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Novi, Michigan

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Developing Drivetrain Robustness for Small Engine Testing

Presented by

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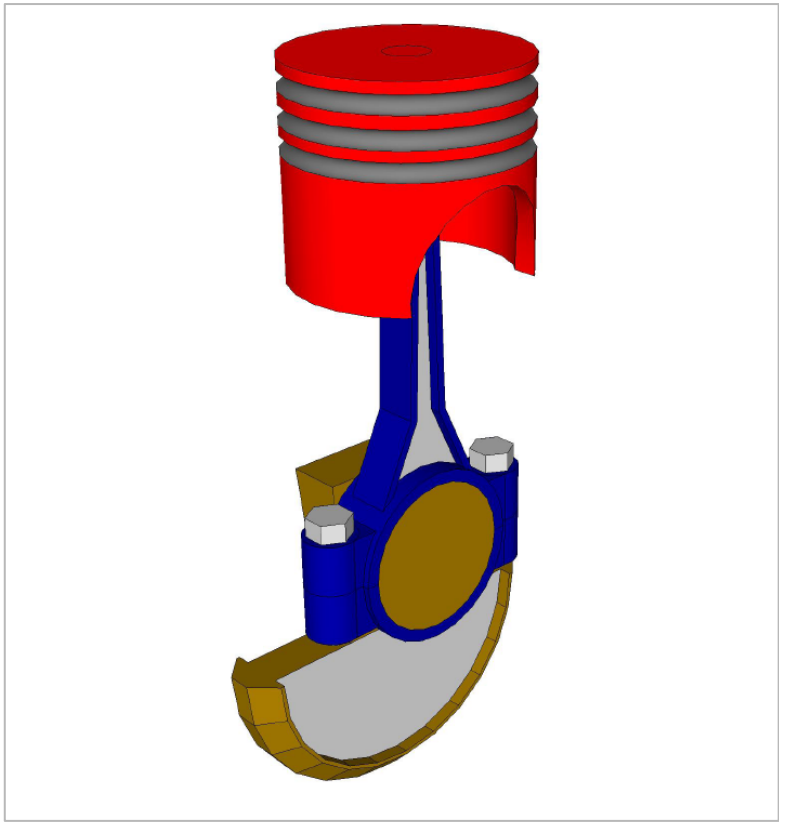

October 12, 2012

FEV

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The Challenges

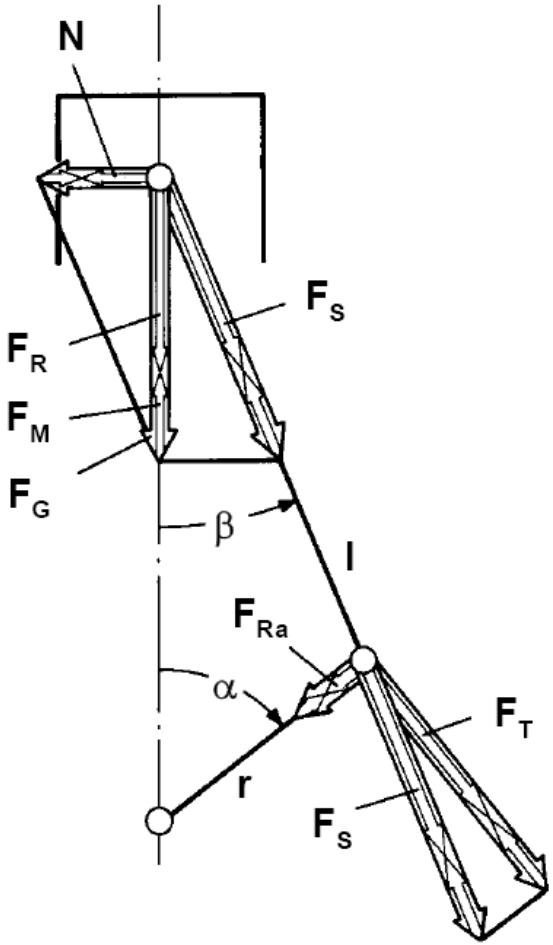
Free Forces for Different Engine Architectures

