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Challenges Associated with Mounting System Design for Electric Vehicle Applications

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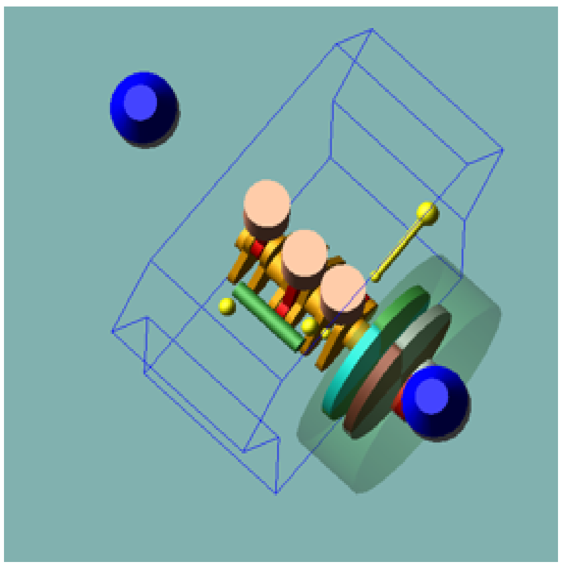
Introduction

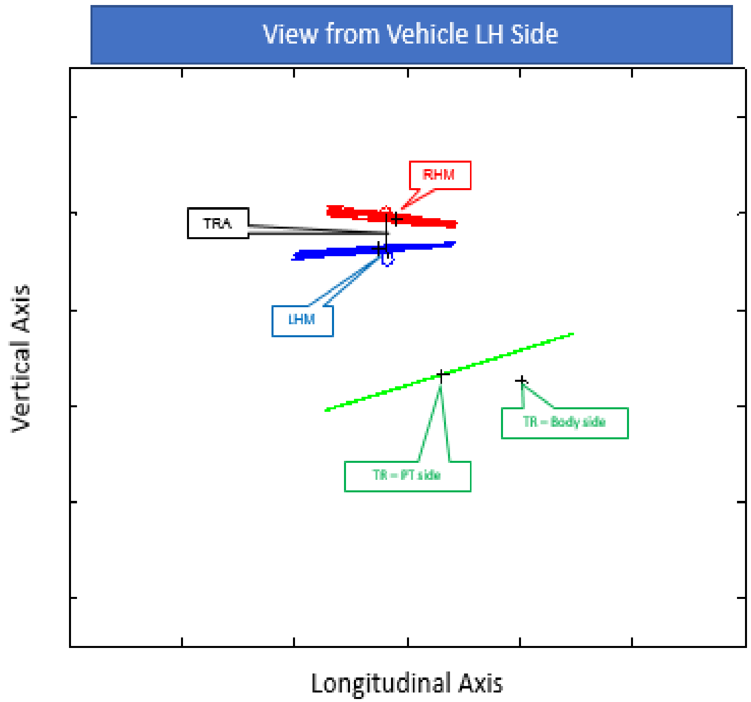
- A robust process for specifying mounting system for Internal Combustion Engine (ICE) powertrains has been established through decades of work and countless applications
- When faced with the task of designing mounting systems for Electric Vehicle (EV) powertrains, engineers may be tempted to replicate the same approach
- However, some key differences between the two types of powertrain suggest that this may not lead to the optimum solution
- Starting with a review of ICE powertrain mounting system requirements, this presentation will explain the differences for EV powertrain mounting system requirements, the necessary shift in priorities, and the associated new challenges

Contents

Review of ICE Powertrain Mounting System Requirements

- Idle and low speed isolation (reduced masking noise)
  - Mostly torque recoil (rotation approximately about TRA)
  - Design focuses on this aspect





