Deploying Altair optistruct for nonlinear simulation of automobile components

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Abstract

Nonlinear analysis of automobile components is becoming increasingly important at the product development stage as the expectation for accurate simulation are increasing day by day. Automotive companies are trying to eliminate test based on simulation to test correlation. In recent times, there is more focus on optimized design, it is therefore necessary to model contact, material and geometric nonlinearity to predict the accurate results. The main challenge lies in developing a robust analytical process that makes it possible to conduct analysis of such loading conditions with sufficient degree of accuracy. Efficient use of a CAE resources and robust simulation processes will help in reducing product development timelines. Selection of FE solver for non –linear analysis is very vital, because it is impact on product quality and product development time.

The present paper focuses on non – linear analysis of automotive component using Altair FEA package Optistruct. The results obtained are used for comparative study with the stress and displacement results obtained from competitive FEA Non-Linear software being used currently and physical testing of the component under operational loads. The study shows the turnaround time for analysis is reduced by an average 50%.

Introduction

The automobile industry provides many challenges which require the use of leading edge technologies to keep up with increasing performance demands. All physical structures exhibit nonlinear behavior to some extent. They may be made of rubber or plastic materials that do not have a constant modulus, they may be operating over a range of temperatures where the material behavior at high temperature is very different than that at ambient, or they may be made up of components that contact each other. In such cases, linear FE analysis is an approximation that makes the analysis of structures more tractable. However, the assumptions of linearity are often not adequate for real structures. If a nonlinear FE method is used, many of these limiting assumptions are no longer required; therefore, the analysis of a structure undergoing some form of nonlinear behavior may be much more accurate if a nonlinear Finite Element analysis is carried out.

In this paper, we will show how Mahindra and Mahindra deployed nonlinear capability of optistruct solver and how the optistruct solver benefited us with decrease in turnaround time with same accuracy.

Process Methodology (details with figures)

The general process for any CAE simulation is as shown in fig. The most important thing is in this process is FEA Software we are using, for pre-processing to post processing. The CAE process time will drastically reduce if we focus on these three things. The FEA software we are using should be user friendly and must be cost effective.
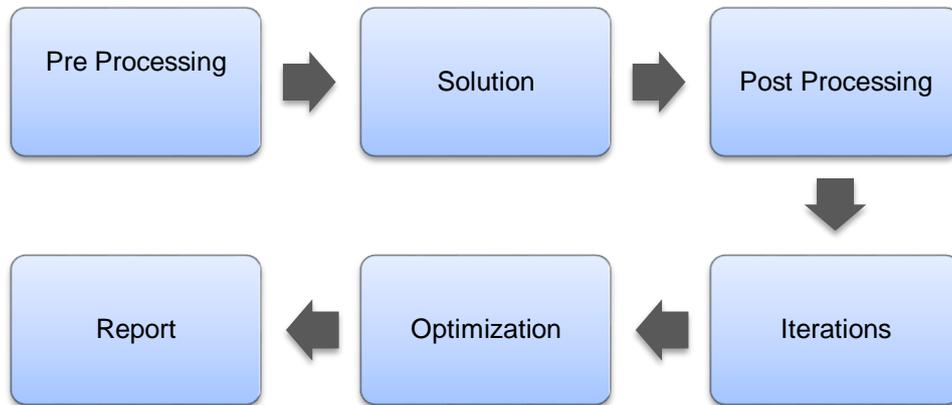