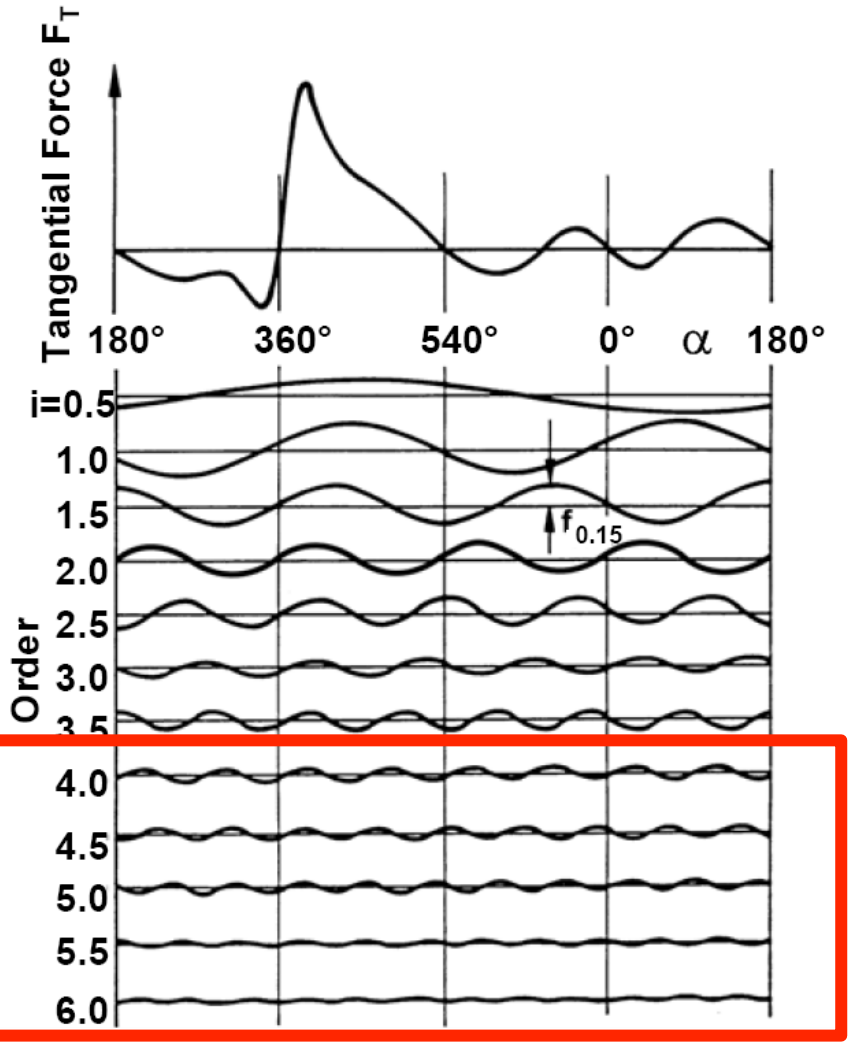
	Type							 V-90°
Free forces	1. Order	F_{01}						
	2. Order	F_{02}	$2 \cdot F_{02}$		$4 \cdot F_{02}$			
Free moments	1. Order		$F_{01} \cdot a$	$\sqrt{3} \cdot F_{01} \cdot a$				$\sqrt{10} \cdot F_{01} \cdot a$ *
	2. Order			$\sqrt{3} \cdot F_{02} \cdot a$			$2 \cdot F_{02} \cdot b$	

Source: Univ.-Prof.Dr.-Ing. S. Pischinger: Internal Combustion Engines

The Challenges

Tangential Forces and Harmonics (Four Stroke Engine)





Negligibly small contribution

Source: Univ.-Prof.Dr.-Ing. S. Pischinger: Internal Combustion Engines

The Challenges

Small Automotive Engines Production Examples

Manufacturer	Cylinders	Displacement [ccm]	Performance Metrics	Speed [rpm]
PEUGEOT	3	999	51 kW 95 Nm 12 bar BMEP	6000 3000
VW	3	999	45 kW 95 Nm 12 bar BMEP	5200 3000
Ford	3	999	93 kW 170 Nm 21 bar BMEP	5000 1400
HYUNDAI KIA MOTORS	3	998	51 kW 95 Nm 12 bar BMEP	6200 3500

