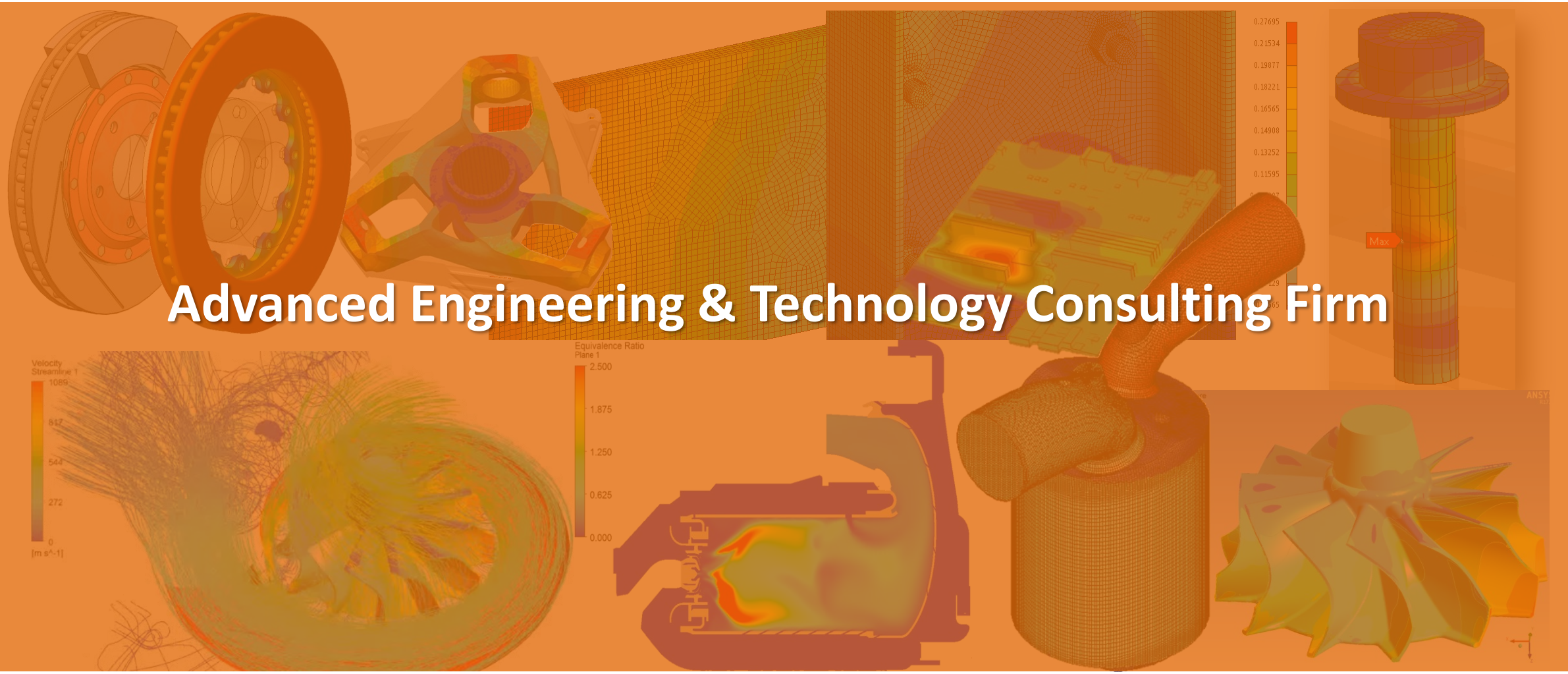
ENDEAVOS Innovations Inc.

Engineering Design Analysis Validation Optimization Simulation



Advanced Engineering & Technology Consulting Firm

453 Kinns Road Clifton Park New York 12065 US Ph: (518) 312-1466

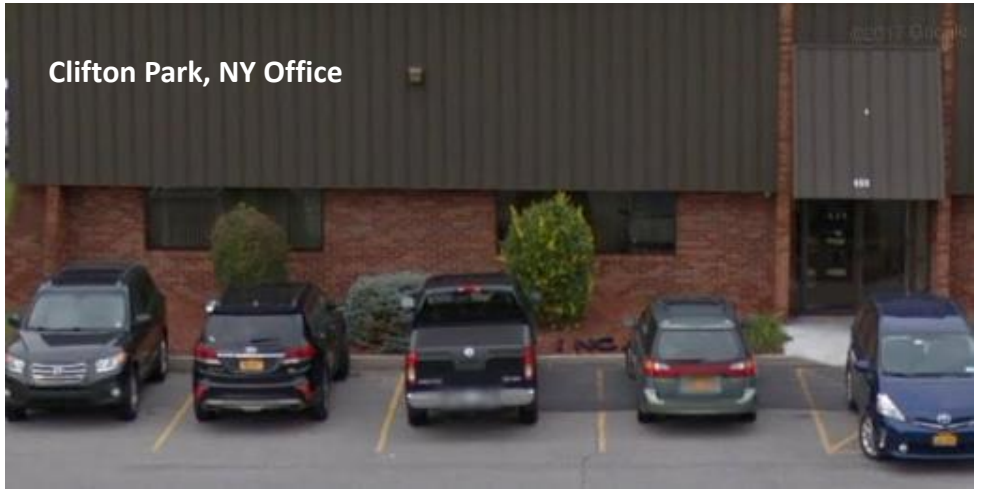
www.endeavos.com

Company Overview & Services

Endeavos Innovations Inc. is a comprehensive product development, research, and engineering services company. Our core philosophy is innovation through collaboration. We work with startups, academia, and large companies as part of their team to help innovation through engineering. We utilize state of the art methods and tools combined with years of experience to move an initial idea through various phases of technology development to market in the least amount of time and cost. Our services can also be employed at any phase of development or for any engineering or consulting need.

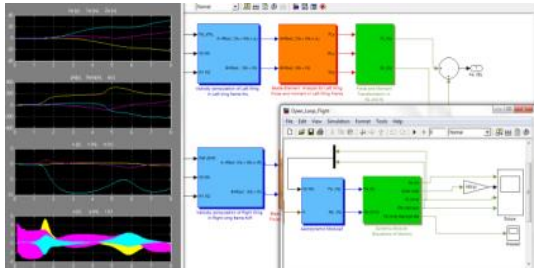
Brief History:

- Established in 2014, based in Clifton Park, New York, USA.
- During 2014-16, we developed structural dynamics lumped parameter simulation models & custom simulation tools for the oil and gas industry.
- Since 2017, we are heavily involved in the rapidly growing wind turbine industry specially bolted connection design & assessment.
- In 2019, we ventured into custom automotive projects.
- In 2021, we received NSF SBIR Phase I award to design a novel bolting technology.

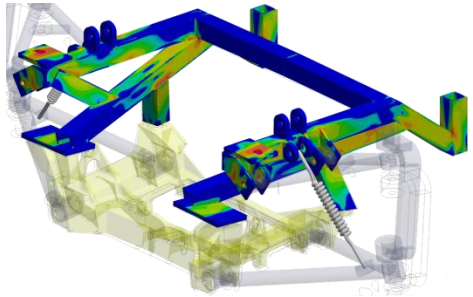


Design

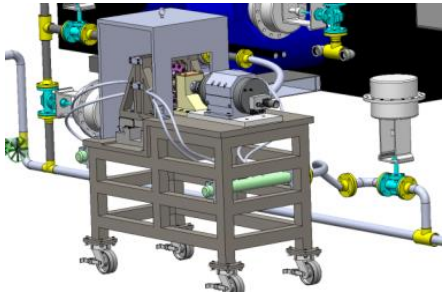
System Modeling



Analysis (CAE)



Test Rigs & Testing



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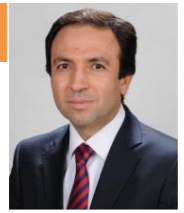
Engineering Team

Dr. Zaeem Khan, Ph.D, (Founder & President)

Dr. Khan is responsible for managing the operations of Endeavos Innovations Inc. He has over 22 years experience performing and supervising engineering analysis. He has previously held R&D position at GE Global Research where he worked on a variety of engineering projects ranging from bio-medical devices to wind turbines. His expertise includes: modeling and simulation of structures and dynamical systems involving Multiphysics (aero, structural, & thermal), design optimization, finite element analysis, conceptual and detailed design.

Dr. Yahya Doğu, Ph.D. (Principal CFD Consultant)



Dr. Yahya Doğu has over 20 years of experience in design and analysis of industrial applications of thermal-fluid systems and has been involved in many R&D projects. His expertise is built on fundamental sciences of fluid mechanics, heat transfer and thermodynamics and validating that with CFD simulations. His experience involves many specific areas: sealing in turbo machinery (brush seal, labyrinth seal, honeycomb seal, cloth seal), flow in porous media, water turbines, solar collectors, optical fiber drawing process, thermal analysis of metal cutting process, 3-D in-cylinder combustion modeling for internal combustion engine, heat exchangers, etc. He has filed two patents on brush seals at GE-CRD and authored many journal and conference papers.