CAE Process

The activities which is involved while preprocessing to post processing is as shown below.
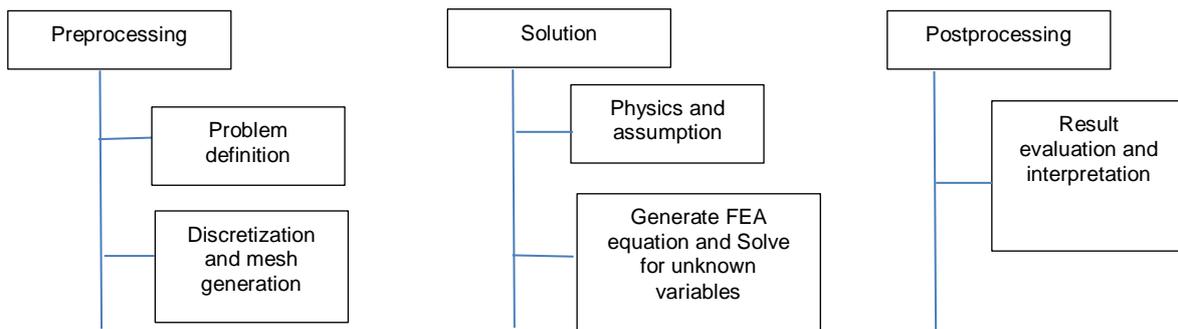
The solution will be more accurate if we include all the complexity in the model and simulate it to actual condition. So, for this to do nonlinear analysis is important. So, main key thing in nonlinear analysis is solver, which will solve the problem in quick time and accurate, having good convergence criteria. Optistruct solver is one of key nonlinear solver which will give all the things in one package. The nonlinearity can be classified into three types.
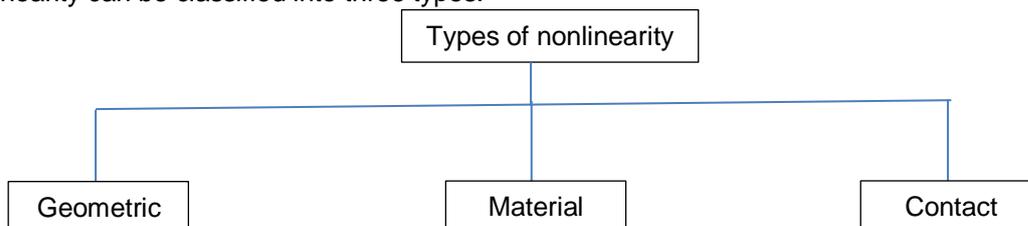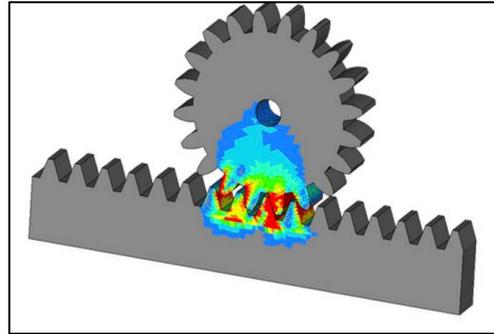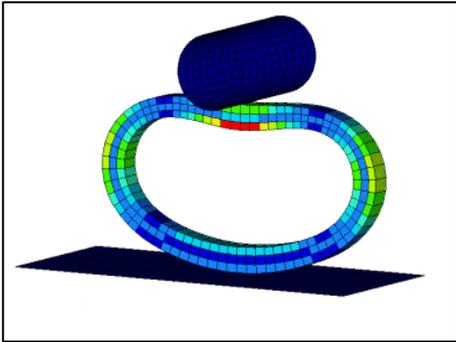
Example of nonlinearity