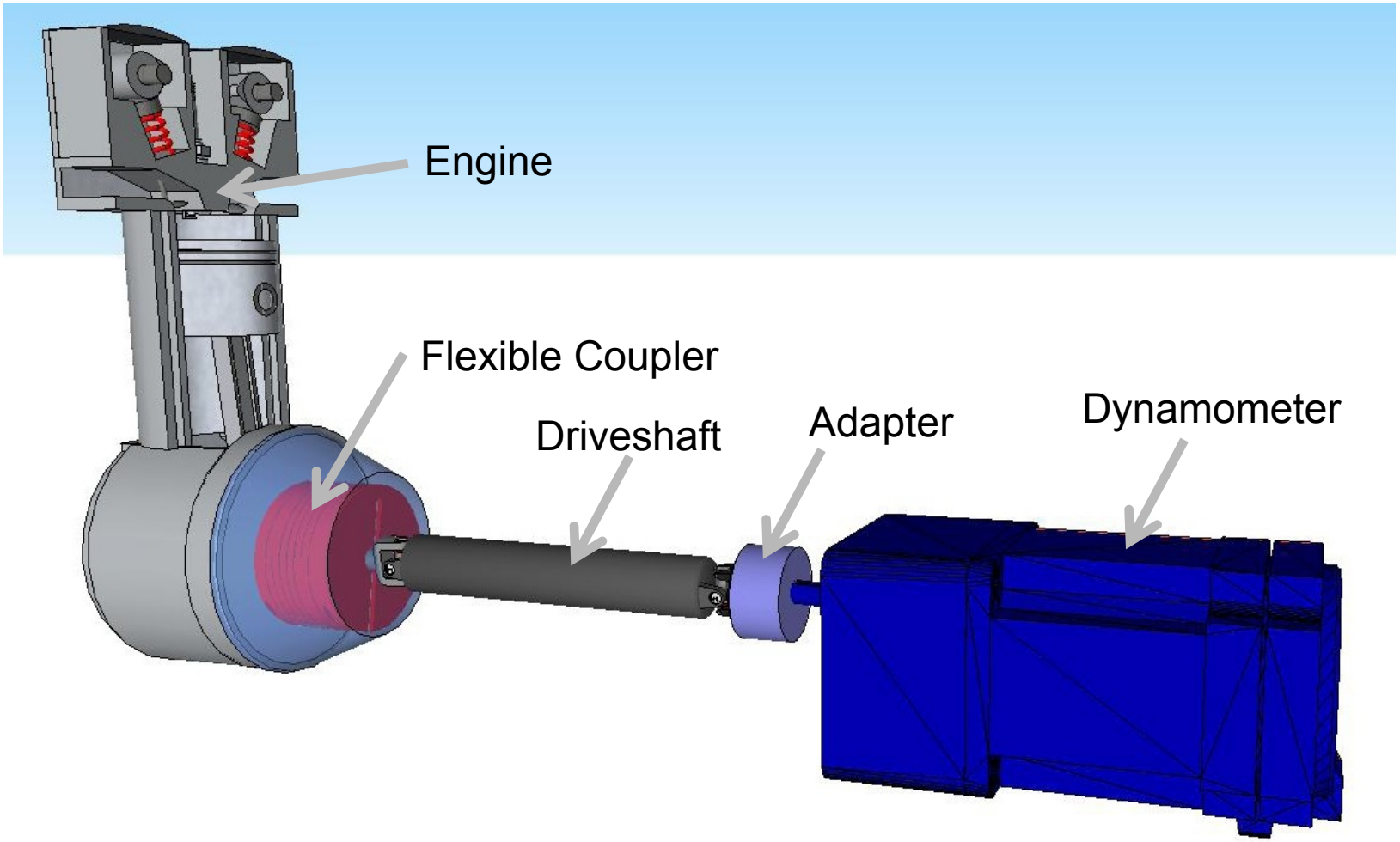
The Challenges

Small Automotive Engines Production Examples

Manufacturer	Cylinders	Displacement [ccm]	Performance Metrics	Speed [rpm]
TOYOTA	3	998	51 kW 93 Nm 12 bar BMEP	6000 3000
BRABUS	3	999	76 kW 147 Nm 18.5 bar BMEP	6000 2500
FIAT	2	875	73 kW 95 Nm 13.6 bar BMEP	5500 1900

