A Comprehensive CAE Analysis of Heavy Commercial Vehicle (HCV) Drive Axles Using HYPERWORKS®

TML Drivelines Ltd

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COMPANY PROFILE

TML Drivelines Ltd.

- TML Drivelines Ltd. is a fully owned subsidiary of Tata Motors Ltd.
- The company has emerged as a Total Drivelines Solution Provider with specialist focus on development and supply of Axles & Gearboxes for TML's Medium & Heavy Commercial Vehicle (M&HCV) Range.
- TML Drivelines Ltd. is currently the market leader in drivelines business in India with an installed capacity of over 5,00,000 Axles & 1,80,000 Transmissions per annum. The company's product range includes:

**Axles:**
- Drive & Non-Drive Front Steer Axles
- Drive & Non-Drive Rear Axles including Single and Tandem with & without hub reduction.
- Non Drive Trailer Axles

**Transmissions:**
- Automotive Transmissions – 5 speed, 6 speed and 9 speed
- Automotive Auxiliary Gearboxes
The company has state of the art manufacturing facilities. It has continuously upgraded & diversified its product offerings through improvement in technology and manufacturing processes.

- TML Drivelines Engineering Research Centre (R&D), aims to:
  - Design & develop new aggregates to meet rapidly expanding (and changing) Heavy and Medium Commercial Vehicle markets
  - Widen Portfolio to Meet Emerging Defense Requirements
  - Develop new Drivelines technology
INTRODUCTION

- The Rear Drive Axle is a critical Driveline aggregate, bearing the majority vehicle weight as well as houses the entire transmission components.

- The service life of the Axle depends on the successful performance of its Housing, Shafts, Drive heads and other major and minor components.

- TML Drivelines Ltd., maintains high quality standards in the design and manufacturing stages of axles in order serve its customers in the highest priority.
FE validation of the entire structural aggregates has become a necessity in the wake of the on-going “Quality Revolution” in the Automotive industry.

➢ TMLDL ERC conducts a comprehensive validation of its Drive Axles using HYPERWORKS®, the dedicated FE Analysis Software.
APPLICATION OF HYPERWORKS IN AXLE DESIGN

HYPERWORKS® powers the designers to validate the product design and the assembly process, by constantly evaluating the product to improve quality, reduce cost and to deliver optimal solutions within stipulated time frame.

**Applications of HYPERWORKS® in HCV Drive Axle CAE validation**

- HYPERWORKS®, through its exhaustive FEA capabilities helps the designer to optimize the axle design ensuring the design quality and helps conclude the per part cost.
- It enables the successful simulation of the “Road Reality” at the design stage itself, reducing the occurrence of field failures and thereby maintain the low life cycle cost for the customers.
Axle Housing - **Structural Analysis**

- The axle housing is analyzed according to the *RLD* data obtained by vehicle testing.
- The impact loads (g multiples) and corresponding moments generated due to various road conditions like potholes, bumps etc., are applied to the five different *hard-points* identified on the axle housing.

![CAD model of Axle with suspension brackets-hard-points encircled](image)

(1,2,3,4,5 Hard Points for RLD Loads on Suspension Mountings)

![FE model of Axle Housing with Loads and Boundary conditions- with Reactions from track points](image)
Axle Housing - **Structural Analysis**

- The static analysis of the axle housing helps the designer to confirm the design is within the allowable deflections and working stresses.
- The finalized design is further analyzed for the fatigue life estimation.
Axle Housing - Fatigue Life Estimation

- Axle Housing fatigue simulation results shows good correlation with the Rig testing results in terms of crack initiation and failure life.
Induction Hardened RA Shafts- *Torsional Fatigue Analysis*

CAD Model of RA Shaft

*Cut section of the RA Shaft showing the hardening depth*

FE Model of the Induction Hardened shaft with Torsional loads and boundary Conditions

HYPERWORKS® permits the realistic modelling of the Hardened Zones and analyzing the shaft for torsional fatigue with assigning different S-N curves for the discrete Hardness values.
Cut section of the Induction Hardened Shaft FE Model - The layered modelling of discrete hardness zones done in HYPERMESH with S-N curves assigned as per the hardness values
Induction Hardened RA Shafts- Torsional Fatigue Analysis

The Torsional test simulation in HYPERWORKS, provides the stresses induced in the axle shaft and the expected life under repeated loading.
Developing an optimum Design of CW-P with teeth contact pattern in center of the face for better performance & enhanced life needed better strategy.

