

**Innovative Method of Deploying MATLAB Based
Application Across Organization Using MathApps
- A Web-based Platform**



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- Introduction
- Application Building and Deployment Process
- MATLAB Tools for Application Building
- Applications Case Studies
- Impact of MathApps



Introduction

MISSION: To strengthen frontloading, standardization of design calculations across product development functions of Auto Farm Sector companies through low fidelity high impact concept simulations.

Design Calculation

*Quick design calculations based on **analytical/empirical equations***

E.g. Beam deflection calculation

Physics based Modelling

Model based simulation** for performance analysis and prediction of system behaviour, including **multi-physics simulation

E.g. Vibro-acoustics of steering hose

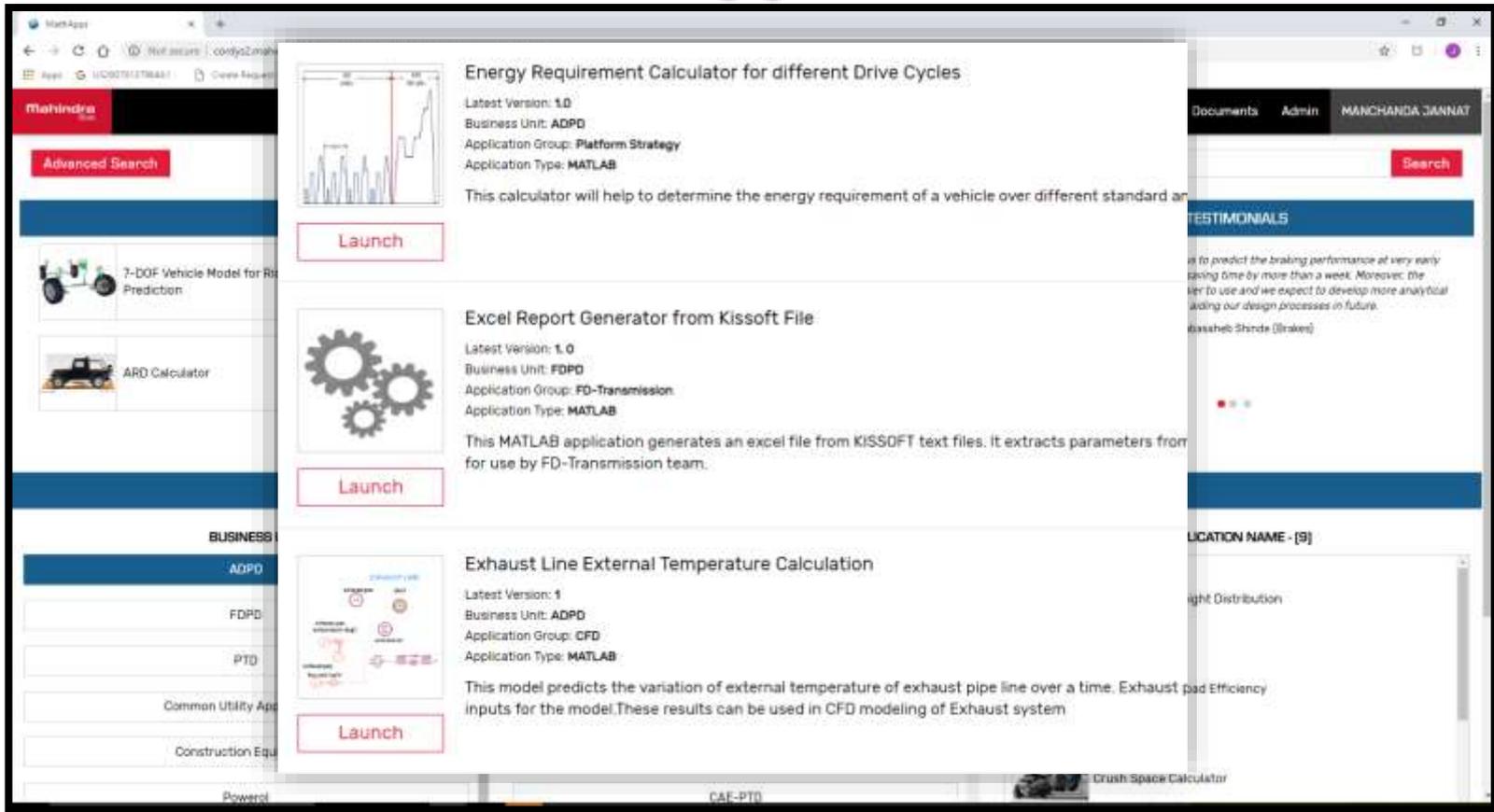
Engineering Analytics

***Experimental data analysis** and **data-driven modelling** - development of applications to process data, derive meaningful conclusions and generate useful reports.*

E.g. Brake FI Attribute Test Data Analysis.



Introduction: MathApps



MathApps: Mahindra's enterprise level design calculator portal

- Concept design calculator
- Frontloading designs
- Reduce product lead time
- Power of calculations to all designers at their disposal by leveraging MATLAB's capabilities



Introduction: MathApps

- The applications are made accessible to the designers through a web browser viz Google Chrome, Internet Explorer etc. and can be run from their workstations without the need to install additional software.
- All applications are restricted for internal use by integration with server-based database and two stage authentications



Front Loading of Bolted Joints

Latest Version: 1.0
Business Unit: Common Utility Applications
Application Group: Common Automotive Application
Application Type: MATLAB