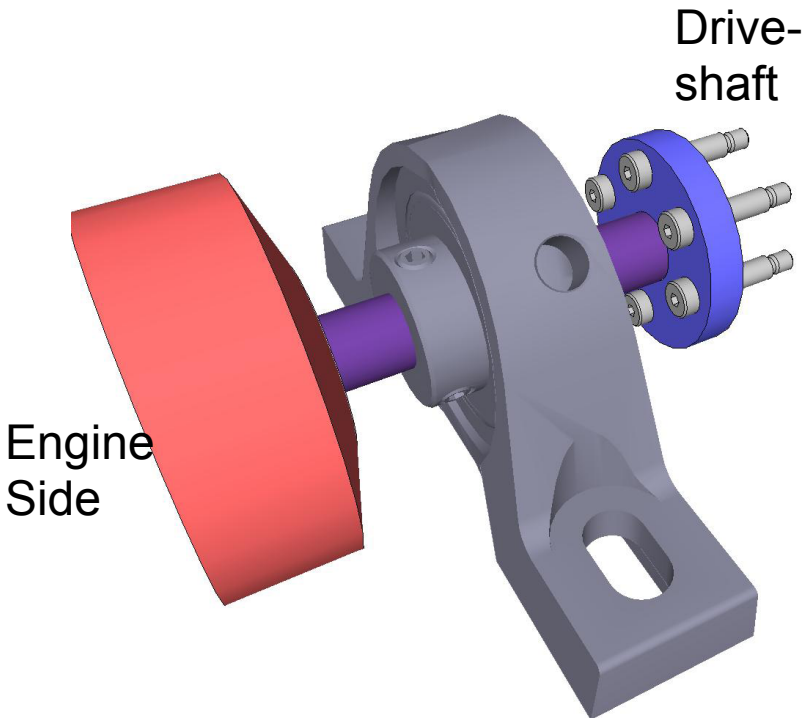
Typical Failures

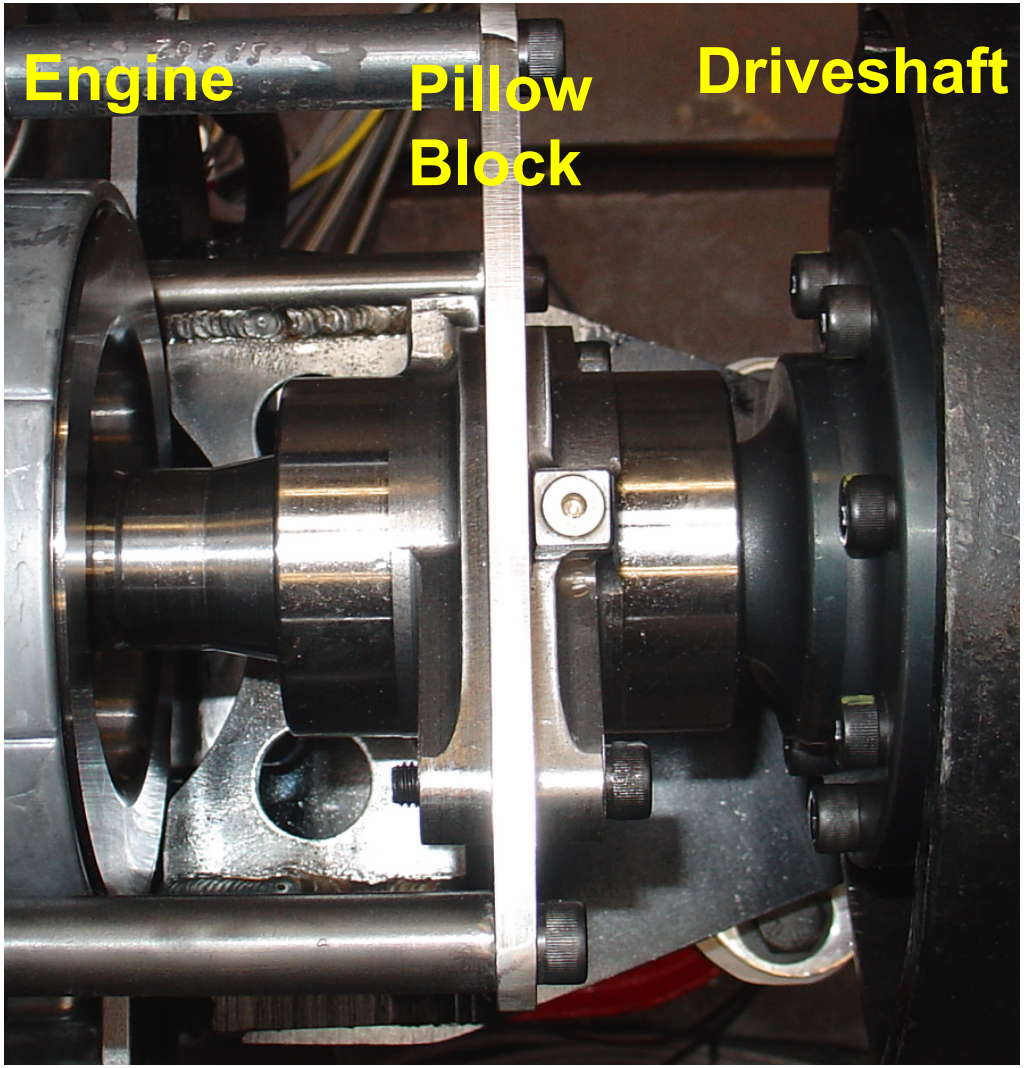
Setup Example of a Single Cylinder Engine