In optistruct, to include these nonlinearities in simulation, we must use following options.
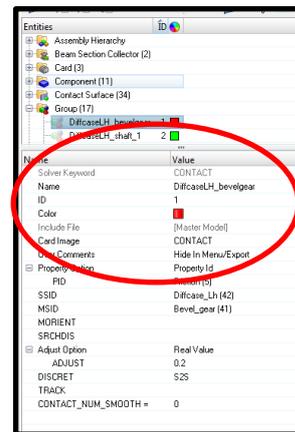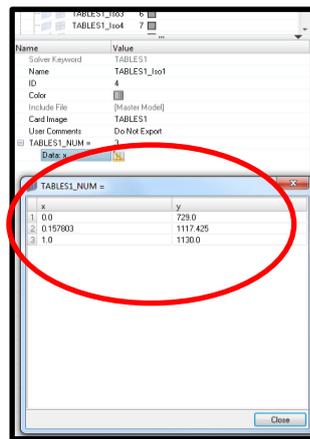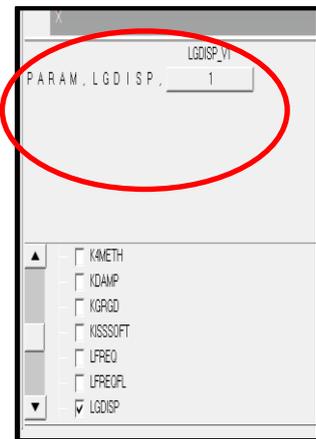

After including these, the nonlinear simulations are run and output are compared with current competitive solver which is discussed in next section.

Results & Discussions of case studies:

1. Front axle:

The Optistruct solver nonlinear capability is validated for nonlinear simulation of automotive components. The parameters like displacement, stress, solving time and turnaround time of optistruct solver is compared with current competitive solver in Mahindra. Also, the strain correlation with actual test is done.

Front axle is one of the important supporting member of vehicle, located in the front of the vehicle. It is subjected to bending and torsion loads during operations as per RWUP. The material, geometric and contact nonlinearity are considered in the analysis.

Normalised Von-mises stress
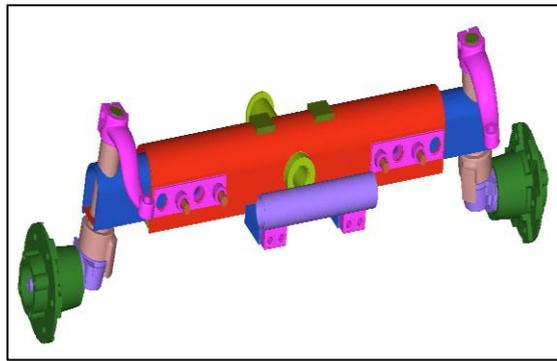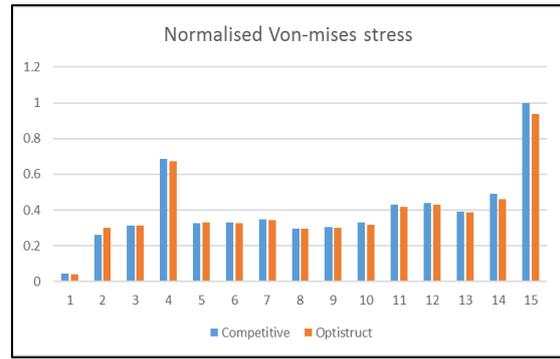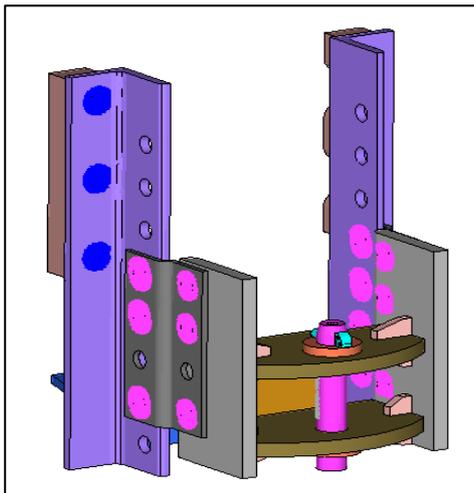
Front Axle

