination modeled in FEM and compared to reference data for vertical displacement and energy release rate (e.g. Hutchinson for hard substrates).
- Modeling approach also works for soft substrates in which case no analytical formulae are available.

Thin layer delamination





Project description:

- NAFEMS benchmark: double cantilever beam is subjected to 2 opposite vertical forces which split the beam.

Project deliverables:

- Vertical force a.f.o. vertical displacement calculated and compared to analytical and measured values.
- Much faster then usual crack propagation calculation method.