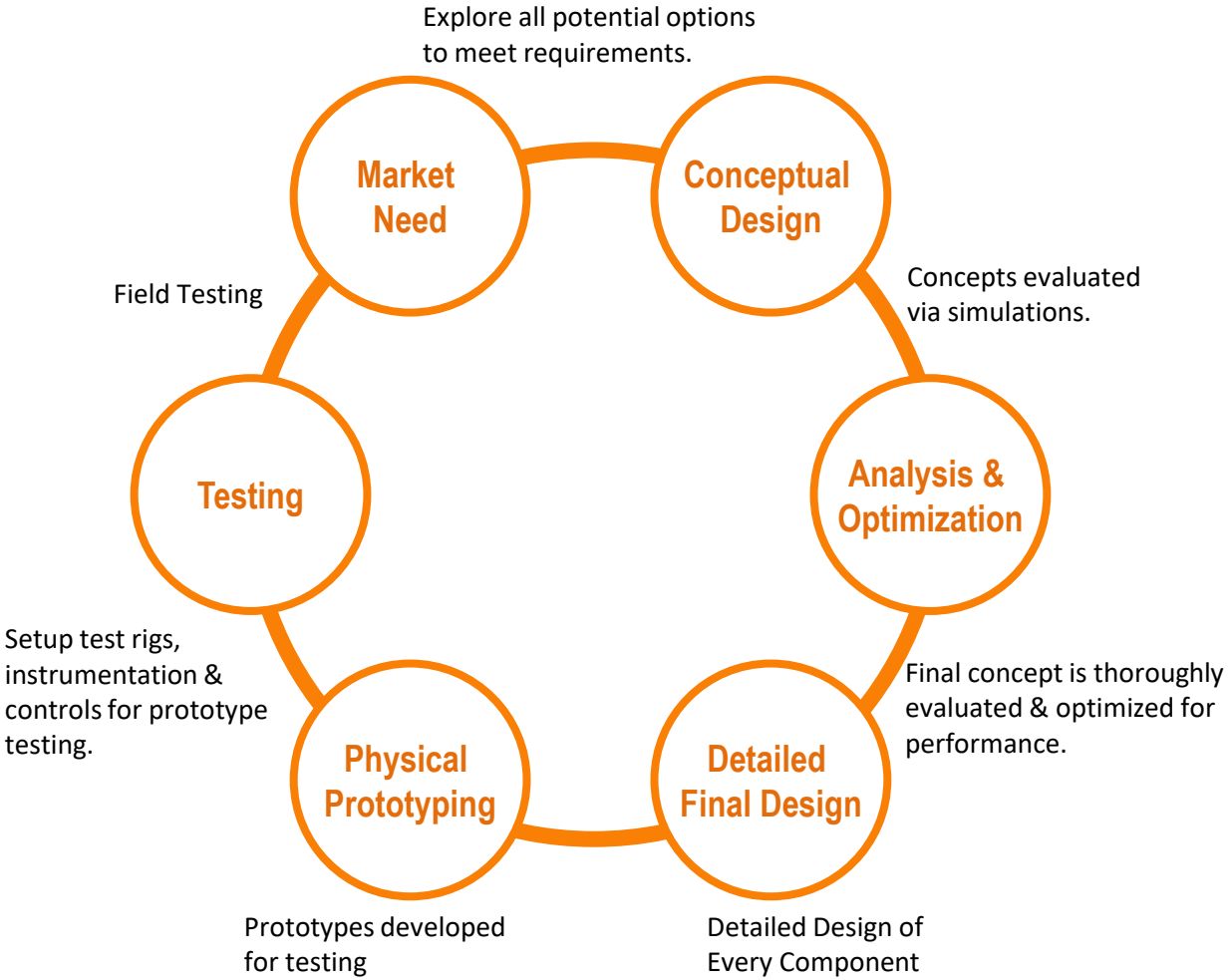
Dr. Murat Ozmusul, Ph.D, (Principal Consultant)

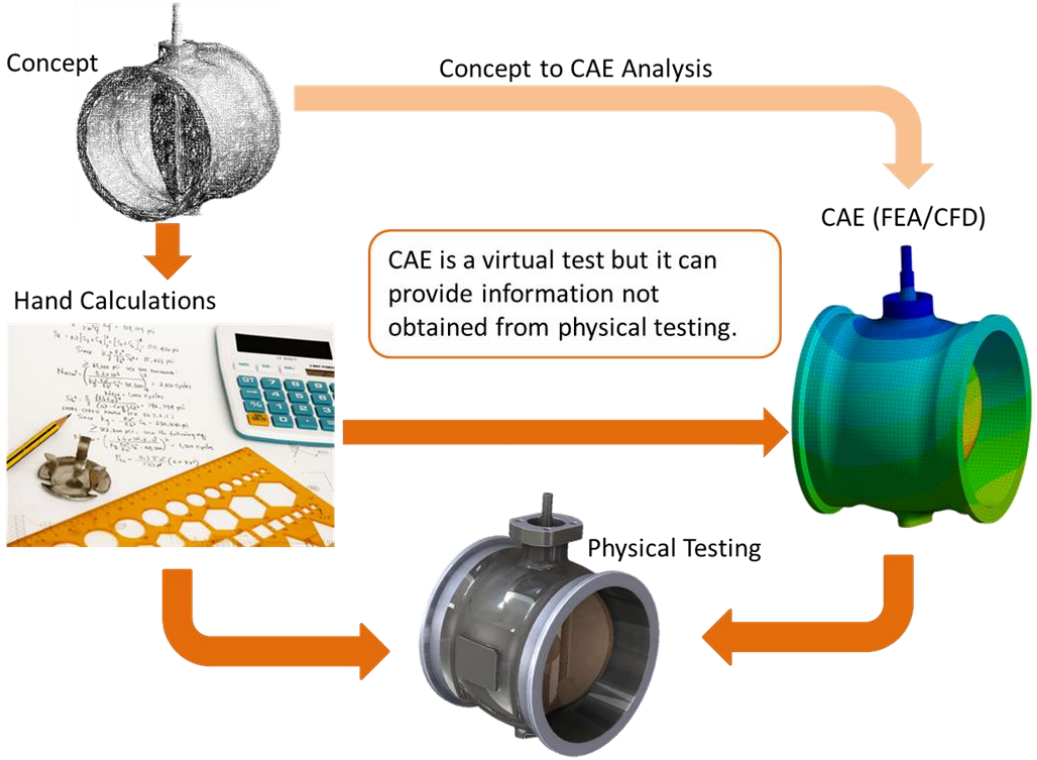
Dr. Murat is a principal consultant. He is a mechanical engineer with more than 23 years of experience in the R&D industry. His expertise is in brush seals, steam turbines and mechanical design of test rigs. He was formerly a co-founder of SDM research and engineering based in Turkey and the founder of Pro-Solutions US engineering company. He has several high profile projects under his belt including multiple patents.

Gerald Reidenbaugh, (Mechanical Design Engineer)

Jay Reidenbaugh has over 26 years of mechanical design and manufacturing experience. He has expertise in new concept development, design, analysis, project management, scheduling, estimating, simulation and optimization. He is a great team player with excellent problem-solving, time management, and organizational abilities when faced with complex multi-disciplinary engineering projects.

Overview of Our Services





- State of the art CAE tools & engineering expertise.
- Expertise is provided when needed. This cuts overhead costs.
- Low rates for pre-seed, seed and early stage startups.
- Valuable resource on standby for established companies.
- One stop resource for all mechanical engineering services

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How We Add Value

Rapid Development Using Simulation Driven Design

We can help you accurately predict real world performance early to reduce product development risk. Simulation-driven design allows virtual prototyping which is significantly less costly compared to physical prototyping especially if multiple design iterations are required.

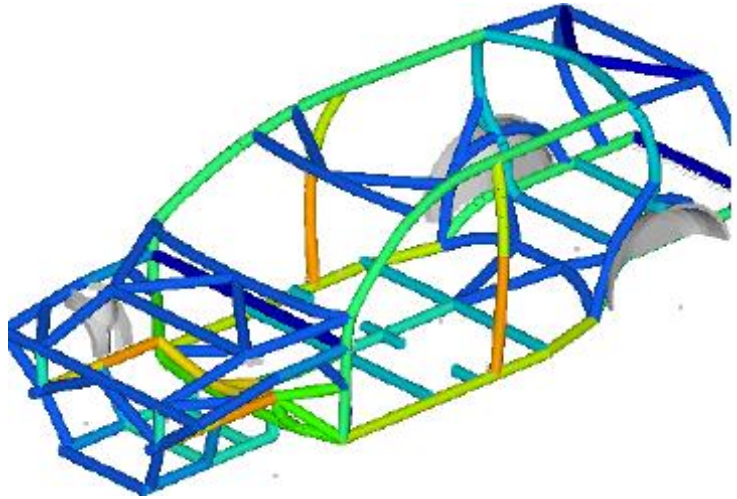
Optimal Design

In a high quality product, there are typically five competing factors: aesthetics, ergonomics, performance, weight and cost. We can help you achieve an optimal balance between these factors to achieve the best or optimal design solution.

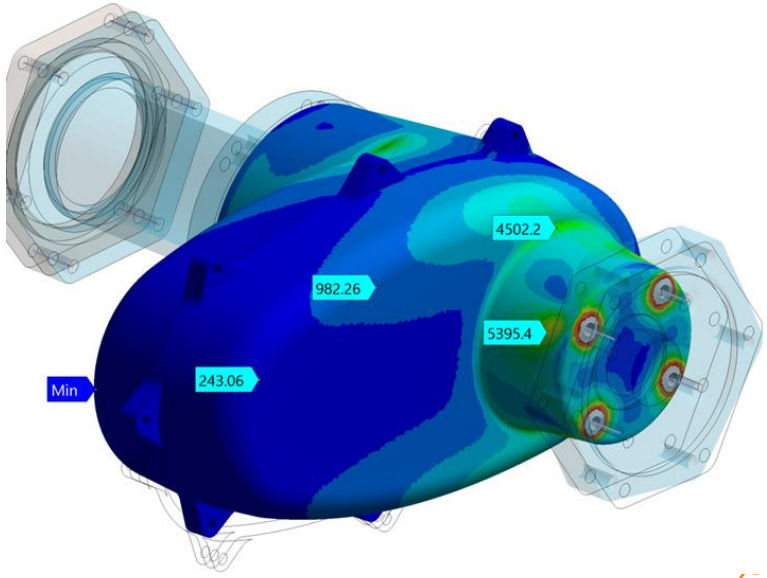
Design for Manufacture & Assembly (DFMA)

A poorly designed mechanical system takes more time and cost to manufacture and assemble. We have the know-how to design components for DFMA.

Our High Fidelity Simulation Driven Design & Analysis provides the manufacturer as well as the buyer more confidence in the product.



The Physical prototype is limited by the number of sensors that can be fitted to gather data. There is no such limitation in a simulation model.