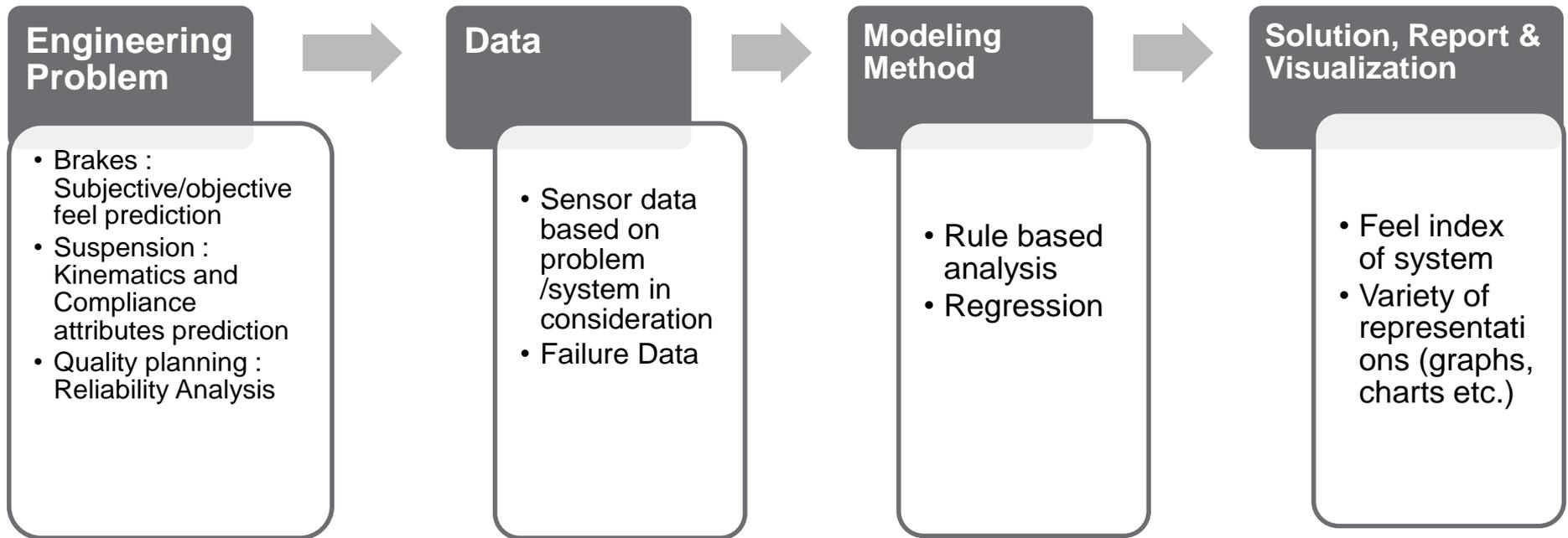
This application provides bolt characterization outputs, cover factor calculations, strength of shank and threads, joint separation and contact pressures for Powertrain & Farm division bolted joints.

[Launch](#)

Example Application: Bolt Design Calculator; This application can be directly launched from MathApps



MathApps Workflow





Application Example: Bolt Joint Analysis

The screenshot displays the Mahindra MathApps web interface. At the top, there is a red navigation bar with the Mahindra logo, 'MSPRINT BUSINESS PROCESS MANAGEMENT', and user information 'MANCHANDA JANNAT'. Below this is a dark navigation bar with 'MathApps' and menu items: Home, About, Documents, Admin, and MANCHANDA JANNAT.

The main content area is divided into a left sidebar and a main panel. The sidebar contains a 'REFINE RESULTS' section with a 'Keyword' search box and a 'Launch' button. Below this are several filter categories: 'Accessible Applications Only' (with a 'Clear All Filter' link), 'Business Unit', 'MPDS Gateway', 'Functional Tags', and 'Type of Applications'. Under 'Type of Applications', there are checkboxes for 'COMSOL', 'Galaxy', and 'MATLAB' (which is checked). There is also an 'Application Stage' dropdown menu.

The main panel displays three application cards:

- Exhaust Temperature Prediction:** This model predicts the variation of external temperature of exhaust pipe line over a time. Exhaust pipe may have multiple layers. Temperature and mass flow rate of Exhaust gas are the inputs for the model. These results can be used in CFD modeling of Exhaust system. Includes a 'Launch' button.
- Field Performance Prediction:** Latest Version: 1.0, Business Unit: FOPD, Application Group: FD-Tractor Vehicle Integration, Application Type: MATLAB. This application calculates field performance of tractors. It is developed in collaboration with North Eastern Regional Institute of Science and Technology (NERIST). Includes a tractor image and a 'Launch' button.
- Front Loading of Bolted Joints:** Latest Version: 1.0, Business Unit: Common Utility Applications, Application Group: Common Automotive Application, Application Type: MATLAB. This application provides bolt characterization outputs, cover factor calculations, strength of shank and threads, joint separation and contact pressures for Powertrain & Farm division bolted joints. Includes a technical diagram and a 'Launch' button.
- Fuel Tank Temperature Calculation:** Latest Version: 1, Business Unit: FOPD, Application Group: FD-Body, Application Type: MATLAB. This model predicts the fuel tank temperature variation with time. Fuel outlet flow rate to engine, fuel return flow rate to tank are considered. Includes a diagram of a fuel tank and a 'Launch' button.