Typical Failures

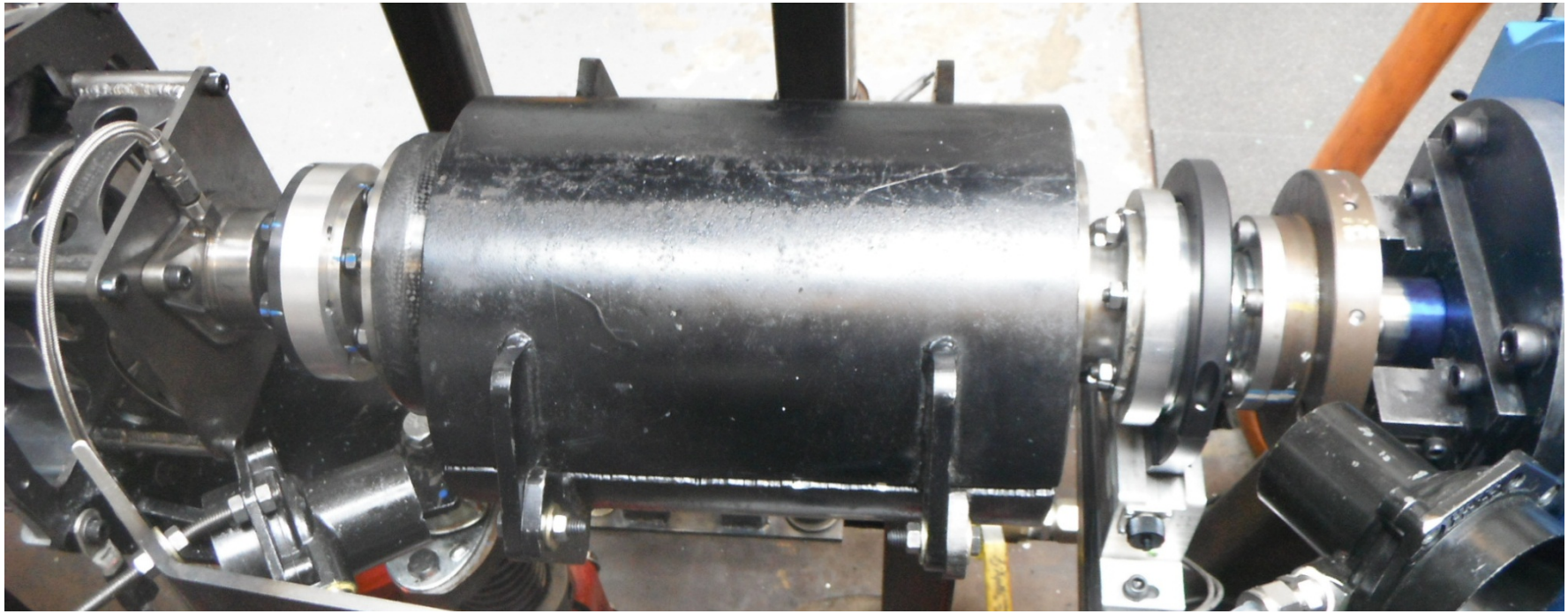
Setup Example of a Single Cylinder Engine