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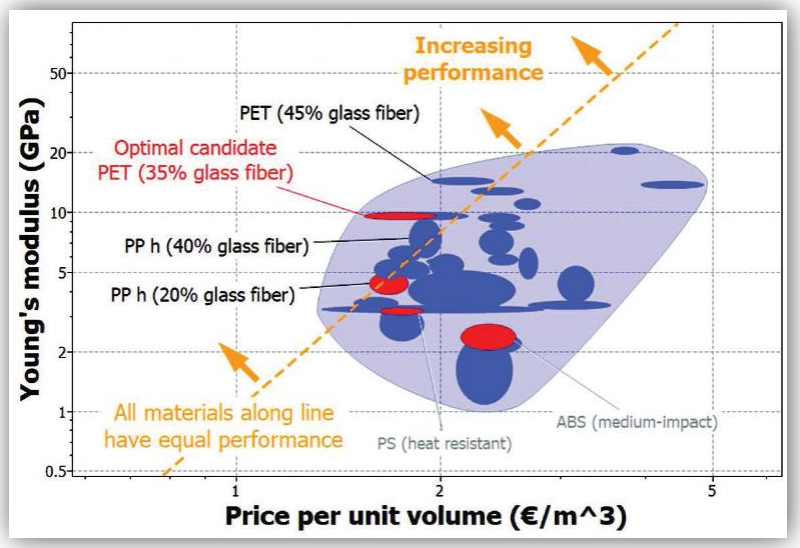
How We Add Value

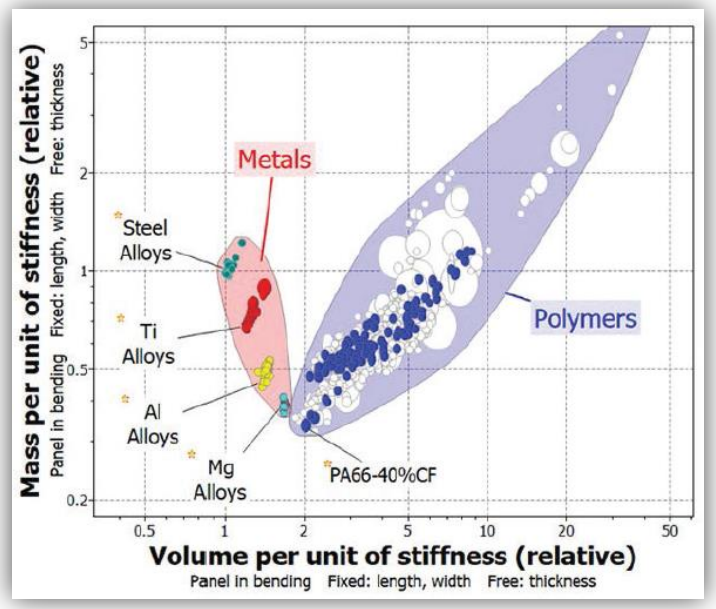
Material Selection

Most businesses rely on simple “rules of thumb” to choose materials, or just choose materials that have “worked well enough” before. This is not good enough in today’s competitive markets, where the choice of the right materials for a product is often the biggest component of its cost and can often make the difference between a me-too product and a groundbreaking cost effective design.

Remember: Optimal Material + Optimal Design = Optimal Product

- Getting the materials choices right the first time during early-stage product development prevents costs and delays later.
- There is a difference between optimal material for low volume production vs high volume or mass production based on manufacturing technology involved.
- We have the capability to select the right material based on material properties, material cost, manufacturing cost, and supply chain availability.
- We have a comprehensive material properties database that enables comparative assessment to select the right material.





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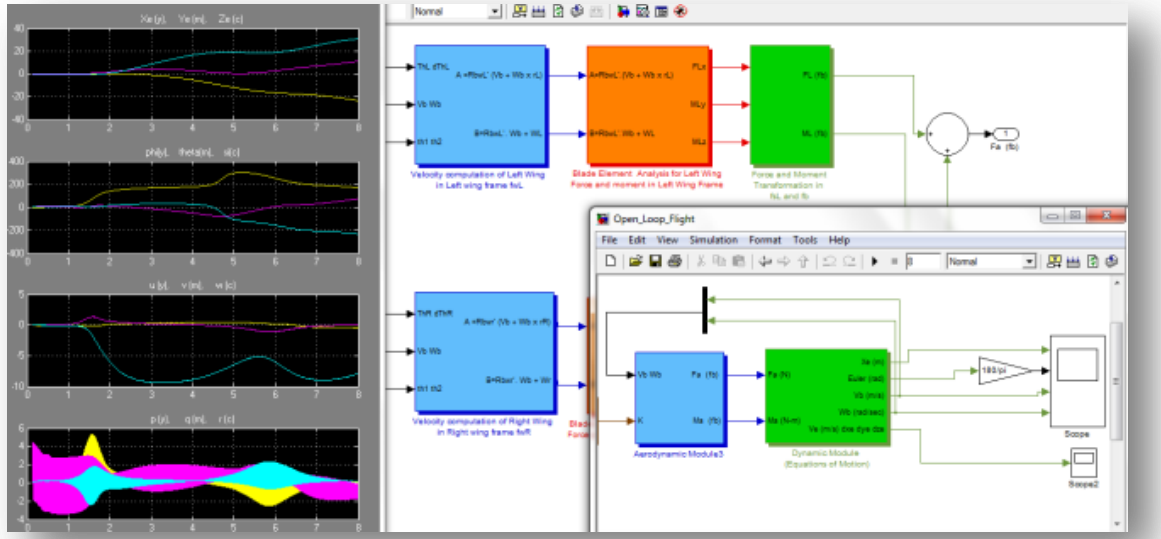
How We Add Value

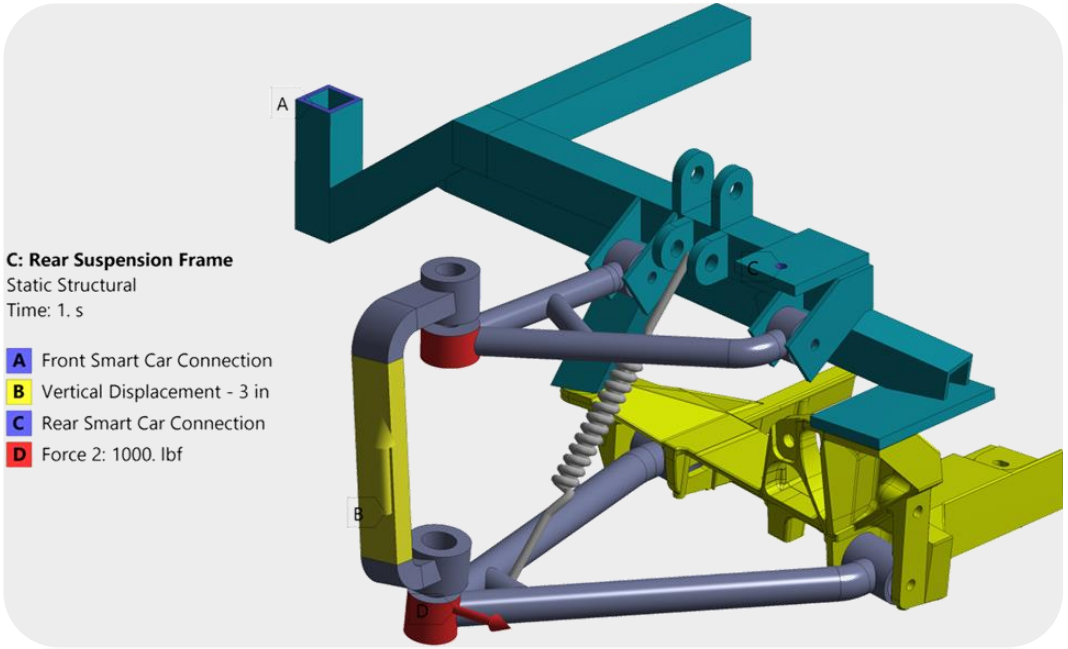
Load Estimation

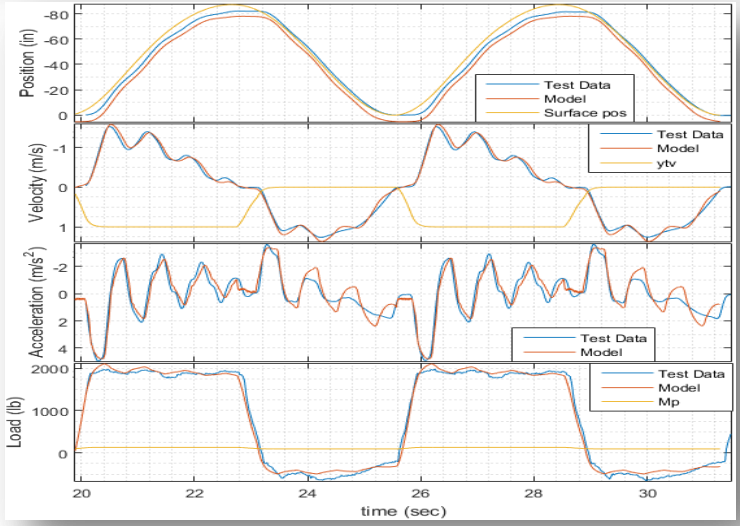
One of the major challenges in product development is an estimation of the appropriate load cases. If loads are incorrect, the entire product design is flawed.

We use state of the art dynamic system models to accurately predict all possible load cases. This includes extreme loads, impact loads, thermal loads, vibration loads, etc.