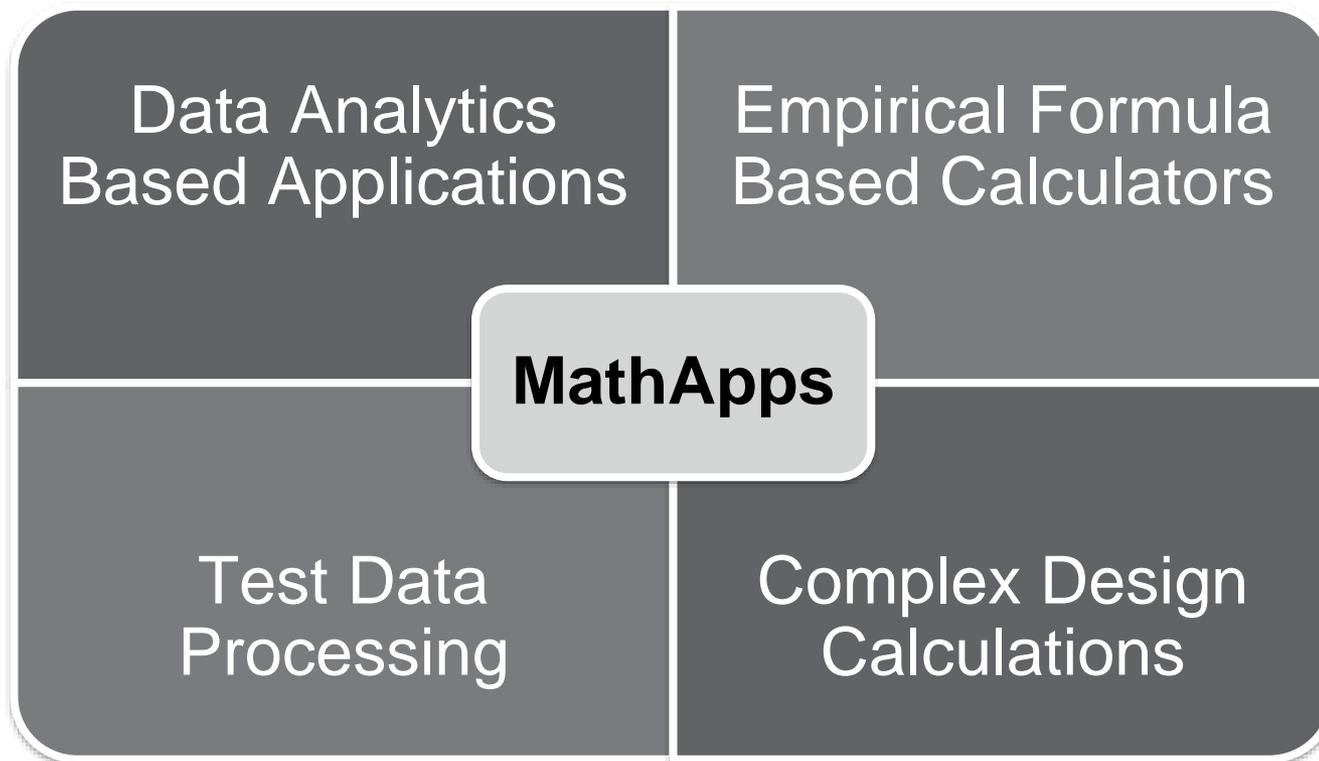
At the bottom of the screenshot, the browser address bar shows 'http://mahindra.com/home/MahindraMathApps/mathapps.html' and the system clock shows '2:18 PM'.

Why MathApps

- Avoid duplication of efforts
- Centralized repository for all the design front loading
- Automate workflows
- Avoid errors; maintain consistency in results
- Ease of access for users across different Mahindra divisions
- Collaborate with different design teams to create requirement specific applications
- Maintain uniformity in processes
- Increase efficiency: Getting quick and reliable results from MATLAB applications
- Applications from different tools are integrated in MathApps

