CFD thermal simulation of wheel rim using ACUSOLVE

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### Introduction to Wheels India

<table>
<thead>
<tr>
<th>Established</th>
<th>1962</th>
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</thead>
<tbody>
<tr>
<td>Turnover (last year)</td>
<td>$450 Million; Exports 14%</td>
</tr>
<tr>
<td>Products</td>
<td>Wheels &amp; Air suspension systems, Structural Components for Power and Windmill Sector</td>
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<tr>
<td>Segments</td>
<td>Cars / UVs, Commercial Vehicles, Tractors &amp; Off – Highway and Power Sector</td>
</tr>
<tr>
<td>Engineering Capabilities</td>
<td>Design, Development &amp; Testing</td>
</tr>
<tr>
<td>Manufacturing Sites</td>
<td>6</td>
</tr>
<tr>
<td>Certifications</td>
<td>ISO-TS 16949, ISO 14001, TPM Certified (Padi), CAT SQEP Gold Certification in 2012, Ford Q1 certified - Padi &amp; WTAD MM Nagar</td>
</tr>
</tbody>
</table>
MANUFACTURING FACILITIES

CUSTOMER FOCUS… OUR PRIORITY

PANT NAGAR
RAMPUR
BAWAL
SRIPERUMBUDUR
PUNE
PADI

CUSTOMER CENTRIC

Strategically located Plants
Warehouse Delivery
JIT Delivery
Flexible Packaging
Fast Response

6 BUSINESS INTERESTS & 13 PLANT LOCATIONS

Wheel - six plants
Air Suspension - one plant
Wheel & tyre - three plants
Assembly
Heavy Engineering - one plant
Energy Equipment
Parts - one plant
Fabrication - one plant

YOU NAME IT, WE MAKE IT!
Wheels India - Global Supplies

YOU NAME IT, WE MAKE IT!
Wheels product range and customers

**Commercial Vehicles**

![Commercial Vehicles Image]

**Cars & UVs**

![Cars & UVs Image]

**Tractors & Single Piece**

![Tractors & Single Piece Image]

**Construction & Earth Mover**

![Construction & Earth Mover Image]
Wheels India - R&D structure and Our Approach in Evaluating Reliable Design

R&D structure

Reliable design

Numerical Assessment

Design for Manufacturing

Experience from Service

Experimental Verification

YOU NAME IT, WE MAKE IT!
Mandatory test requirements

- Cornering fatigue test
- Radial fatigue test
- Biaxial test
- Computational fluid dynamics
- Rigidity test
- NVH

➢ For first time right we require all above test to be simulated in the design/concept stage.
Product description

Commercial vehicle wheel

- VALVE SLOT
- VENT HOLE
- WHEEL BORE
- BOLT HOLE
Vent hole shapes

1. CIRCULAR
2. ELLIPTICAL
3. D-TYPE VENT
4. ELLIPTICAL
5. D-TYPE
**Problem definition**

There could be various levels of problems that may arise due to heat generation resulting from braking and some of them are:

1. Early tire wear and reduction in tire life
2. Air valve heat damage and air leak issues
3. Frequent puncture problems
4. Failure of other mating components and other heat initiated failures
REGULAR WHEEL - INTRODUCTION

CONSTRUCTION OF REGULAR WHEEL

CROSS SECTION OF REGULAR WHEEL
THE DISC GUTTER WHEEL - INTRODUCTION

- Increased clearance (as shown) facilitates faster cooling
- Reduces risk of brake drum fouling with wheel
- Valve clearance notch avoided
Scope for CFD analysis

• Transient conjugate heat transfer analysis of brake drum and rim is done to predict cooling period.
• Two models of different rim geometry are compared for cooling performance.
• Two types of approaches are studied
  ➢ Approach 1: wheel rotation is considered and air flow with vehicle speed (80kmph: 22.22m/s) is modelled.
  ➢ Approach 2: vehicle is assumed to be coming to rest and external air flow velocities (0.5 m/s) are considered.
• Initially flow analysis is done as steady state. This flow field is used while calculating transient temperatures.
• Both models are cooled from initial drum temperature of 100°C and 300°C.
• It is found that regular wheel cools slightly faster than disc gutter wheel when Approach 1 is used.
• It is found that disc gutter wheel cools slightly faster than regular wheel when Approach 2 is used.
FINITE ELEMENT MODEL FOR ANALYSIS - REGULAR WHEEL

- Lockring
- Rim base
- Disc
- Brake drum

Vent hole shape

YOU NAME IT, WE MAKE IT!
FINITE ELEMENT MODEL FOR ANALYSIS - DISC GUTTER WHEEL

Lockring

Rim base

Disc

Brake drum

Vent hole shape
Finite Element Model for Analysis

Regular wheel

Disc gutter wheel

In both cases drum is similar but rim hole shape and structure is slightly different. Disc gutter wheel has smaller hole width compared to regular wheel.
ASSUMPTIONS