Stress at different location of Front Axle

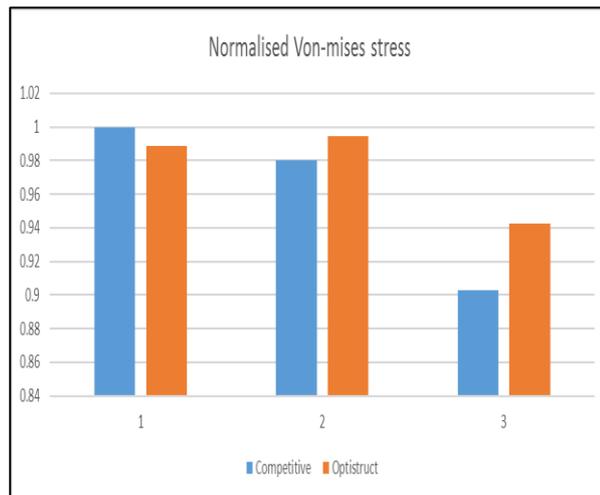|	Competitive Solver	Optistruct Solver	Difference in %
Normalised Displacement	1	1.0019	+0.19
Normalised Stress	1	1.1517	+15.17
Solving time(hr.)	03:55:00	03:56:00	+0.42
Turnaround time(hr.)	09:55:00	03:56:00	-60.34

Output Comparison for Front Axle

2. Tow hook

A tow hook assembly attached to the differential housing of a vehicle through angular brackets for towing the trailer. The assembly is subjected to different towing load conditions as per RWUP. The material and contact nonlinearity are considered in the analysis

Normalised Von-mises stress

Tow Hook

Stress at different location of Tow hook

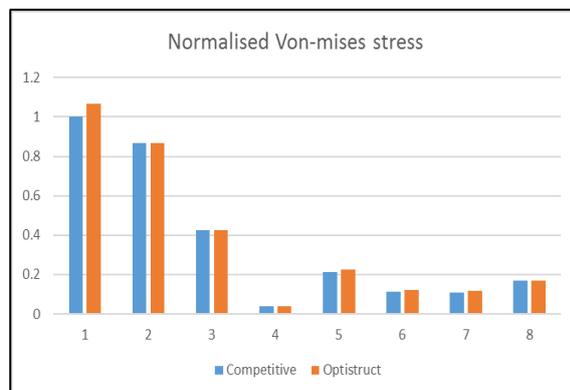|	Competitive Solver	Optistruct Solver	Difference in %
Normalised Displacement	1	1.0092	+0.97
Normalised Stress	1	1.1016	+10.15
Solving time(hr.)	01:42:33	01:32:43	-9.58
Turnaround time(hr.)	03:42:33	01:32:43	-67.18

Output Comparison for Tow hook

3. Break and clutch assembly

The break and clutch assembly is subjected to different loading conditions as per RWUP, but only human foot load considered for current study. These load case is to evaluate the strength of assembly, when it is subjected to human foot loads. All nonlinearities (material, geometric and contact nonlinearity) are considered in the analysis.
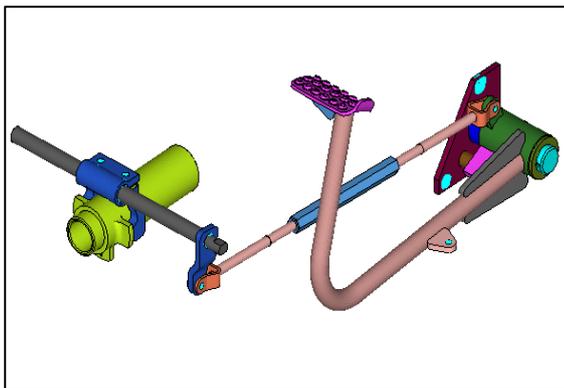
Break and clutch assembly

Stress at different location of Break and clutch assembly

	Competitive Solver	Optistruct Solver	Difference in %
Normalised Displacement(mm)	1	1.0104	+1.04
Normalised Stress(MPa)	1	1.0666	+6.65
Solving time	00:19:22	00:18:31	-4.39
Turnaround time	03:19:22	00:18:31	-90.71