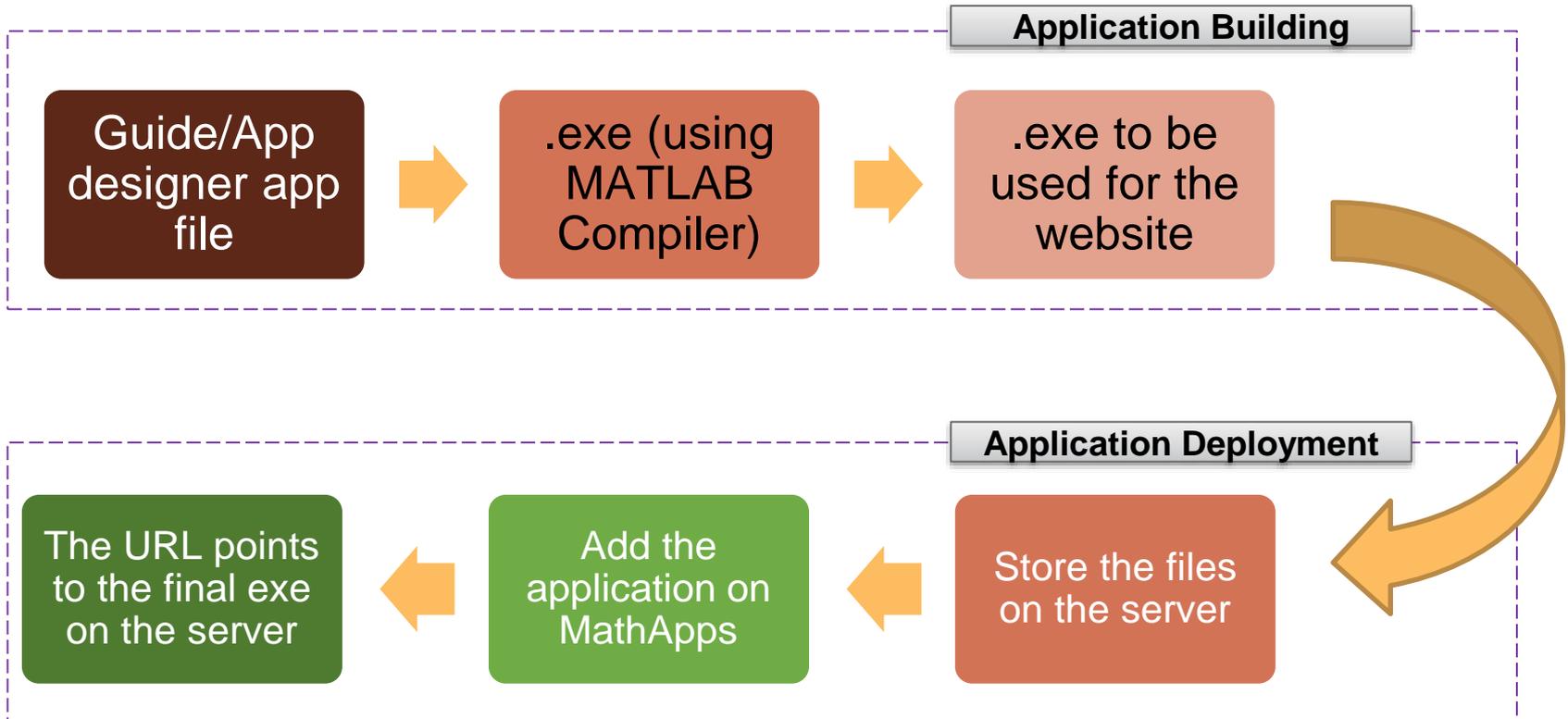


Different MATLAB Applications Deployed on MathApps



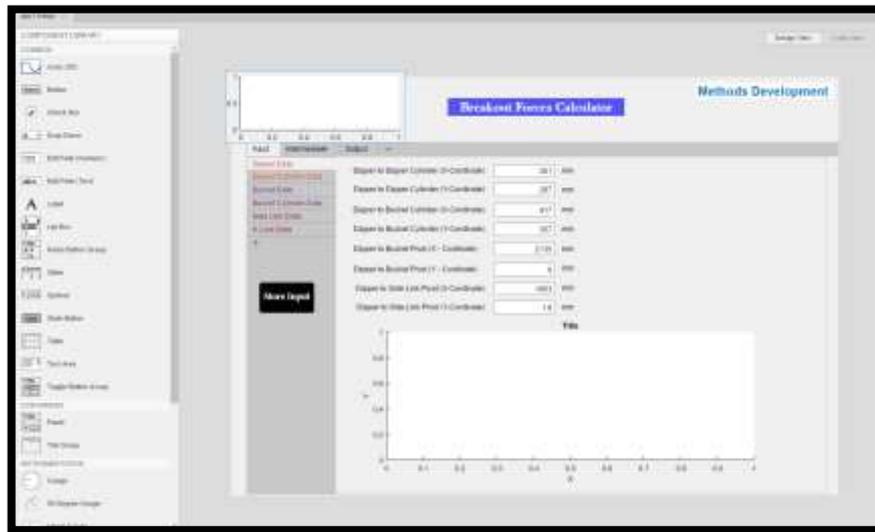


Application Building and Deployment Process

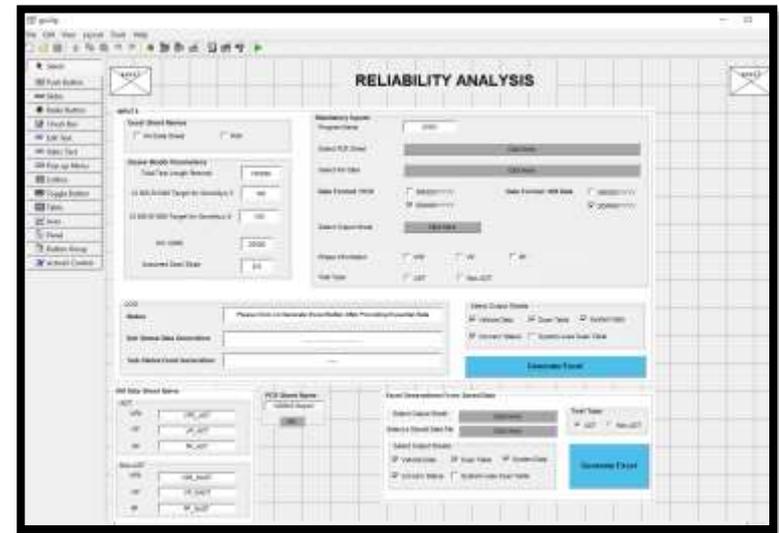


MATLAB Tools for Application building

MATLAB App Designer And Guide



App Designer



Guide

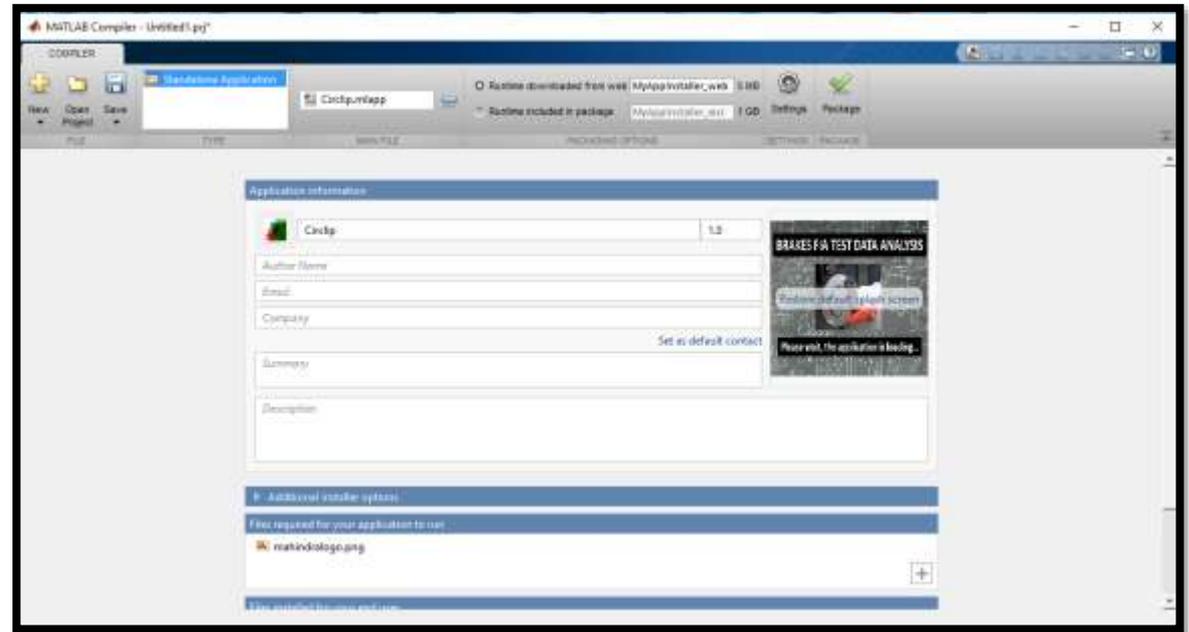
Methods team at MRV create numerous applications using MATLAB's App Designer and GUIDE. The physics model is converted to a mathematical model which is further written into the code for the application in the form of .mlapp and .m files for App Designer and .fig and .m files for MATLAB Guide.



MATLAB Tools for Application Building

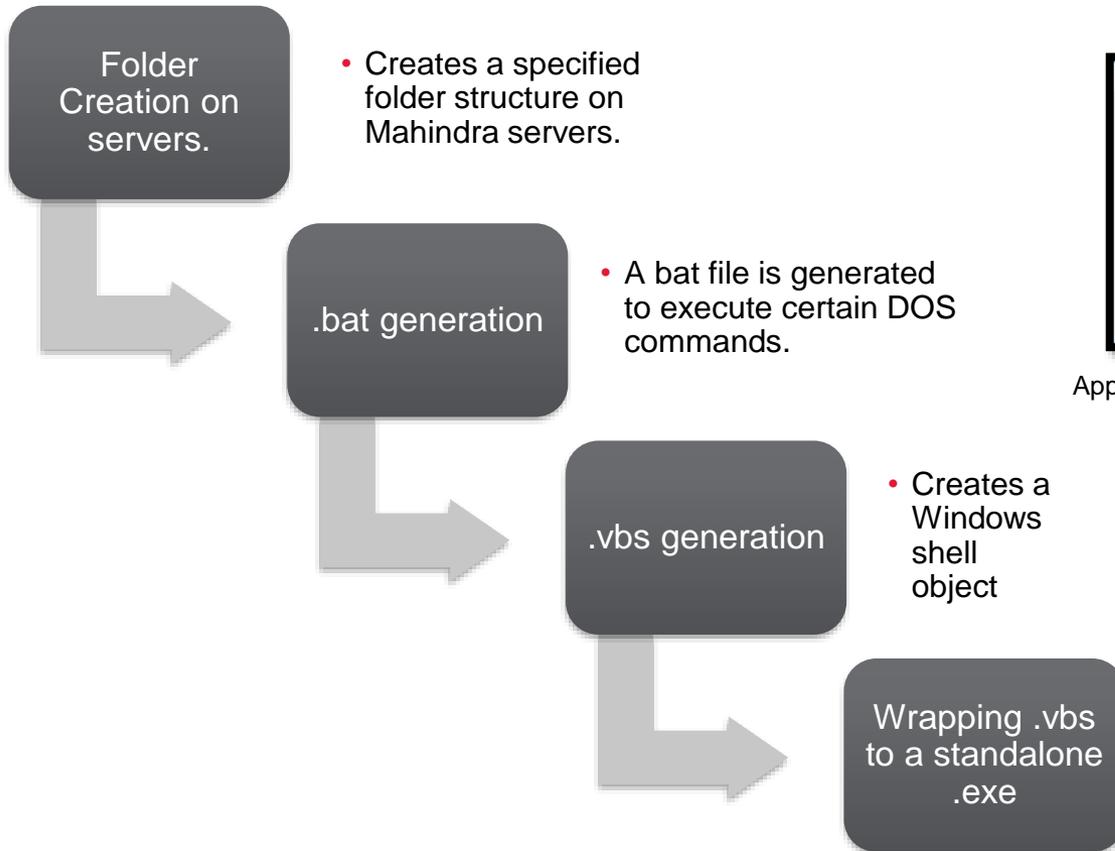
MATLAB Application Compiler

- Packages MATLAB programs for deployment as standalone applications.
- This MATLAB generated .exe is deployed for use within MAHINDRA by a GUI created on MATLAB GUIDE.
- Link the generated EXE to MathApps application link, a secondary EXE file needs to be generated which points to the main EXE file generated through MATLAB compiler.



MATLAB Application Compiler

Application Deployment Process



Application built using Guide for MATLAB Application Deployment



MathApps

Case Study - 1

Vehicle Performance Test Calculation

Performs analysis on sensor data to calculate the performance of the Vehicle in different gears for different tests: IN Gear test and THROUGH Gear test.