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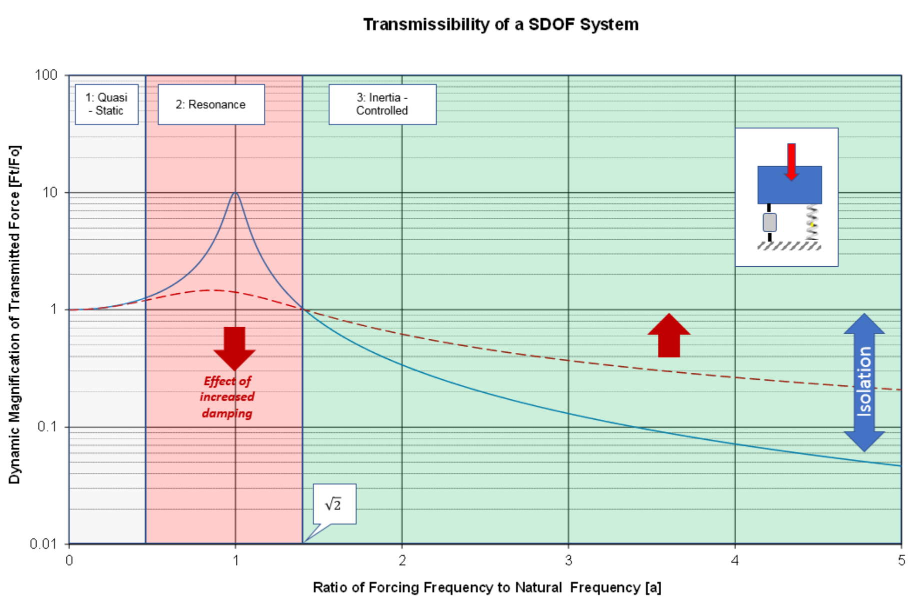
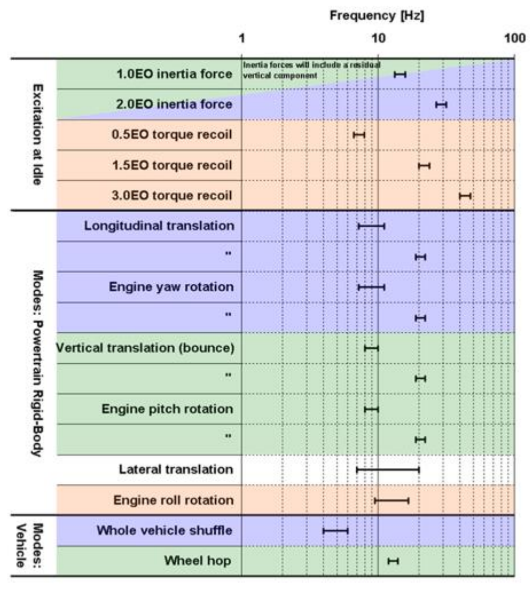
  - Away form excitation (operation in inertia controlled region)
  - Modal mapping and clean shapes





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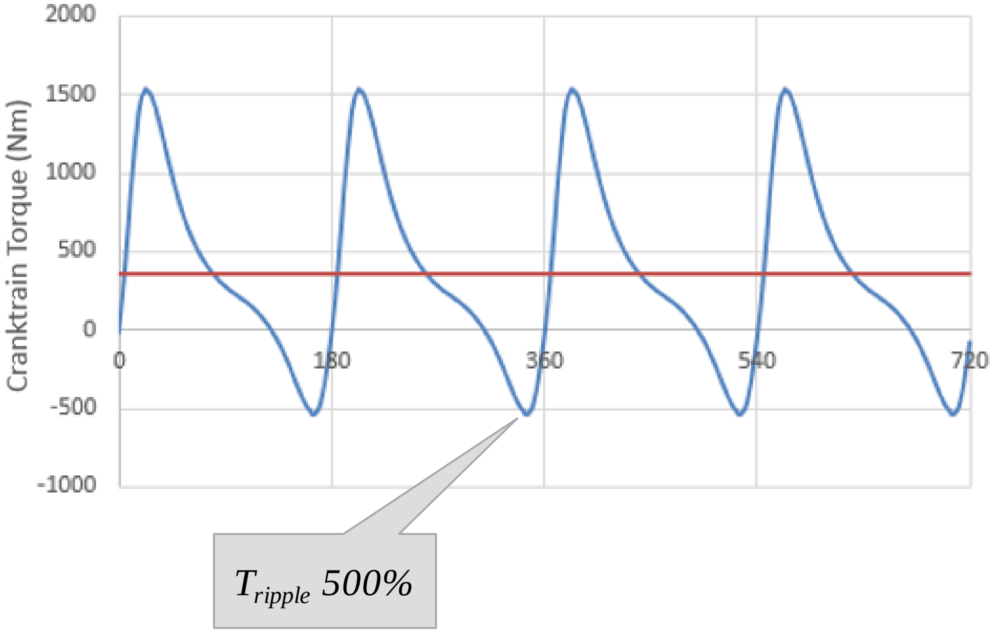
- Smooth engine shut-down and start-up performance
- **Ideally, different tasks should be allocated to different mount stiffness directions, (tuning independently minimises compromises)**