Entire System Model For Dynamic Load Estimation







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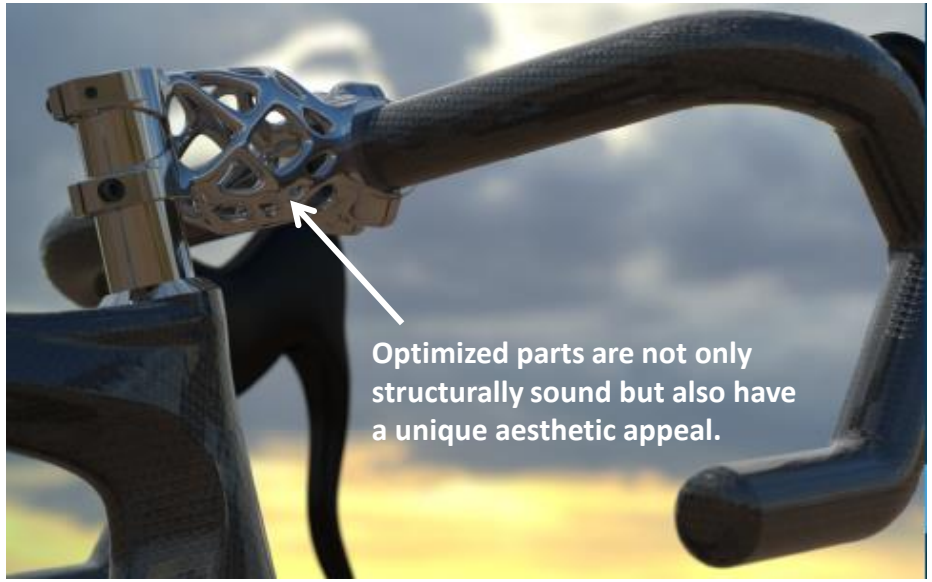
How We Add Value

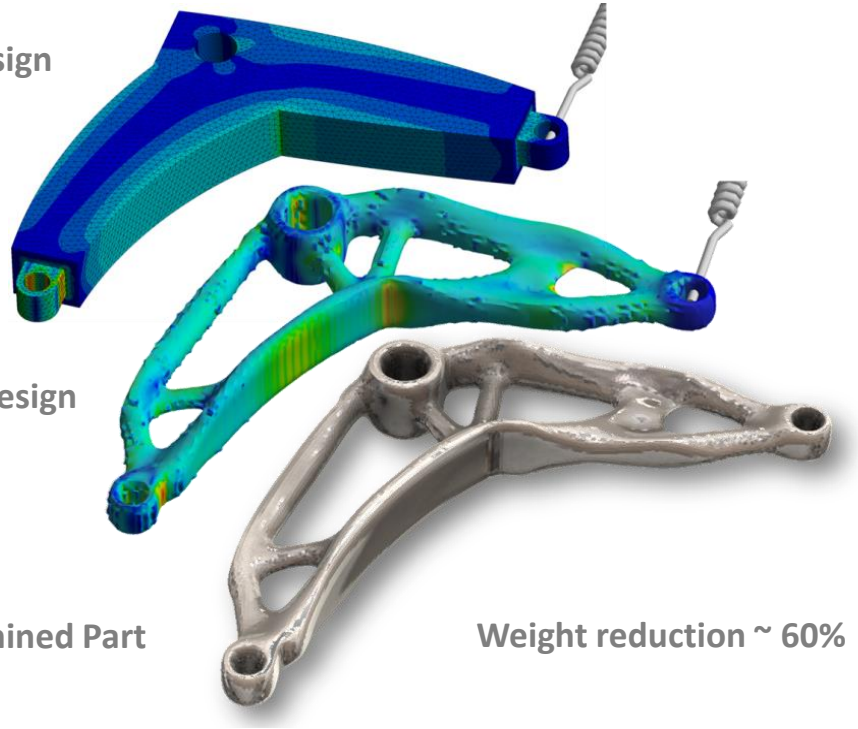
Simulation Driven Weight Reduction

We have the capability to reduce weight of component parts while still maintaining, strength, stiffness and manufacturability.

The process involves optimization of material distribution in a component or assembly based on given load cases.



Original Design

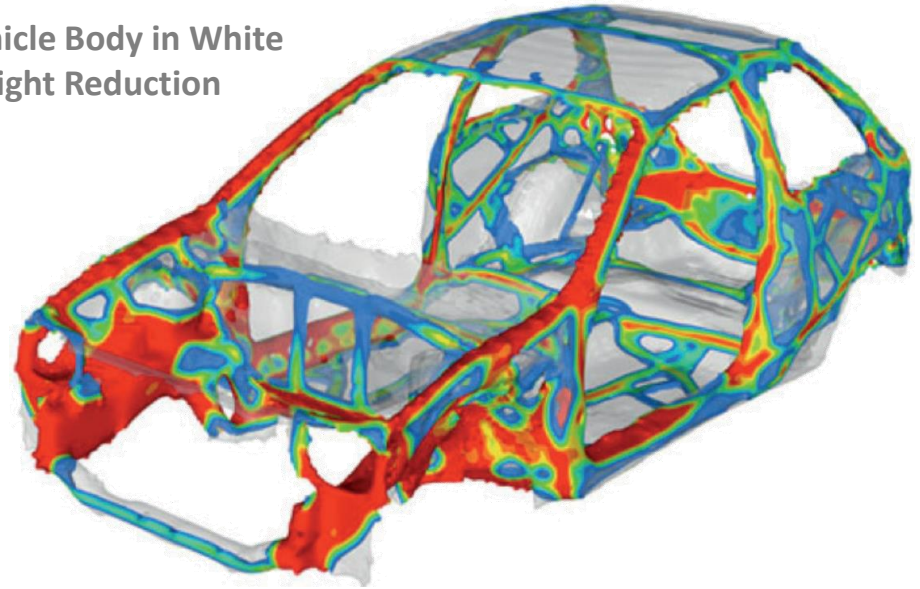


Optimized Design

Final Machined Part

Weight reduction ~ 60%

Vehicle Body in White
Weight Reduction



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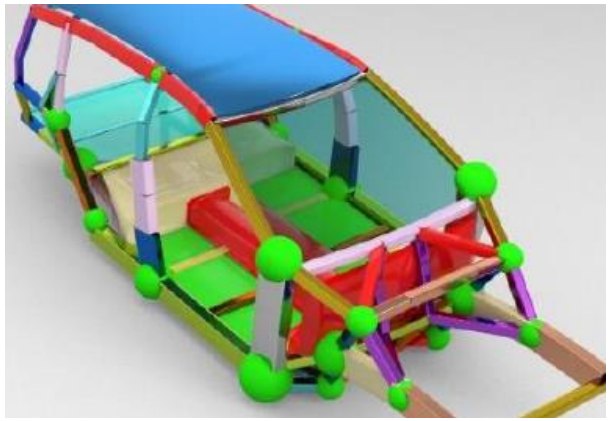
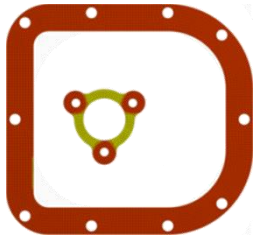
How We Add Value

Joint Design

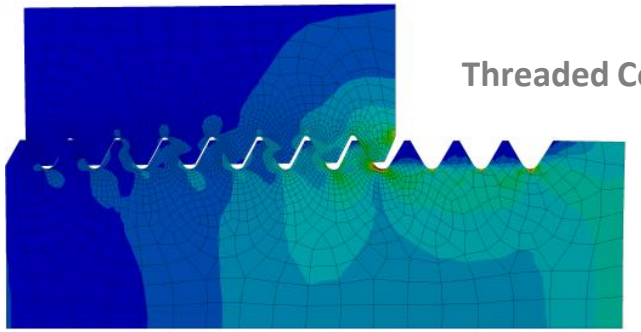
One of our expertise areas is the design of joints of various types such as bolted, welded, bonded, riveted, etc. Joints are one of the key areas where failures initiate during service.

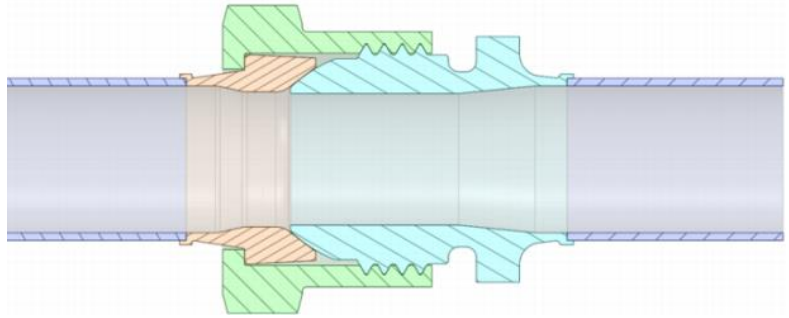


Gasket Joint Leakage Analysis

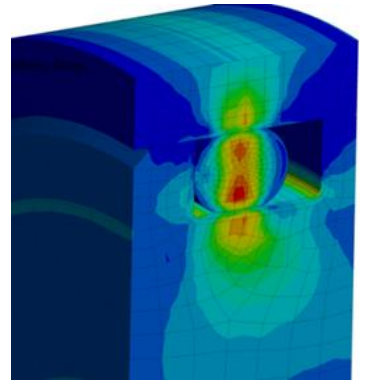


Threaded Connections

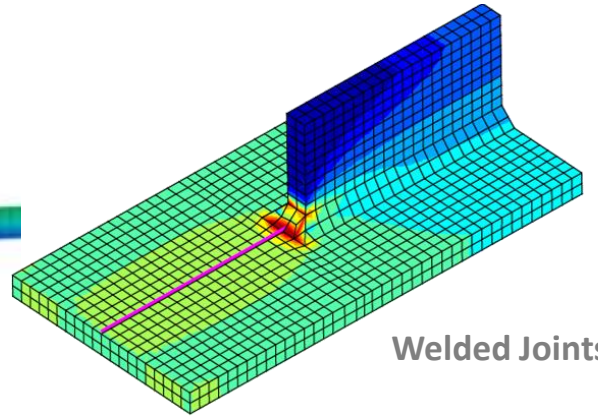




Seals Leakage Analysis

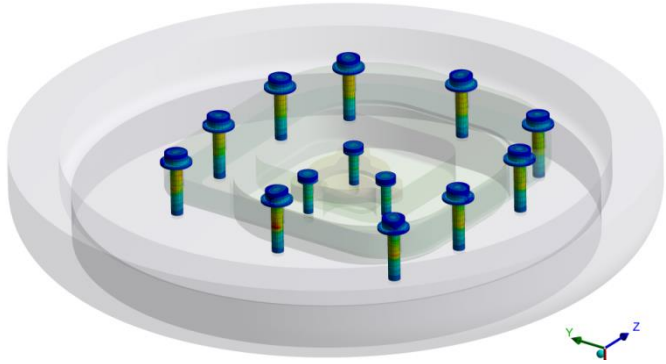


Bonded Connections



Welded Joints

Bolted - Joints



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How We Add Value

Fatigue Life & Component Durability

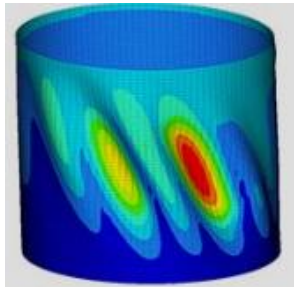
One of the key questions, product designers have is how long their product will last. This is an important question to ensure product service life warranty costs are low.