VEHICLE PERFORMANCE TEST CALCULATION

Methods Development Group

Inputs: Analysis Output

Gear	Speed Range	Up	Down
1	3-7	1,1,1	7,7,7
2	4-9	2,2,2	8,8,8
3	6-12	3,3,3	9,9,9
4	10-15	4,4,4	10,10,10
5	15-25	5,14,14	11,12,13
6	20-35	15,16,17	18,19,20
7	35-55	21,24,25	22,23,
8	35-55	27,29,	28,30,

In

Through

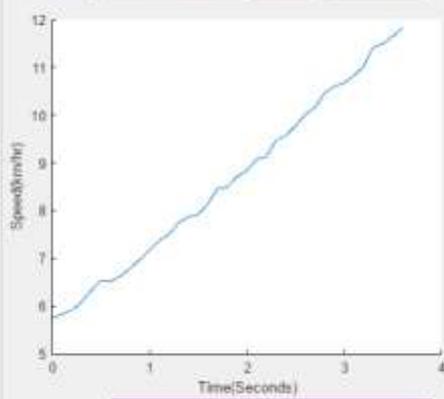
File Number: Time(seconds):

File Number: Time(seconds):

File Number: Time(seconds):

Time(seconds)	Speed(km/hr)	Engine RPM	Distance(m)
0.00	5.74	829.70	162.17
0.10	5.83	873.06	162.34
0.20	5.91	881.55	162.50
0.30	6.07	856.97	162.66
0.40	6.32	835.06	162.84
0.50	6.54	855.18	163.02
0.60	6.52	896.75	163.20
0.70	6.62	990.79	163.38
0.80	6.78	1005.38	163.57
0.90	6.97	999.57	163.76
1.00	7.17	978.56	163.95
1.10	7.37	996.89	164.16
1.20	7.60	1076.85	164.36

File Directory:



Status In Gear analysis complete

Impact: Previously done using Excel, after automating through MATLAB, saves 3-4 hours.





MathApps

Case Study - 2

CAE Material Database

This app offers a centralized Material Database for CAE users allows the user to perform various operations on a list of materials: Search, Compare, Update, Deck Export

CAE MATERIAL DATABASE

Methods Development Group

Linear NonLinear Compare Add Material Generate Deck Delete Record Database Change Record

Database AD FD

Search by:

Young's Modulus

Density

Poisson's Ratio

Yield Strength

FD

Alternating Endurance Limit

Pulsating Endurance Limit

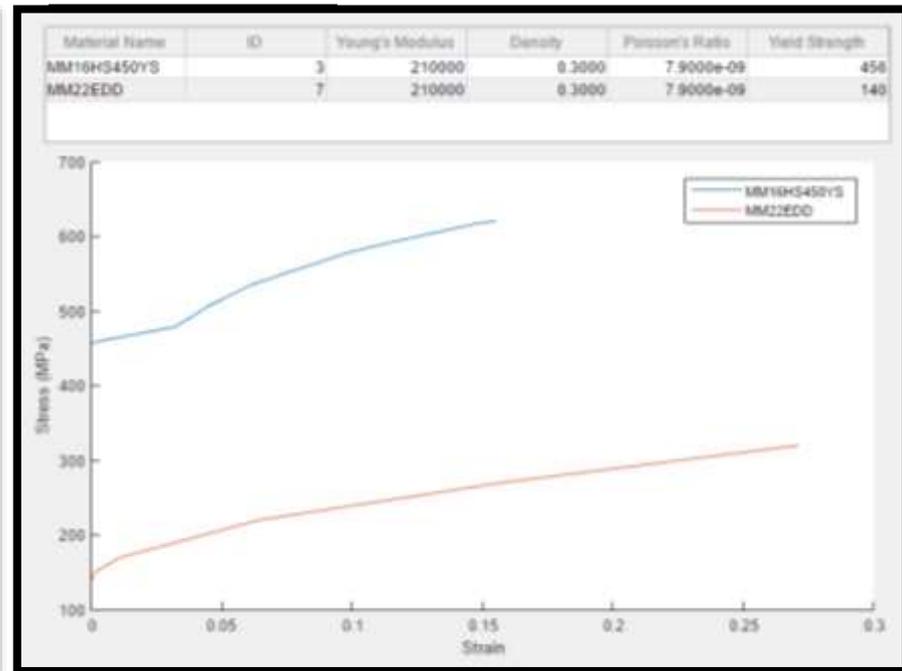
UTS

Percentage Elongation at Failure

Used On Part:

Date Reference:

ID	Material Name	Young's Modulus	Density	Poisson's Ratio	Yield Strength	Type
82	MMQ1 D	210000	7.8000e-08	0.3000	160	Steel
83	MMQ1 DD	210000	7.8000e-08	0.3000	160	Steel
84	MMQ2 EDD	210000	7.8000e-08	0.3000	150	Steel
85	MMQ1 GA	210000	7.8000e-08	0.3000	170	Steel
86	MMQ2 F25	210000	7.8000e-08	0.3000	140	Steel
87	MMQ2 F38	210000	7.8000e-08	0.3000	126	Steel
88	MMQ2 F27	210000	7.8000e-08	0.3000	100	Steel
89	MM11 D	210000	7.8000e-08	0.3000	170	Steel
90	MM11 DD	210000	7.8000e-08	0.3000	170	Steel
91	MM11 DD	210000	7.8000e-08	0.3000	170	Steel
92	MM11 EDD	210000	7.8000e-08	0.3000	170	Steel
93	MM13 330	210000	7.8000e-08	0.3000	205	Steel
94	MM13 360	210000	7.8000e-08	0.3000	230	Steel
95	MM13 510	210000	7.8000e-08	0.3000	350	Steel
96	MM21 F 260	210000	7.8000e-08	0.3000	200	Steel
97	MM21 F 360	210000	7.8000e-08	0.3000	300	Steel
43	DDK 480 M	210000	7.8000e-08	0.3000	400	Steel
45	MM12 410	210000	7.8000e-08	0.3000	200	Steel



Impact: Easy comparison between materials being used in automotive and farm division. Nastran deck can be generated for different materials which can be directly used for simulation.