Output Comparison for Break and Clutch assembly
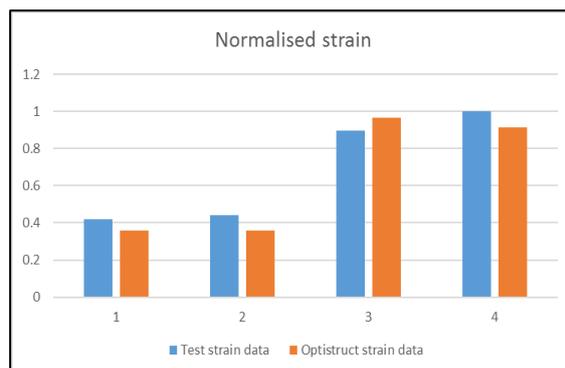
Test Correlation

4. Fuel tank

The fuel tank is subjected many loading condition w.r.t. RWUP, but only leak test is considered for current study. Leak test is to evaluate the fuel tank strength with internal force excreted by fuel filled Inside of fuel tank. All nonlinearities (material, geometric and contact nonlinearity) are considered in the analysis.

Fuel Tank assembly

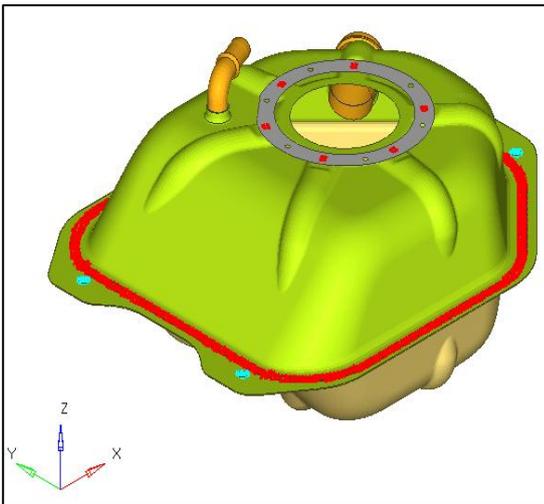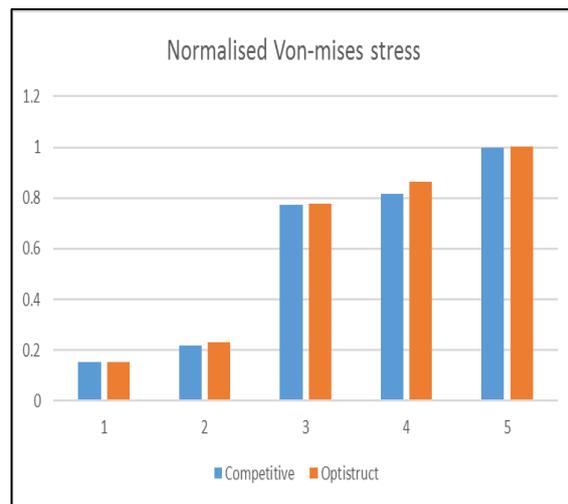Normalised Von-mises stress

Stress at different location of Fuel Tank assembly

	Competitive Solver	Optistruct Solver	Difference in %
Normalised Displacement	1	1.0412	+4.12
Normalised Stress	1	1.0555	+5.55
Solving time(hr)	00:04:00	00:02:47	-30.41
Turnaround time(hr)	02:04:00	00:02:47	-97.75