Traditional Crown wheel - Pinion design practice neglects the effect of the elastic deflections of the Carrier Housing Casting, Differential case & cover and bearings under Load. Therefore, the estimation of gear teeth contact pattern doesn’t include the CW-P misalignments which is unrealistic.

TML Drivelines Ltd. utilizes the potential of HYPERWORKS in FE modelling of the housings and provides the extracted stiffness matrix to the Transmission design software Romax Designer, for the calculation of exact misalignment values of CW-P based on given torque.
Drive-Head Analysis - Effect of Housing Stiffness on Gear Contact

- The structural parts of the axle drive-head including Carrier housing, Plummer blocks & Differential case was meshed using 3D tetrahedral elements.

- 1D elements were used to model the hardware connecting various parts.

- The FE Model was constrained as per the assembly for proper calculation of the stiffness matrix.

- Optistruct extracts the stiffness matrix from the FE model at the nodes in the bearing locating area in the housings.
Drive-Head Analysis - Effect of Housing Stiffness on Gear Contact

Calculated misalignment values with housing stiffness effect

Contact shifted towards the tooth tip
Drive-Head Analysis - **Effect of Housing Stiffness on Gear Contact**

Deflections and stress induced in the carrier housing at a peak torque of 12000 Nm on the pinion gear

- \( \Delta \varepsilon = 1.022 \text{ mrad} \)
- \( \Delta = 292.09 \mu \text{m} \)
- \( \Delta = 671.18 \mu \text{m} \)

Calculated misalignment values with redesigned Housing (Romax Designer)

Newly added ribs

Redesigned carrier housing to increase stiffness

Optimized CW-P contact pattern incorporating the deflections of the new housing design
Analysis of Knuckle Assy- Assembly Fit Simulation

Live Front Axle- CAD Model

- 36µ clearance
- 50µ interference
- 13µ clearance

INSET: KNUCKLE ASSEMBLY

Fits Defined in the Knuckle Assembly

2014 India ATCx Multiphysics
CASE STUDY
Analysis of Knuckle Assy- Assembly Fit Simulation

- HYPERWORKS enables the simulation of assembly Fits (Clearance and Interference) in the nonlinear contact property definition.

- The Hole and Shaft portions are meshed to the nominal dimensions in HYPEREMESH. Further, Contact Surfaces are defined between the regions of interest and proper Contact Interfaces are generated with between the slave and master contact surfaces.

- Optistruct solver supports the Assembly Fits thru’ the contact interaction definitions according to their Fit nature.

Meshed model of knuckle assembly with contacts defined

Displacement plot of knuckle assembly
Thus, HYPERWORKS helps in simulating the realistic contact condition in the knuckle assembly joints by introducing the fits in the model.
BENEFITS SUMMARY

- HYPERWORKS has proved to be a powerful tool for the virtual validation of the following Drive axle structural components:

  - **Axle Housing Design:** Hyperworks has helped us in designing the axle structural housing with required structural rigidity, taking into consideration of the expected service life & the life estimates are in Good Correlation with Physical Rig test results.

  - **Axle Shaft Design:** Hyperworks capability to model the Layered Hardness of Axle Shaft & assigning different SN Curves at various layers helps the designer to analyze the Torsional fatigue life which is possible to study only in Physical Testing.

  - **Housing Stiffness Analysis:** The flexibility of Hyperworks to interface with the & Transmission validation Software (Romax Designer) helps to design the drive head with adequate stiffness for torque transmission in the conceptual stage which was a limitation due to the lack of single software tool supporting both structural and transmission validation. This, strategy has proved to improve the service life of the Crown wheel and pinion and there by reduce the life cycle cost for the rear axle.

  - **Knuckle Assy:** The nonlinear simulation capability of Optistruct has enabled the designers to successfully simulate the assembly fits in the steering knuckle assembly, which yields the realistic picture of stresses generated in the corresponding parts under, service loads.

- Overall, HYPERWORKS, provides a complete solution for the comprehensive CAE validation for the structural components in the Drive axles, which helps the design team to foresee the design constraints and work towards the established quality standards of the company and thereby serving the customer the best by providing low life cycle cost.
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