Case study - 3

Bolt Calculator

An integrated bolt calculator for catering the need of FD-CAE and CAE-PTD.

Bolt and Joint Properties

	Minimum	Maximum	
Direct Torque	18	22	N-m
Angle Tightening	85	95	deg

Coefficient of Friction between

Friction Coefficient Data

	Minimum	Maximum
Threads (mu_n)	0.1	0.14
Bolt Head & Washer/Component	0.1	0.14
Components	0.1	0.14

External Longitudinal Load: 8500 N

External Transverse Load: 15100 N

Vibration Amplitude: 0 mm

Cone Angle (theta): 30 deg

Minimum Outer In-plane Diameter (D): 13.75 mm

Nut Parameters

Nut Outer Diameter: 40 mm

Nut Inner Diameter: 8 mm

Washer Parameters

Inner Diameter of Washer: 8 mm

Outer Diameter of Washer: 15 mm

Thickness of Washer: 4 mm

Bolted Part Parameters

Thickness of Component 1 (t_1): 20.9 mm

Thickness of Component 2 (t_2): 12.56 mm

Bolt Parameters

Major Diameter of Threads (d): 8 mm

Pitch of Threads (p): 1 mm

Length of Shank (L_s): 4.7 mm

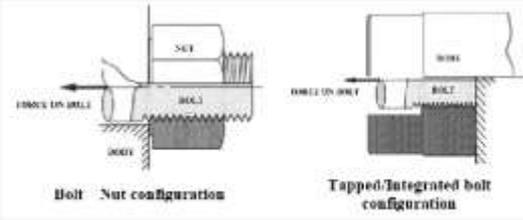
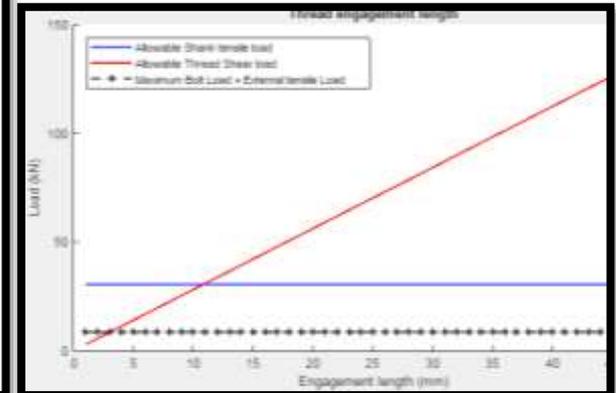
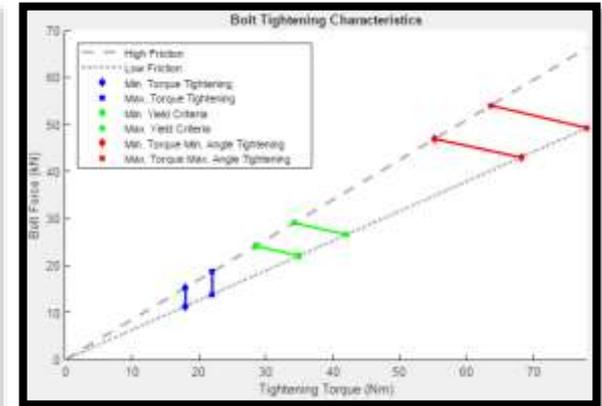
Length of Unengaged Thread (L_uet): 22.5 mm

Length of Engaged Thread (L_et): 12.8 mm

Thread Angle (beta): 60 deg

Inner Contact Diameter of Bolt Head (d_i): 8.25 mm

Outer Contact Diameter of Bolt Head (d_o): 14.8 mm

Impact: Single point for multiple calculations related to Bolts.



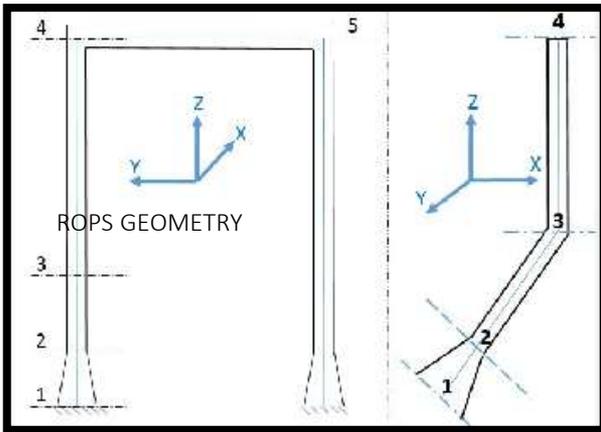

MathApps + MATLAB



Case study - 4

Non-Linear Structure - ROPS

- This tool performs Non-Linear Structural Analysis on a parametric tractor ROPS (for Longitudinal Load Case) according to OECD Code-4.
- The Elasto-plastic material behavior is approximated in the form of a bi-linear stress-strain curve.



- Geometric parameters
- Material Properties
- Vehicle Parameters

Titled Geometry Data

	x (mm)	y (mm)	z (mm)	Height (mm)	Width (mm)	Thickness (mm)
P1	0	0	0	100	50	7
P2	61.5000	0	126.0000	100	50	7
P3	200	0	500	100	50	6
P4	200	0	1300	100	50	6
P5	200	-250	1300	100	50	6