We have the capability to analyze fatigue life or design of enhanced fatigue life. There are two parts to fatigue analysis 1) loading history and 2) fatigue modeling. We can generate loading history by means of dynamic modeling if real life data is not available. For fatigue modeling we use state of the art methods.

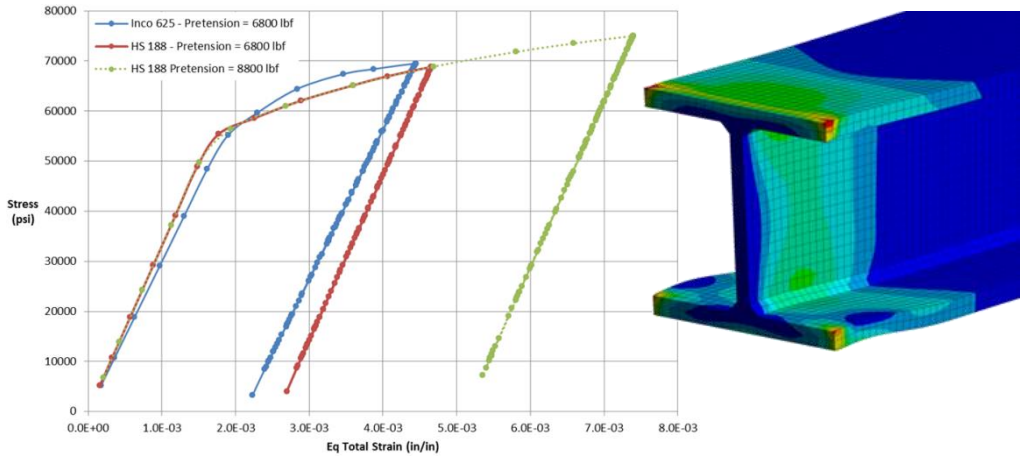
Extreme Loads & Buckling Failures

In certain load cases, there is a danger of components failing in the very first load cycle due to yielding, fracture or buckling. We have the capability to evaluate all complex failure modes to ensure product safety.

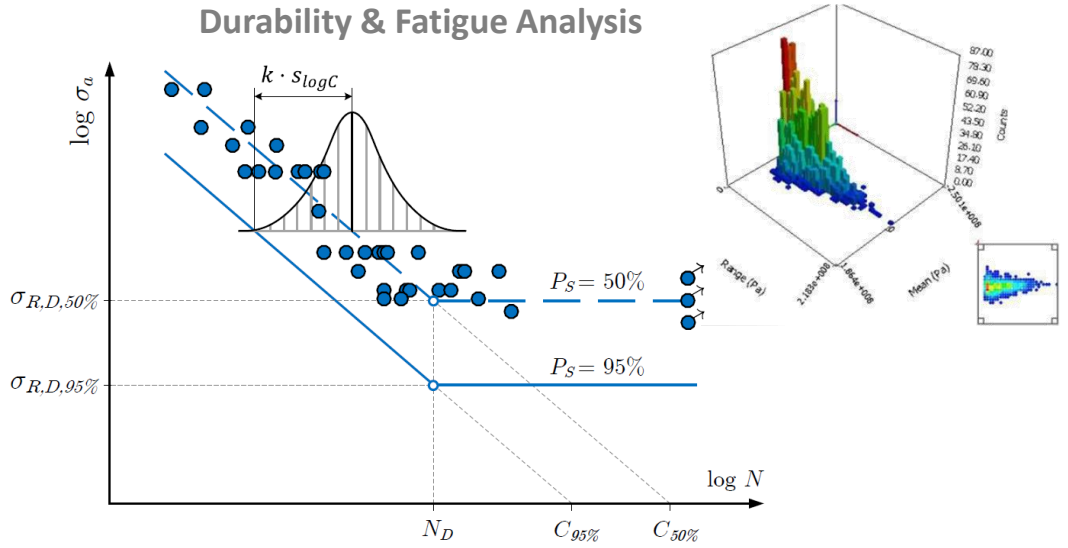
Non-Linear Buckling Analysis



Non-Linear Plasticity Analysis For Post Yield Behavior



Durability & Fatigue Analysis



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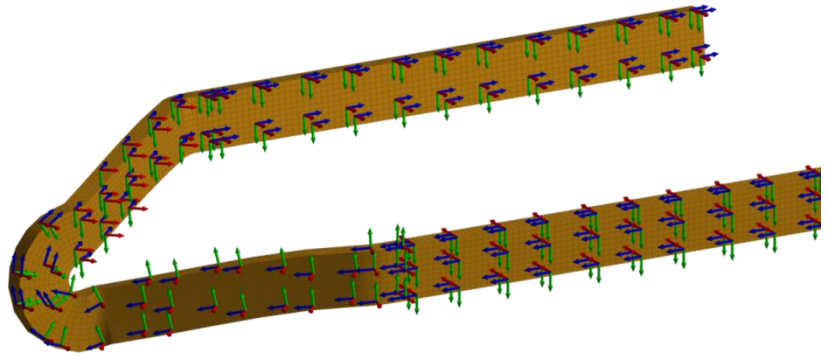
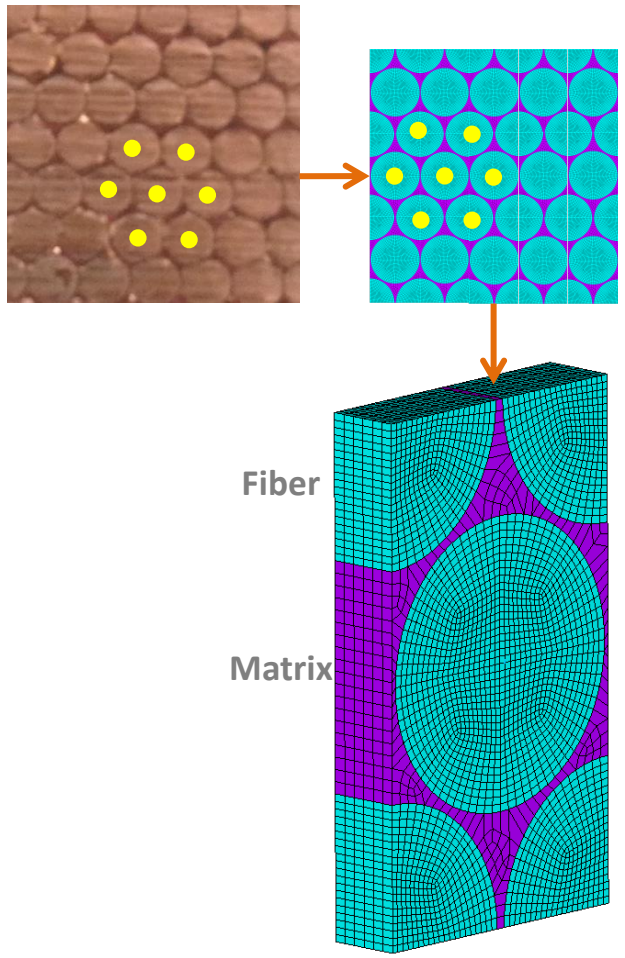
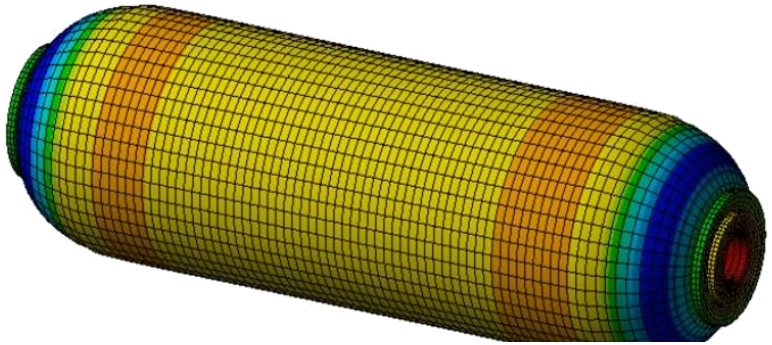
Composite Material Structures

Composite Meso-Scale (Laminate Analysis)