Output Comparison for Fuel Tank

5. Differential case

The differential assembly play vital role in vehicles for assisting it in turning of vehicle. The differential case subjected to different gear loads due to different loading condition w.r.t. RWUP. The assembly behaves nonlinearly due to presence of contact nonlinearity.
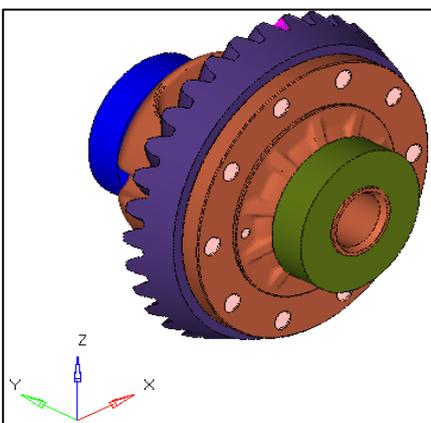
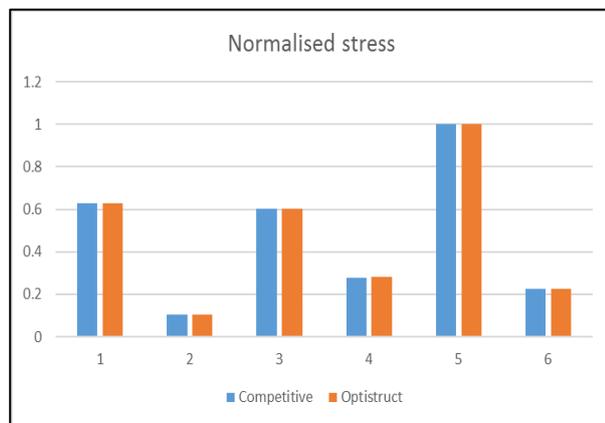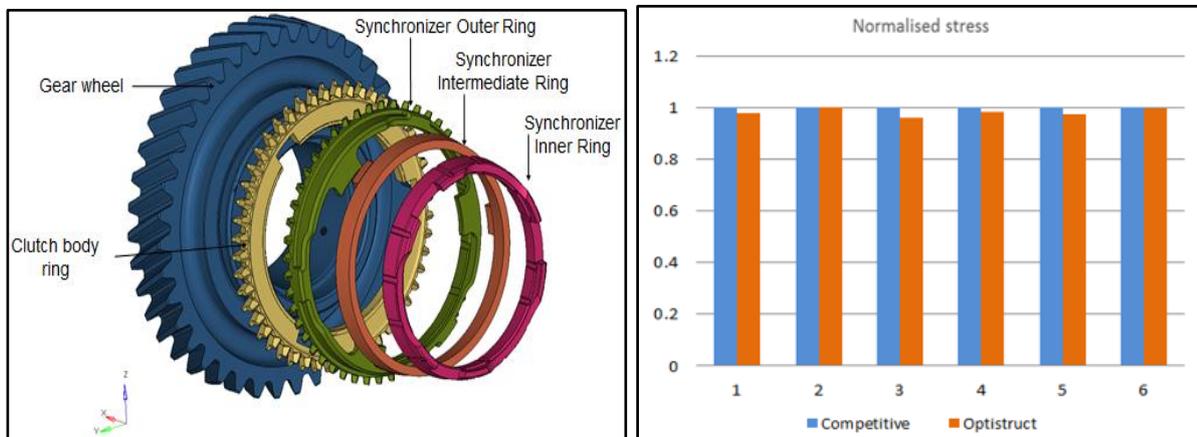**Differential Case assembly**

Normalised stress

Stress at different location of Diff Case assembly

	Competitive Solver	Optistruct Solver	Difference in %
Normalised Displacement	1	1.0004	+0.04
Normalised Stress	1	1.0098	+0.98
Solving time(hr)	00:42:49	00:44:25	+3.74
Turnaround time(hr)	02:42:49	00:44:25	-72.72

Output Comparison for Differential Case

6. Synchronizer

The Synchronizer assembly is a critical component of transmission. In a synchromesh gearbox, to correctly match the speed of the gear to that of the shaft as the gear is engaged, the collar initially applies a force to a cone-shaped brass rings attached to the gear, which brings the speeds to match prior to the collar locking into place. The transmission synchronizer components are subjected to tangential loads while gear engagement is happening. Due to presence contact surfaces, the FEA model becomes nonlinear.