Powertrain Configuration	Static Weight Direction	Torque Reaction Direction	Low Speed Isolation Direction
TRA Transverse	Vertical	Longitudinal	Longitudinal
Non-TRA Transverse	Vertical	Vertical	Vertical
Longitudinal	Vertical	Vertical	Vertical / Transverse

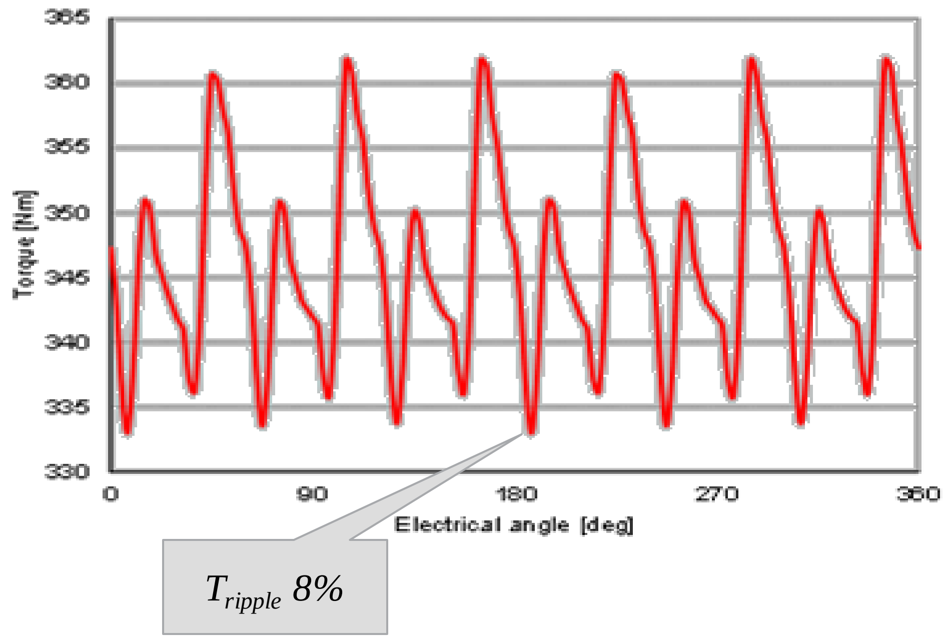
Contents

EV Powertrain Mounting System Requirements
Torque Fluctuations

- ICE Powertrain



- EV Powertrain



$$T_{ripple} = \frac{T_{max} - T_{min}}{T_{mean}} \cdot 100 \qquad [\%]$$

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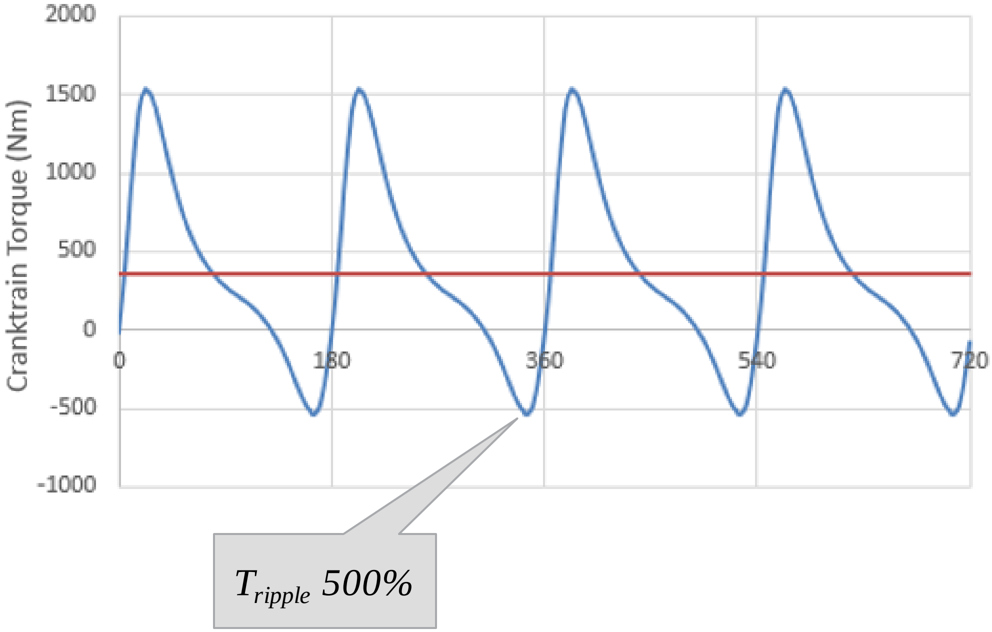