Material Data

Steel

Constraint Data

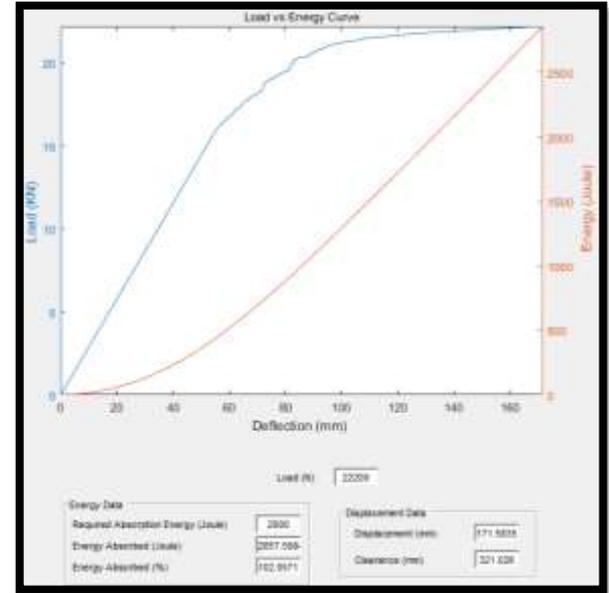
	X	Y	Z
Seat Reference Point	-200	0	0
Rear Seat Point	-1050	0	500
Steering Point	-1050	0	500
Bonnet Point	-1050	0	400

Steering Radius: 50

Allowable Clearance (mm): 0

Tractor Mass (Kg): 2000

Required Longitudinal Deformation Energy (Joule): 1.4 * Tractor Mass



Impact: CAE : 2-3 hours MathApps: 5 minutes





Impact of MATLAB

Without MATLAB	With MATLAB through MathApps
Design calculations not easily accessible to everyone	Easy access to designers throughout the organization
Formulas being used varies which increases errors	Maintains uniformity of the calculations
Time Consuming	Processes and calculations are automated: Saves time

Excel

Female thread shear strength	T_f	260.00	MPa
Bolt shear strength	T_b	600.00	MPa
External tensile load	L_k	28	kN
External transverse Load	L_y	5	kN
Applied Torque	T	0	Nm
Distance from the torque axis to bolt axis	x	1	mm
Vibration amplitude	a	0	mm
Output parameters	Symbol	Value	Unit
Bolt preload	F	51.886	kN
Tightening torque	T		N-m
Tensile stress due to preload	σ	615.7	MPa
Critical slippage	S_{cr}	0.96	mm
Shear stress	τ	59.33	MPa
Bolt shearing		No	
Bolt joint loosening		No	
Total tensile stress (Preload+external load)	σ_t	666.4	MPa
Min length of thread engagement	L_{er}	12.5	mm
Distance between bolts fro leak proof joint		40.7	mm
Crushing Stress		152.9	
Total stress		674.31	MPa
Total stress to Bolt yield strength ratio		75%	
Calculations	Symbol	Value	Unit

Calculator Comparison Instruction Sheet1 +

MATLAB

Bolt and Joint Properties

Direct Torque: Minimum 18, Maximum 22 N-m
 Angle Tightening: 80, 90 deg
 Coefficient of Friction between: **Friction Coefficient Only**
 Threads (m_{1,2}): 0.5, 0.14
 Bolt Head & Washer Component: 0.5, 0.14
 Components: 0.5, 0.14
 External Longitudinal Load: 1000 N
 External Transverse Load: 1000 N
 Vibration Amplitude: 0 mm
 Cone Angle (theta): 30 deg
 Minimum Outer Insipare Diameter (D): 13.75 mm

Nut Parameters
 Nut Outer Diameter: 40 mm
 Nut Inner Diameter: 8 mm

Washer Parameters
 Inner Diameter of Washer: 1 mm
 Outer Diameter of Washer: 17 mm
 Thickness of Washer: 1 mm

Bolled Part Parameters
 Thickness of Component 1 (L₁): 20.8 mm
 Thickness of Component 2 (L₂): 12.58 mm

Bolt Parameters
 Major Diameter of Threads (d): 8 mm
 Pitch of Threads (p): 1 mm
 Length of Shank (L_s): 6.7 mm
 Length of Unengaged Thread (L_{uneng}): 22.8 mm
 Length of Engaged Thread (L_{eng}): 12.8 mm
 Thread Angle (beta): 60 deg
 Inner Contact Diameter of Bolt Head (d_i): 6.25 mm
 Outer Contact Diameter of Bolt Head (d_o): 14.8 mm

Diagrams: Bolt - No configuration, Tapped/Drilled hole configuration



Current Issues

- The correct version of Matlab Runtime should be installed in the user's machine to run the MATLAB exe
- Applications created in different versions would require different versions of runtime requiring the user to have all the Matlab Compiler Runtimes (MCRs) installed
- Though the process is automated here at MRV, it is only for a single version of MCR
- Across different Mahindra divisions: Mahindra Trucks and Buses in Pune, Mahindra Electric in Bangalore and Swaraj in Mohali it becomes a tedious task to ensure runtime installation in users' machines and always requires the local IT to intervene for the installation

What Next?

Projects

- 1D mechanical system modeling using Simscape
- Enhancing Data Analytics capabilities using Deep Learning and Computer Vision toolbox

MATLAB's Web Apps

- Web apps are MATLAB apps that can run in a web browser
- Hosted using MATLAB Web App Server. Each web app has a unique URL and can be accessed from a web browser using HTTP or HTTPS protocols
- Web apps are designed to run only within a trusted intranet environment, not in the open Internet
- Apps and components can be shared as both standalone desktop applications and as software components to integrate with web and enterprise applications



Key Takeaways

- MATLAB GUIDE/App designer helps create customize UI based on the application requirements
- Using the Compiler we are able to create a standalone MATLAB application that doesn't require MATLAB license
- The MATLAB application is integrated with MathApps, which is a unified web portal covering –MATLAB and multiple platforms catering to the needs of all the system designers
- MathApps also acts as a repository for all the Knowledge Management Documents
- User Statistics helps gauge impact of the developed applications



MathApps

QUESTIONS?

Thank you

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