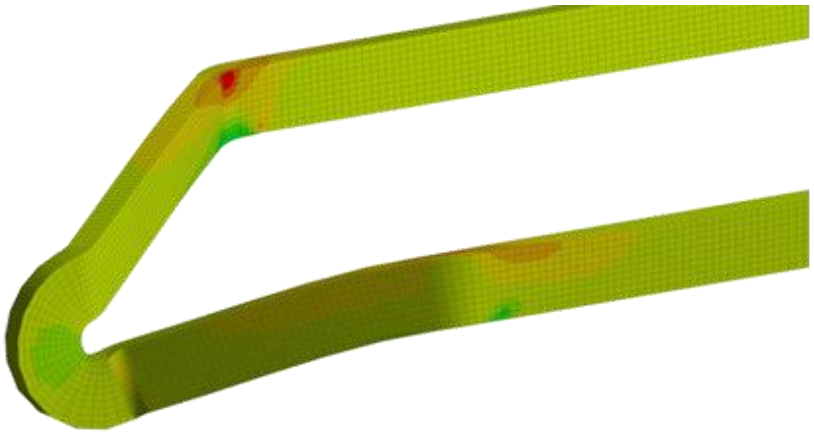


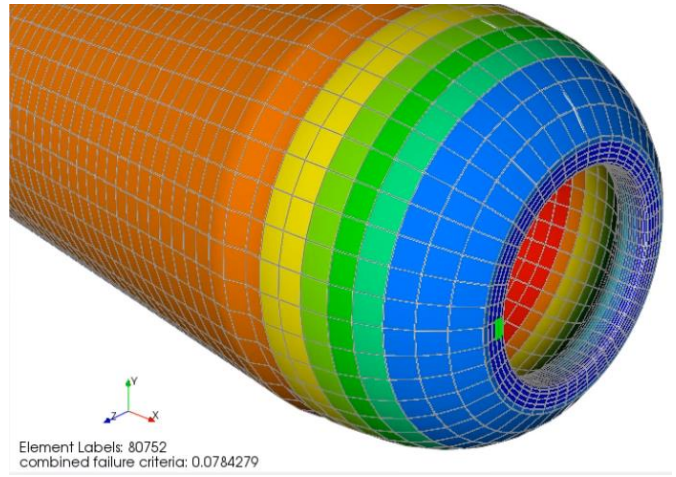
Micro Mechanical Analysis





Composite Macro-Scale Analysis





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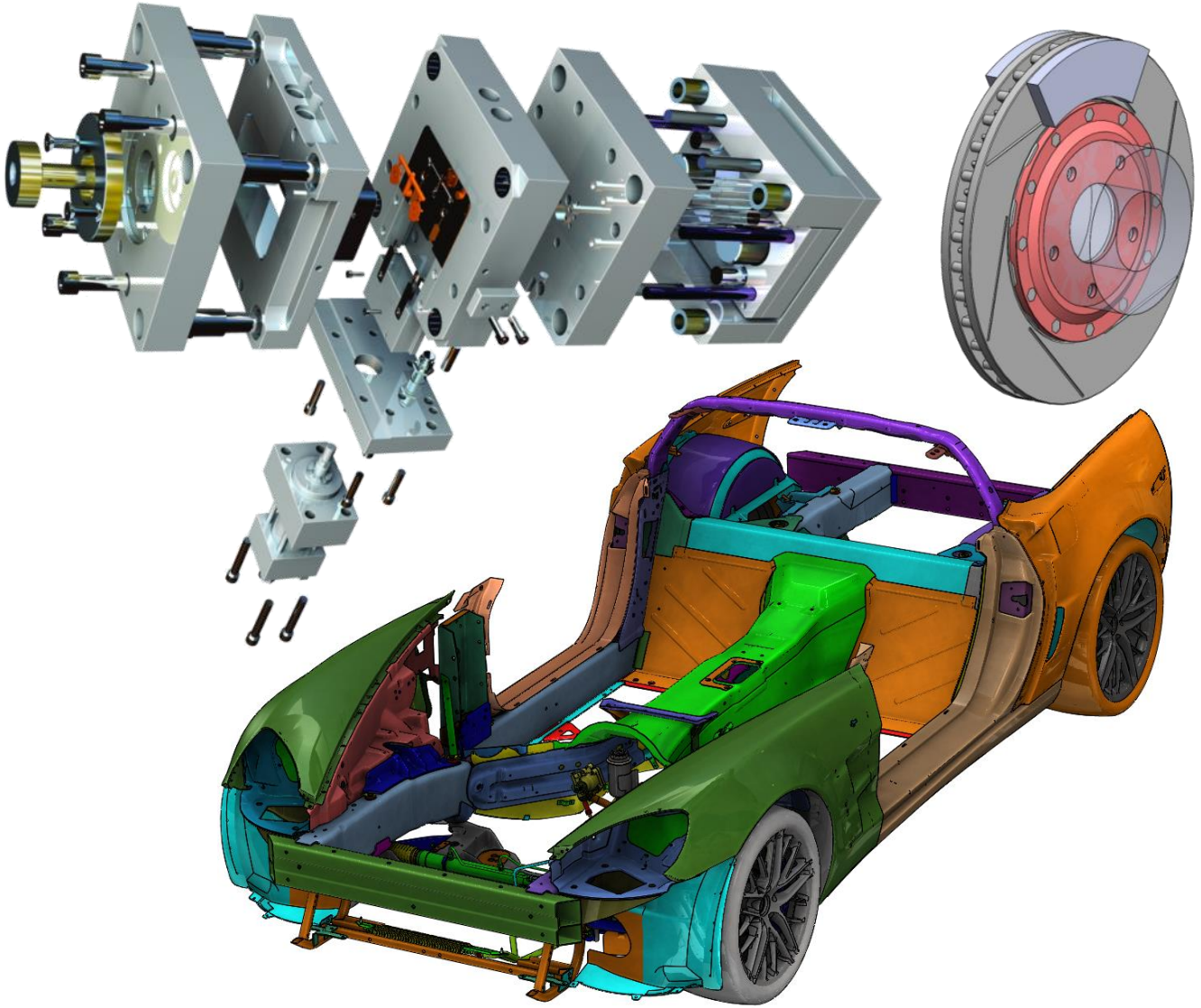
Engineering Design

- Engineering design involves conceptual design based on simple first order engineering calculations. This process enables initial material selection, size and performance estimation.
- Based on this CAD (computer aid design) of initial concept is generated.
- This service also includes generation of engineering drawings for machining from provided CAD models as well as creation of CAD models from engineering drawings.
- Physical models are created using rapid prototyping tools such as 3D printing, desktop CNC machining as well as laser cut cardboard and foam.



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Analytical Spread Sheet & FEA Tools

We provide full spectrum of numerical simulations, however, not every aspect of real world physics can or should be modeled and numerically computed. On the other hand, physical experiments using test rigs might be needed. In some cases, simple analytical spread sheet models are sufficient for quick design assessment, concept evaluation etc.

- We have developed in house analytical tools for analysis such as bolted joints, gaskets and flanges based on current and established design and analysis methods.
- We also have the capability to link spread sheet tools with finite element analysis using ANSYS APDL. This standardizes analysis and removes any dependence on user skill level. All post processing can be automated.
- Based on your product development needs, we can custom build simple analytical spreadsheet tools for your organization.

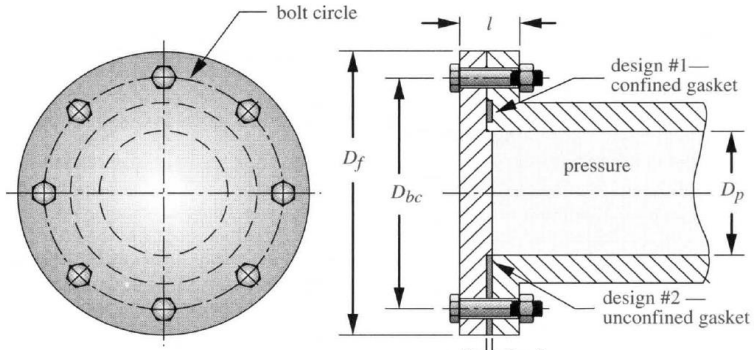
Spread Sheet Tool

Bolt Analysis (UNC)

Parameter	Value	Unit	Description
d	0.750	in	Bolt Nominal Diameter
TPI	16.00	-	threads per inch
Lc	1.50	in	Clamped Length
Lb	2.5	in	Bolt length
Eb	30E+06	psi	Young's Modulus Bolt Material
Sy	3.60E+04	psi	Bolt Yield Strength
K	0.2		Bolt Torque Constant
p	0.0625	in	Thread Pitch
dm	0.6688	in	minor bolt dia
dp	0.7094	in	bolt pitch dia
dt	0.6891	in	Tensile Dia, Used in FEA
At	0.3730	in^2	Tensile Area "At"
Ab	0.4418	in^2	Nominal cross section area of bolt
Lthd	1.75	in	Thread length upto 6" bolts
Ls	0.75	in	Bolt Shank length
Lt	0.75	in	Thread length in grip
kb	8.089E+06	lb/in	Bolt Stiffness
Sp	3.06E+04	psi	Proof Load
Fi	2.70E+04	lbf	Bolt Preload based on 0.75*Sp
T	337.5	ft-lb	Bolt Torque Constant

Gasket Design for Pressure Vessel

Parameter	Value	Unit	Description
Gasket Type	1	-	Confined (0) or unconfined (1)
Dpv	4	psi	Internal Dia of Pr Vessel
Df	7.25	in	Outside Flange Dia
Dbc	5.5	in	Bolt Circle Diameter
Pr	1500	psi	Internal pressure
t	0.125	in	Gasket Thickness
nb	8	-	No of bolts around flange
Eg	1.000E+04	psi	Young's Modulus Gasket Material
Ag	3.4790	in^2	Gasket contact Area per Bolt
km	1.05E+07	lb/in	Joint Member Stiffness
kg	1.088E+07	lb/in	Gasket Stiffness
kmc	5.346E+06	lb/in	Combined member Stiffness
C	0.602	-	Joint Stiffness Ratio
P_total	695	lbf	Total Force on End Cap of Pr vessel
P	29	lbf	Applied force per bolted joint