• In this benchmark, objective is to identify which model cools faster.
• So to make comparison, same type of flow and thermal initial conditions are applied to both cases.
• The cooling effect is because of the air flow through ventilation holes provided on rim and passage between drum rim gap.
• A steady state flow analysis is done with same inlet air velocity for both cases. This will give the flow field in drum-rim gap.
• A transient thermal analysis is done with 100°C and 300°C initial temperature of drum. Both cases are analysed with constant initial temperature of drum at 100°C and 300°C their cooling periods are compared.
• Two temperature cases are run to validate model.
BOUNDARY CONDITIONS FOR THE SYSTEM - APPROACH 1

Inlet Velocity = 80 km/h = 22.22 m/s

Domain Type - Fluid

Wheel Assembly - Solid

OUTLET

INLET

7.5 m

22.5 m

7.5 m

7.5 m
BOUNDARY CONDITIONS FOR THE MODEL

Approach 1:

- Inlet air Velocity = 22.2222 m/s (80 kmph vehicle speed)
- Wheel/drum/rim rpm = 385.8 rpm (40.4 rad/s)
- Initial temperature of drum = 100°C and 300°C
- Inlet air temperature = 25°C
MESH - APPROACH 1

Nodes ~ 2.5 million
Elements ~ 15 million
Results: Approach 1

Contours of velocity magnitude with local scale

REGULAR WHEEL

DISC GUTTER WHEEL

Regular wheel has higher velocities in channel through rim and drum.
Results: Approach 1

Contours of surface film coefficient with local scale

Regular wheel has higher surface film coefficient. Indicating higher heat transfer.
Results : Approach 1

Contours of surface film coefficient with same scale

On same scale you can see that surface film coefficient is higher for regular wheel.
RESULTS - APPROACH 1: COOLING CURVE 100°C

- Graph shows that regular wheel cools faster than disc gutter wheel.
- In second plot Delta T is the temperature difference between two cases at particular time.
RESULTS - APPROACH 1 : COOLING CURVE 300°C

- Graph shows that regular wheel cools faster than disc gutter wheel.
- Compared to earlier slide with cooling from 100°C the delta T increases for cooling from higher temperature.
BOUNDARY CONDITIONS FOR THE SYSTEM - APPROACH 2

- Approach two is good to study the effect of air flow in clearance between rim and drum.
- In this approach air with very small velocity passes through a stationary rim drum assembly.

Air Inlet = 0.5 m/s

Air Outlet = 0 Pa gauge pressure (ambient pressure)

Rim-drum assembly without any rotation.

- The domain can be kept same as Approach 1 and change direction but it is not recommended as in Approach 2 we are focusing on flow in gap between rim and drum only. Outer domain is of not important hence its modelling is not necessary. It will unnecessarily increase element count.
BOUNDARY CONDITIONS FOR THE MODEL

Approach 2:

- Inlet air Velocity = 0.5 m/s
- Initial temperature of drum = 100°C and 300°C
- Inlet air temperature = 25°C
Nodes ~ 2 million
Elements ~ 10 million
Results: Approach 2

Contours of velocity magnitude with local scale

Disc gutter wheel has higher velocities in channel through rim and drum.
Results: Approach 2

Contours of surface film coefficient with local scale

REGULAR WHEEL

Disc gutter wheel has higher surface film coefficient. Indicating higher heat transfer
Results: Approach 2

Contours of surface film coefficient with same scale

- On same scale you can see that surface film coefficient is higher for disc gutter wheel.
RESULTS - APPROACH 2: COOLING CURVE 100°C

- Graph shows that disc gutter wheel cools faster than regular wheel.
- In second plot Delta T is the temperature difference between two cases at particular time.
RESULTS - APPROACH 2 : COOLING CURVE 300°C

- Graph shows that disc gutter wheel cools faster than regular wheel.
- Compared to earlier slide with cooling from 100°C the delta T increases for cooling from higher temperature.
RESULTS - APPROACH 2: with higher air flow speed (Comparison)

Air Inlet = 0.5 m/s
And 22.222 m/s

Air Outlet = 0 Pa
gauge pressure
(ambient pressure)

Rim-drum assembly
without any rotation.

Inlet velocity 22.222 m/s

Temperature (°C)

Time (seconds)

Regular wheel

Gutter wheel
FIELD RESULTS

Graph showing the Heat transfer coefficient as a function of air velocity for both regular and Disc gutter wheel

Graph showing temperature mapping study in Wheel at Highway service

Graph showing temperature mapping study in Brake drum at Highway service

Graph showing temperature mapping study in Tire at Highway service
FIELD RESULTS

Graph showing temperature mapping study in Wheel at Uphill service

Graph showing temperature mapping study in Tire at Uphill service

Graph showing temperature mapping study in Brake drum at Downhill service

Graph showing temperature mapping study in Wheel at Downhill service
• Field study results show disc gutter wheel cools faster than regular wheel, CFD results also show the same
THANK YOU