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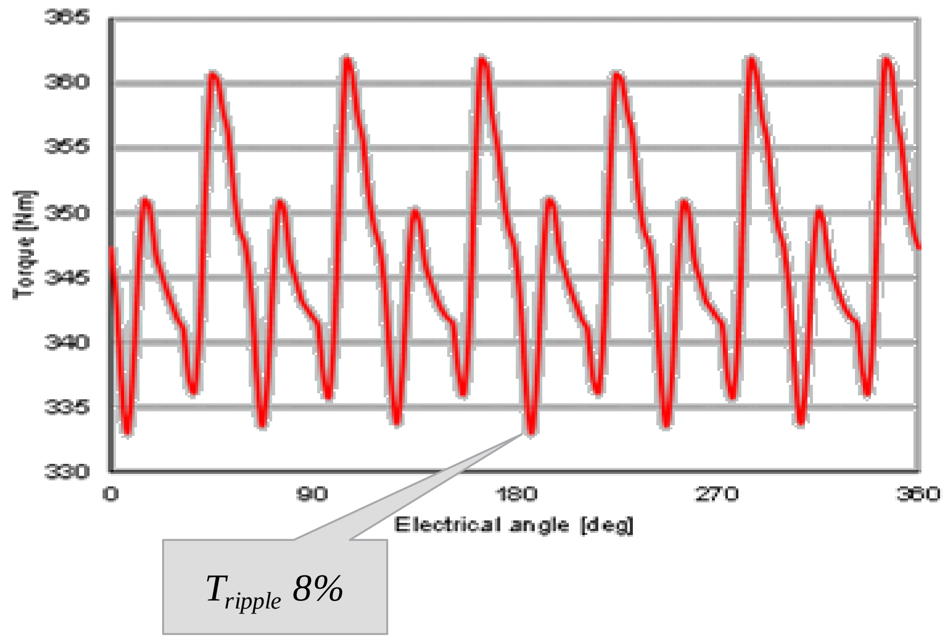

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ICE	10^3 Nm	10^1 Kg.m^2	10^2 rad/s^2	2 EO is 50 Hz	0.1 mm
EV	10^1 Nm	10^0 Kg.m^2	10^1 rad/s^2	6 MO is 150 Hz	0.001 mm

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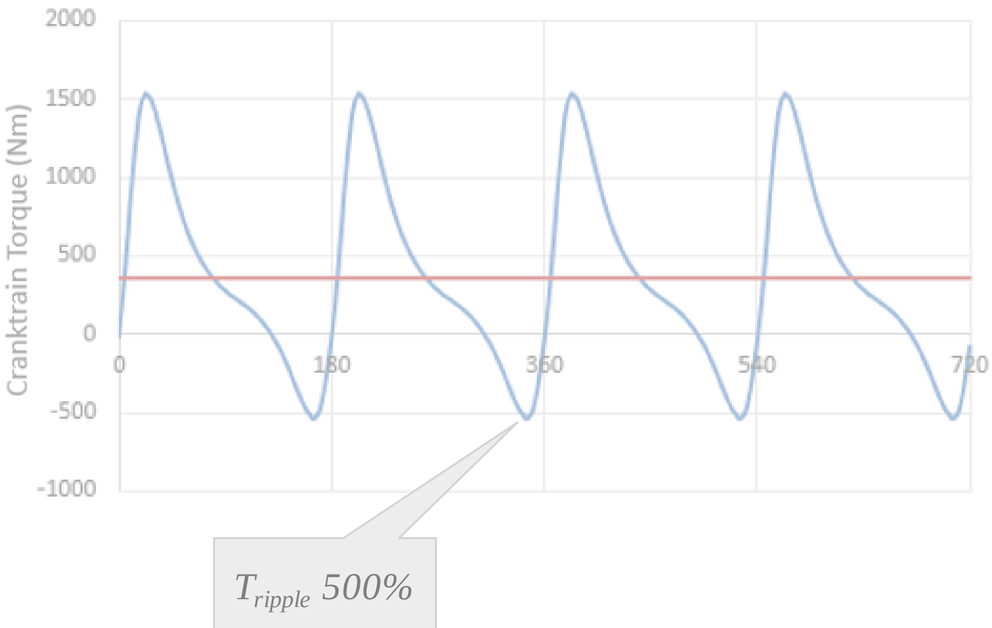