ANSYS FEA APDL Tool

```
/PMACRO

!Clear Database
fini
/clear

jobname = 'rve-0'
/FILNAME,jobname ! Changes jobname


/TITLE, Full Model of RVE, hexagonal array

PI = ACOS(-1) ! Calculating pi = 3.14.. for subsequent calculations

*AFUN,DEG     !Change to degree for all trignometric calculations

! INPUT GEOMETRY PARAMETERS
!==========================
   Vf = 0.85     ! Fiber Volume fraction
   df = 1        ! Diameter of fibers in mm
Theta = 60       ! Theta defines geometric distribution of fibers in deg
  epo = 0.1      ! Applied Strain: 1 = 100%, 0.1 = 10%, 0.05 = 5%

! INPUT MATERIAL PARAMETERS
!==========================
  E_f = 138e3    ! Fiber material properties [MPa]
 nu_f = 0.343    ! Fiber Poisson's Ratio
rho_f = 8941     ! Fiber Density [kg/m^3]
  E_m = 7e3      ! Matrix material properties [MPa]
 nu_m = 0.28     ! Matrix Poisson's Ratio
rho_m = 2190     ! Matrix Density [kg/m^3]

MULTIPRO,'START',3 ! Geometric Parameters 3 -> # of parameters
*CSET,1,3,Vf,'Fiber Volume Fraction',Vf
*CSET,4,6,df,'Diameter of Fibers',df
*CSET,7,9,Theta,'Hex Angle of Fiber',Theta
*CSET,61,62,'Enter Geometric Parameter Values','. UNIT = mm'
*CSET,63,64,'NOTE: There is no error checking','. Check before pressing OK'
MULTIPRO,'END'

MULTIPRO,'START',6 ! Material Parameters 6 -> # of parameters
*CSET,1,3,E_f,'Fiber Modulus',E_f
*CSET,4,6,Nu_f,'Fiber Poisson Ratio',Nu_f
*CSET,7,9,rho_f,'Fiber Density [kg/m^3]',rho_f
*CSET,10,12,E_m,'Matrix Modulus',E_m
*CSET,13,15,Nu_m,'Matrix Poisson Ratio',Nu_m
*CSET,16,18,rho_m,'Matrix Denisty [kg/m^3]',rho_m
```

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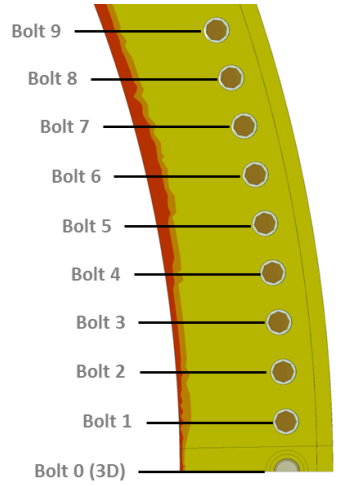
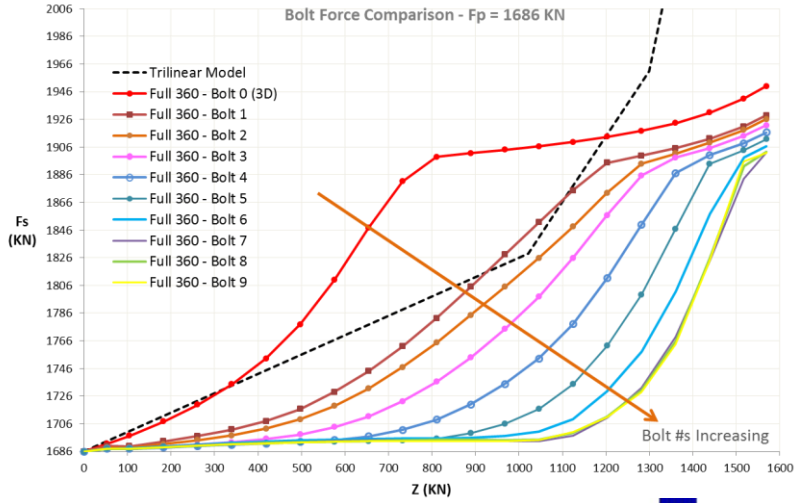
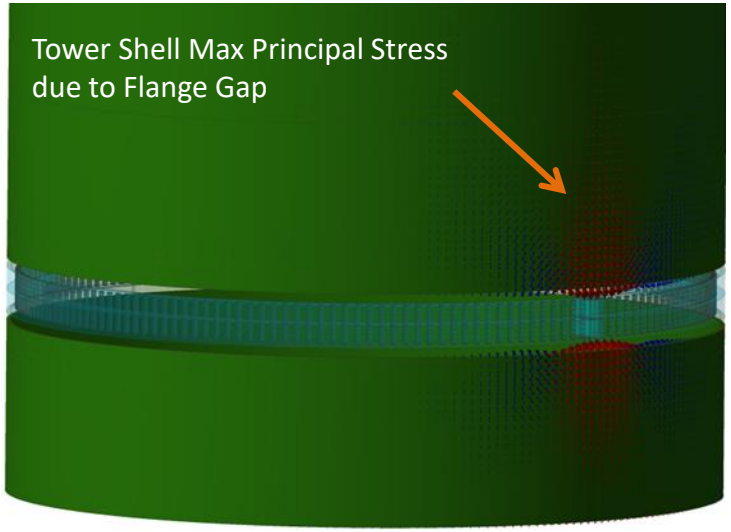
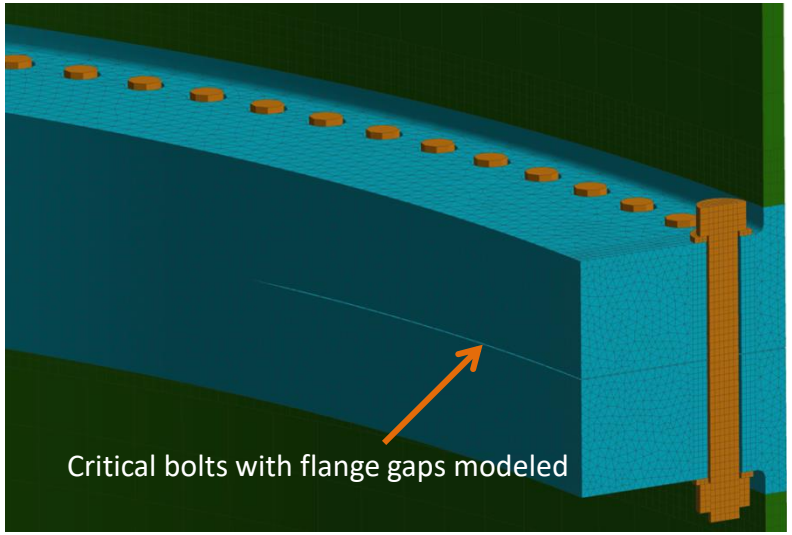
Past Projects: Wind Turbine Structures



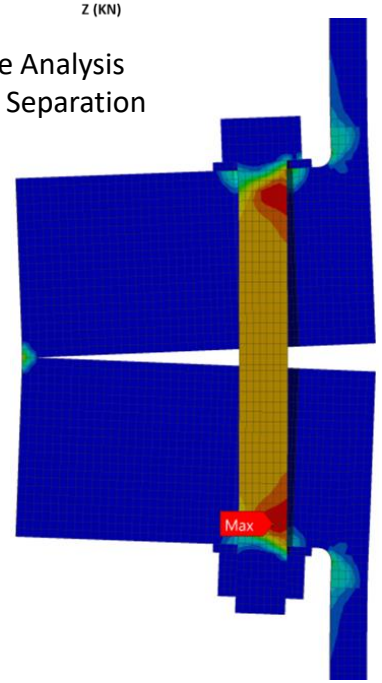


Bolted Flange Contact/Gap Analysis





Nonlinear Failure Analysis Involving Flange Separation & Bolt Rupture.