Synchronizer assembly	**Stress at different location of Synchronizer assembly**

	Competitive Solver	Optistruct Solver	Difference in %
Normalised Stress (Mises)	1	0.9775	- 2.2
Normalised Stress (Max. Principle)	1	0.9745	- 1.9
Solving time(hr)	05:29:00	05:40:00	+3.34
Turnaround time(hr)	07:29:00	05:40:00	-24.28

Output Comparison for Synchronizer

Benefits Summary

As in case of nonlinear simulation, the biggest challenge is to get a nonlinear solver which can be very easy to use and optimistic in memory utilization and should give results in quick time.

1) The only single package of Altair can you be used from meshing to post processing, so this will avoid using multiple solver at a time and will reduce the simulation time.
2) The Solver is user friendly and having good convergence criteria.
3) The optistruct solver is giving accurate results close to reality at competitive price.
4) The time taken by optistruct solver is less or equal to competitive solver. But turnaround time is almost half of the competitive solver, which gives us to delivers the project on time.

Challenges

The lot of challenges faced while deploying optistruct solver for nonlinear simulation of various automotive component in Mahindra and Mahindra.

1) The major challenge is the availability of all parameters which is available in competitive solver and compatibility of the same. For this the comparative study of parameters between optistruct solver and competitive solver is done, which is as shown below.

Parameter	Optistruct	Parameter	Optistruct	Parameter	Optistruct	Parameter	Optistruct
Master & Slave Surface Definitions	Support	Friction – Surface behavior	Support	Material (Plastic Strain Vs Stress)	Support	Bolt Pretension	Support
Contact-Tie	Support	Contact-Small Sliding	Support	Large displacement (NLGEOM)	Support	Restart option	v14.0.210
Contact-surface to surface	Support	Contact-Finite sliding	Support	Required-Termination time	Support	Contact Formulation-Augmented Lagrange	No Support
Contact-Node to surface	Support	Contact Formulation-Penalty method	Support	Initial time step size	Support	Contact Formulation-Direct	No Support
Contact-Adjust	Support	Output request at required interval	Support	Step-Minimum increment size	Support	Output-Energy	No Support
Contact-Adjust tolerance	Support	Output-CPRESS, COPEN, CDISP	Support	Step-Maximum increment size	Support		
Contact-Clearance	Support	Output-Strain, True strain, Plastic strain	Support	OP New	Support		
Contact-Position	Support	Fast Contact option for	Support	OP Mod	Support		

tolerance (tie)		linear contact					
Contact controls-Stabilize	Support	Corner data in result out put	Support	Sequential loading	Support		

2) The another one is the deviation between results as compared to competitive solver. So, for this, we have compared the deviation of results of various simulations and then found that deviation in results are varies as max 10%, which is within acceptable limit.

3) The biggest challenge is setting the server, which will give output in same time as compared to competitive solver. For this we have tried different server configuration. Below table shows one example, for which the time taken by optistruct varies with server configuration

Solver	Server	MPI	Threads	Host	Total Domain	Total Cores	RAM	Elapsed Time
Competitive	M& M	X	4Y	Z	XZ	4XYZ	W	00:19:21
Optistruct	M& M	X	4Y	Z	XZ	4XYZ	W	01:29:00
Optistruct	Altair	3X	Y	1.33Z	4XZ	4XYZ	0.75W	00:25:37
Optistruct	Final M& M	3X	Y	1.33Z	4XZ	4XYZ	W	00:20:05

After lot of iterations and inputs from Altair team, finally we will able to set up the server which will give solution at same time as competitive solver.

Future Plans

The future work includes
1) The nonlinear optimization using optistruct.
2) The correlation improvement between competitive and optistruct solver.
3) Deployment of optistruct in all domains.

Conclusions

Optistruct Non-Linear solver is the way forward. We can able to reduce the turnaround time and deliver the project in quick time with great accuracy due to optistruct. The Altair Range of product is helping Simulation group in Mahindra to meet the vision of First time right and every time right optimum design.

REFERENCES

[1] Altair Hyper works help manual and Tutorials.