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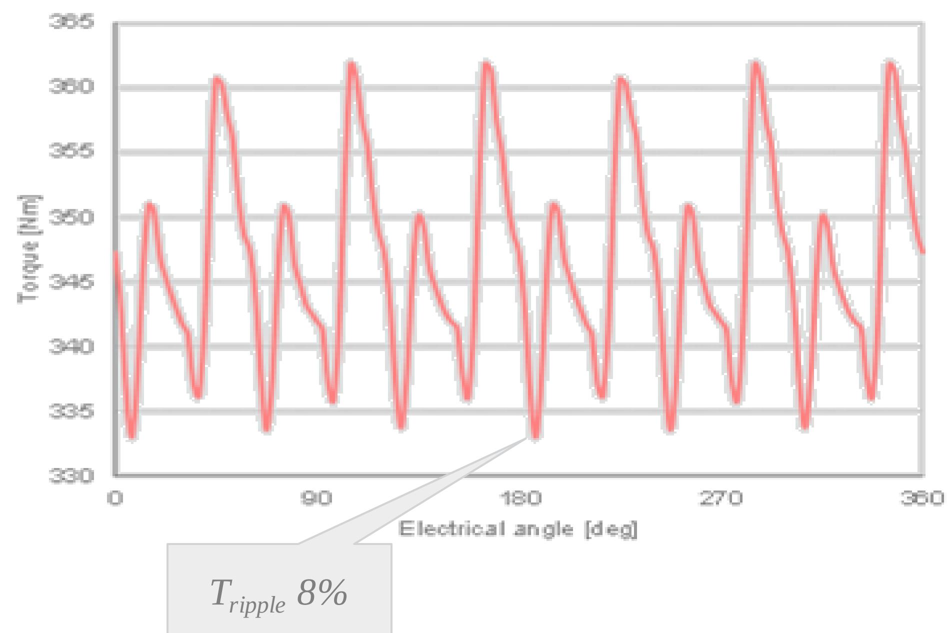

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- **The importance of torque recoil excitation is much lower in electric powertrains**

EV Powertrain Mounting System Requirements
Modal Requirement

- EVs do not idle – rigid body modes are always excited during stop-start driving
  - Torque ripple excitation (high motor order)
  - Other mechanical sources (imbalance, ancillaries...)

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- **Torque reaction capability should become an important priority for the EV powertrain mounting system layout definition**
  - **Layout different from ICE's optimum TRA powertrain mounting system**
  - **EV symmetry can help alignment of TRA and SRA**
- **New modal strategies and targets can be explored**

EV Powertrain Mounting System Requirements
Frequency of Excitation

- EV powertrains have higher frequency excitation than ICE powertrains, because of both higher speed and higher motor order excitation
  - Fundamental powertrain flexible modes can be excited
  - EV powertrains cannot, in principle, be considered a rigid body (which is true in ICE powertrains)

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- **Possible approaches to overcome this problem include**
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  - **Taking care of flexibility in the designs – minimum mount bracket length maximum attachment point stiffness etc.**
  - **Using information from existing similar powertrains**

EV Powertrain Mounting System Requirements
Mount Behaviour

- Mounts are usually modelled as ideal springs
  - But they have mass and elasticity, hence will exhibit some resonant behaviour
  - In ICE powertrains this is typically above engine main excitation, but in EV powertrains this may not be so

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- **The availability of high frequency mount dynamic stiffness data (typically up to 200 Hz only for ICE applications) is important for EV powertrains**
  - **Acquiring these data poses a number of important challenges and is currently the subject of study**
- **An alternative approach for secondary ride shake control is recommended for EV applications**
  - **Optimisation of the vehicle modal map**
  - **Do not focus on pure dampening of powertrain resonances**

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Conclusion

Powertrain Type	Torque Recoil Isolation	Modal Tuning	Torque Reaction Capability	Flexible Behaviour
Internal Combustion Engine	High	Medium	Medium	Low
Electric Machine	Low	Medium High	High	High

Conclusion
A process used for ICE powertrain mounting system design can be employed for electric vehicles but a shift in focus is required

Powertrain Type	Torque Recoil Isolation	Modal Tuning	Torque Reaction Capability	Flexible Behaviour
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- **Prioritise modal tuning and torque reaction capability**
- **Account for flexible behaviour**
  - **Softest possible mount**
  - **Stiff attachment points and short brackets**
  - **Further research work aimed at developing more efficient techniques for coping with the high frequency issues required**
- **De-emphasise isolation of torque recoil vibration**