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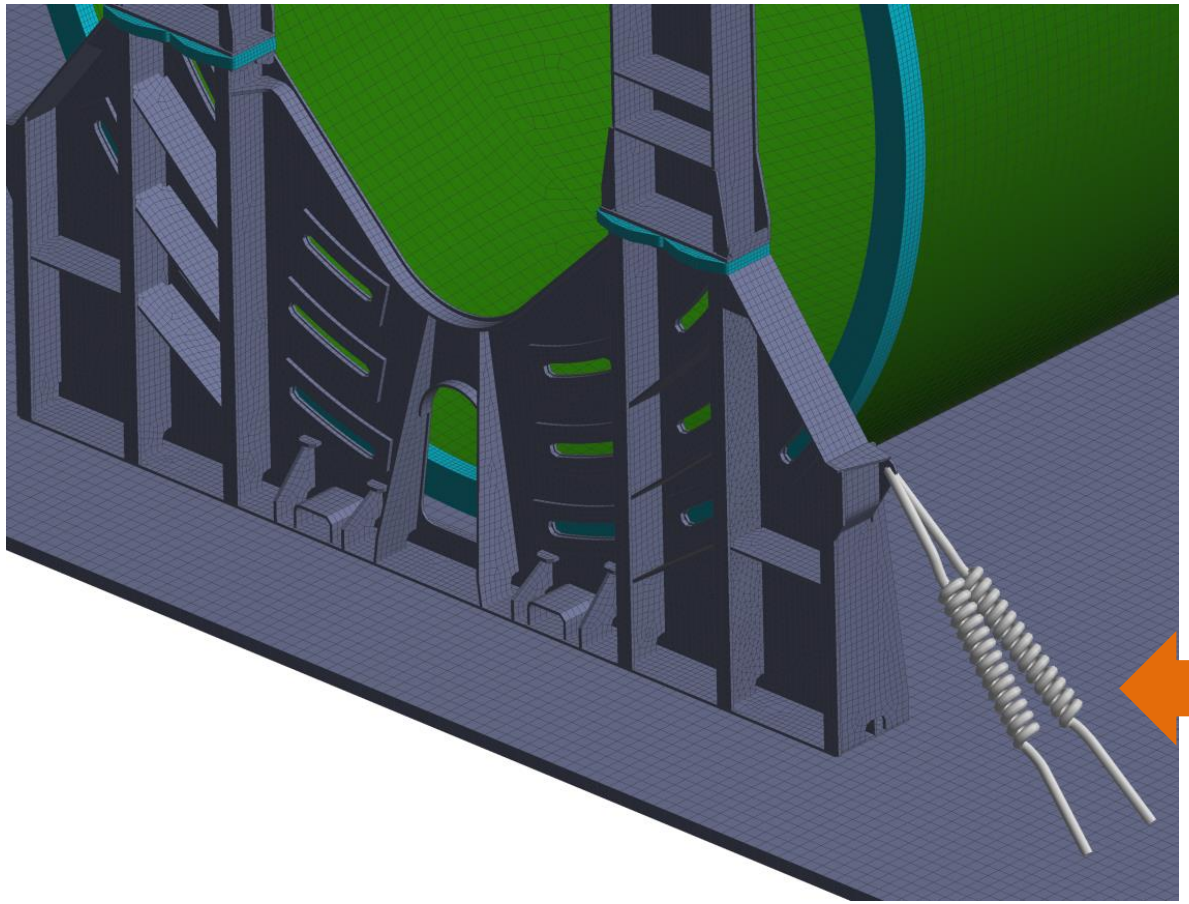
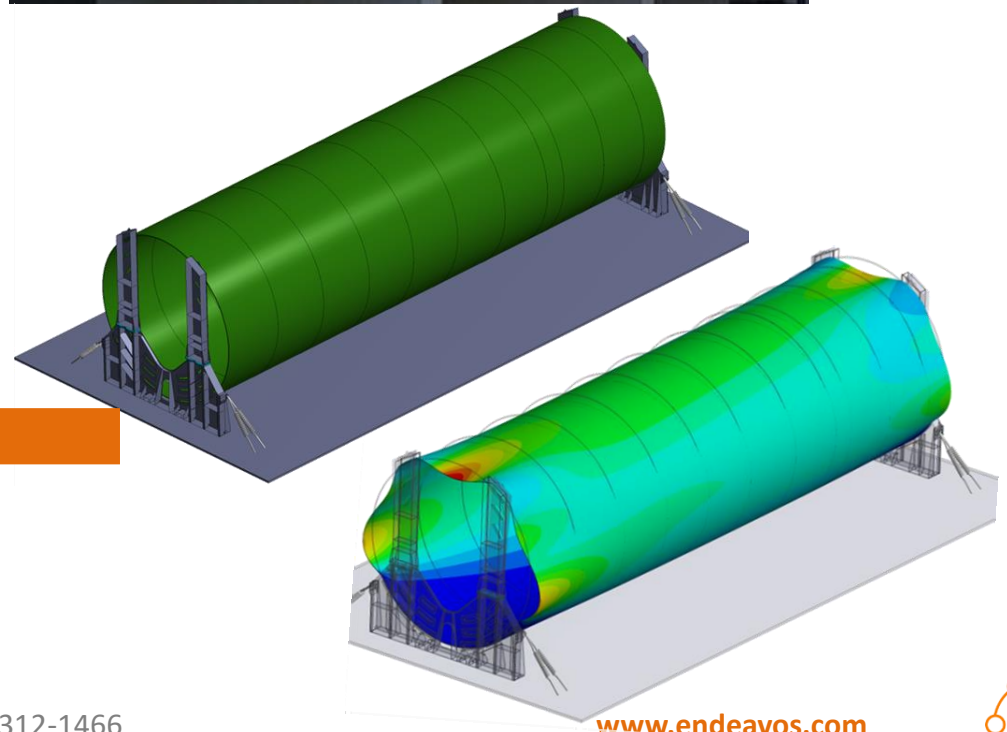
Past Projects: Wind Turbine Structures





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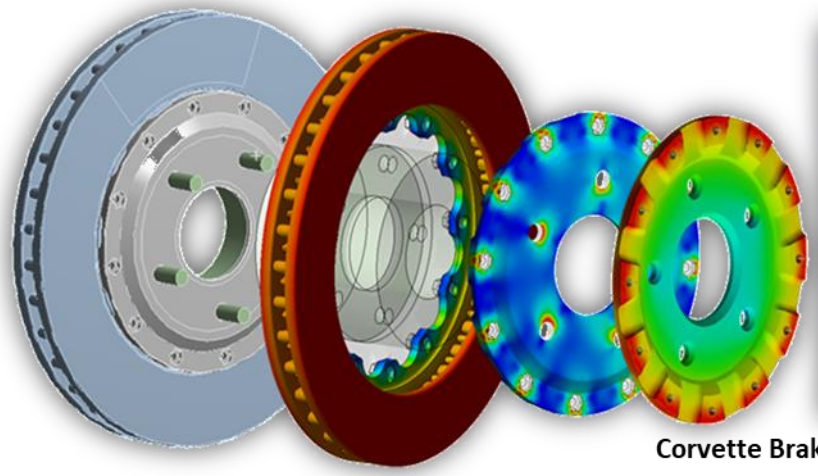
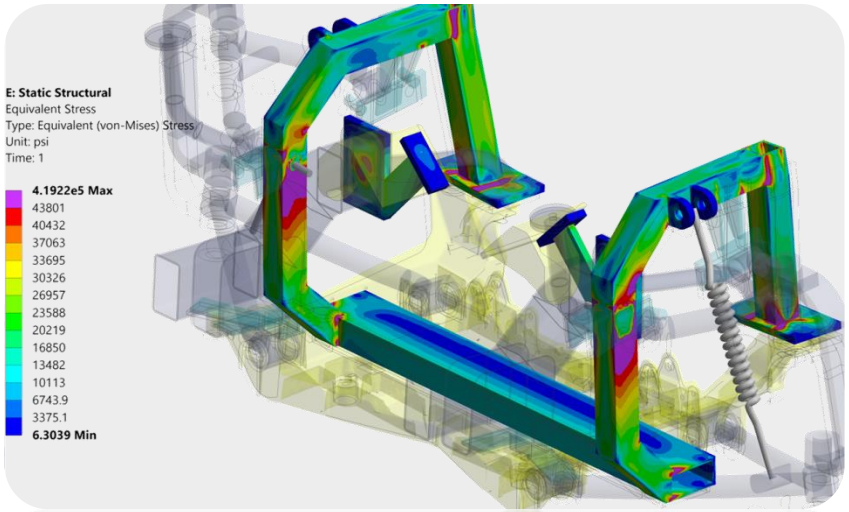
Past Projects: Automotive Chassis Design & Brake Analysis

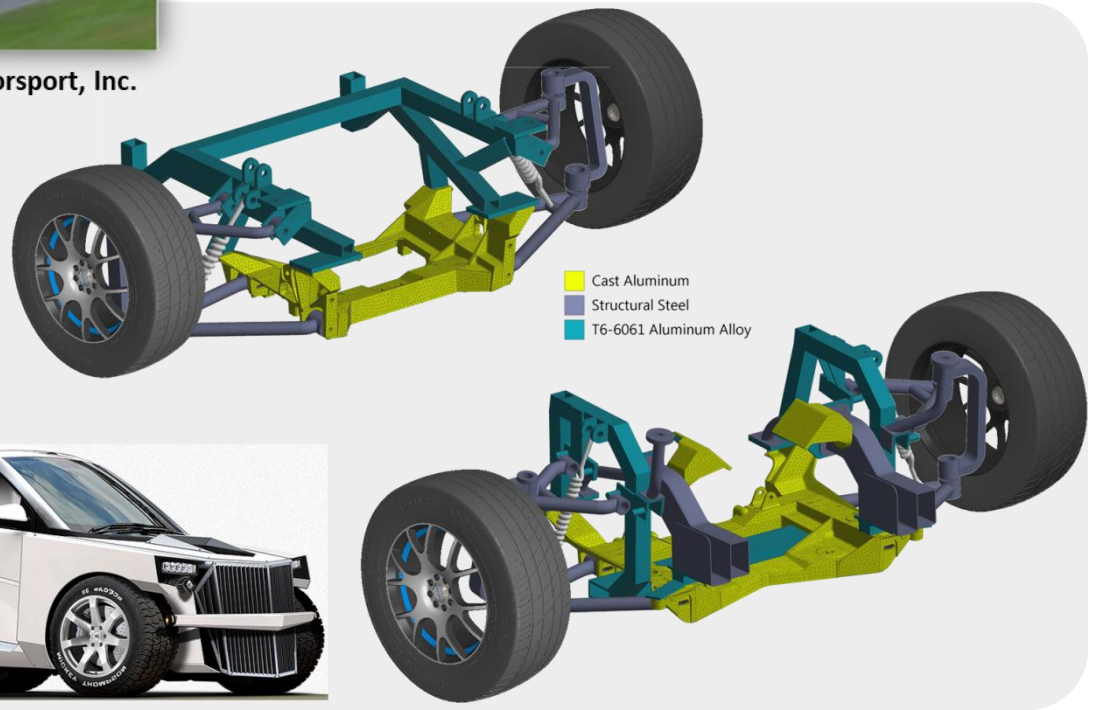


Corvette Brake Rotor Analysis for AMT motorsport, Inc.



Hearn Automotive Redesign Chassis

Hearn Automotive Redesign Chassis



Selected Clients & Testimonials

"I was very impressed with the creativity and engineering workflow of Endeavos. They have deep knowledge of developing complex simulation models at multiple levels from lumped parameter to very detailed FEM. They worked well with our internal staff and made valuable contributions that helped our R&D project move along seamlessly amid tight deadlines. Due to their collaborative working style, I am happy to consider them an extension of our engineering team."

***Alex Kagan P.E.*, Principal Engineer, GE Global Research Center**

"Endeavos worked on the simulation of a Corvette brake rotor analysis for my company AMT Motorsport, Inc. I wanted to ensure the safety and structural integrity of a redesigned rotor hat for our 2-piece racing rotor design. The analysis was impressive and the results were very clearly explained to a non-engineer like myself, and provided actionable data on how to improve the effectiveness of our design."

***Mark Petronis*, President/Owner, AMT Precision Manufacturing & AMT Motorsport, Inc.**

"Endeavos has provided creative engineering solutions on several of my projects, always backed by solid analysis results. Whether the challenge is in mechanical design or detailed finite element analysis, they have demonstrated reliability in meeting schedules, communicating clearly, and exceeding expectations. Based on my first-hand experience working with Endeavos, I will continue to engage them for future engineering support."

***Norman Turnquist*, Senior Principal Engineer, GE Global Research Center**

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