Typical Failures

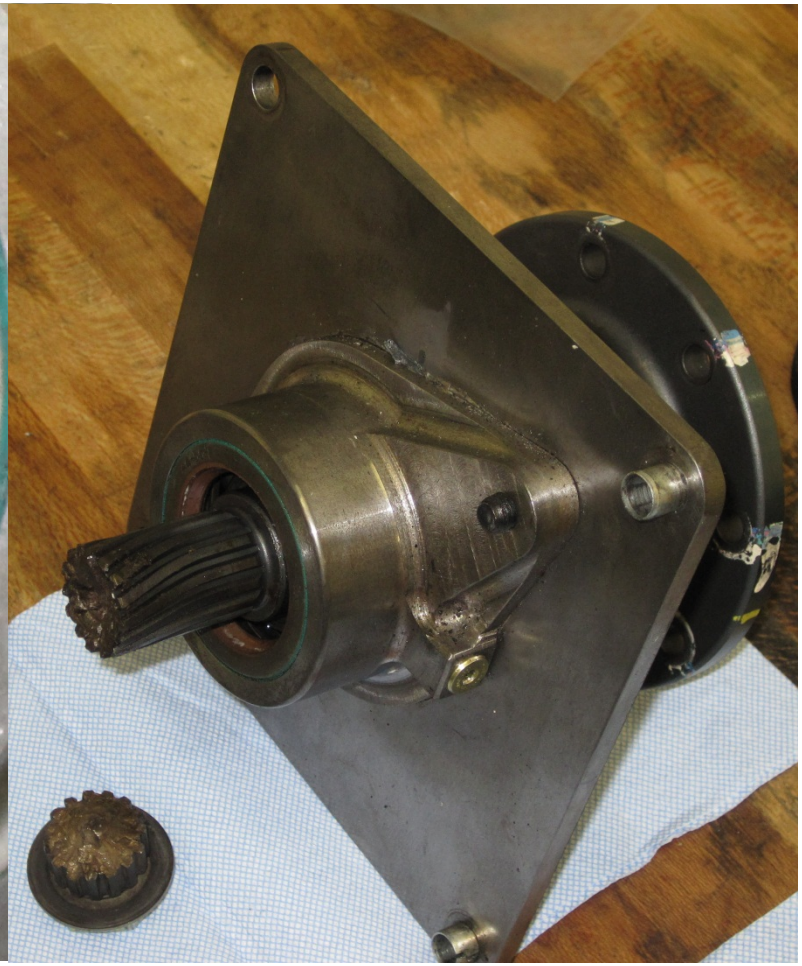
Setup Example of a Single Cylinder Engine



Engine | Driveshaft | Torque Measurement | Dynamometer

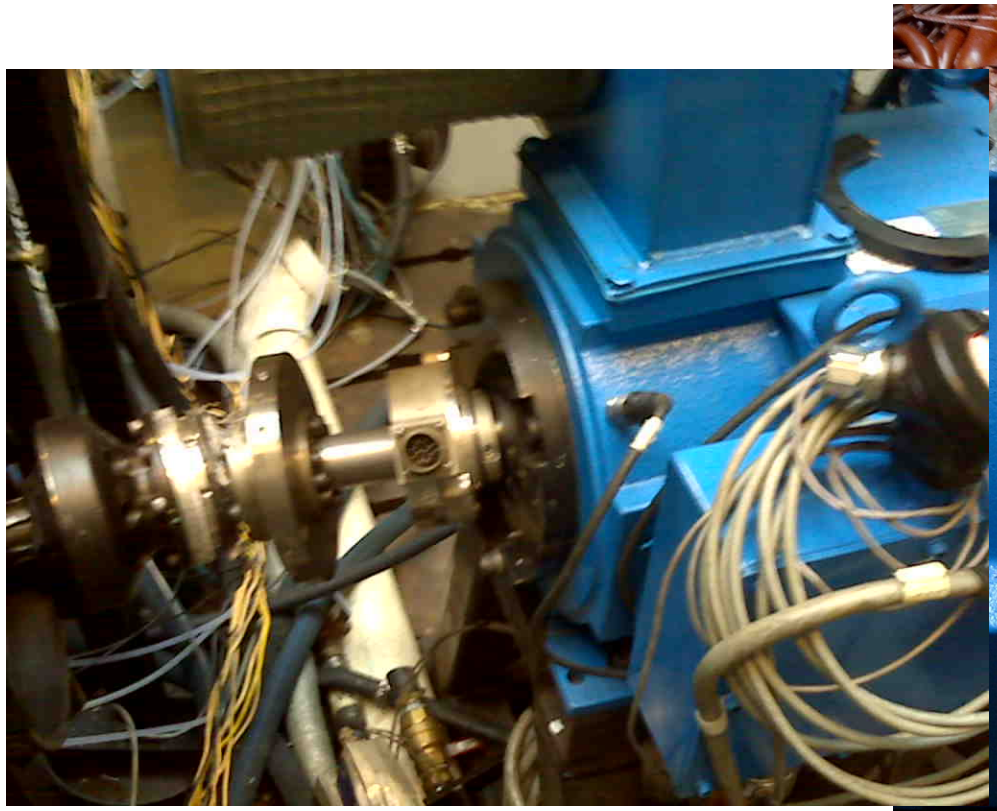
Typical Failures

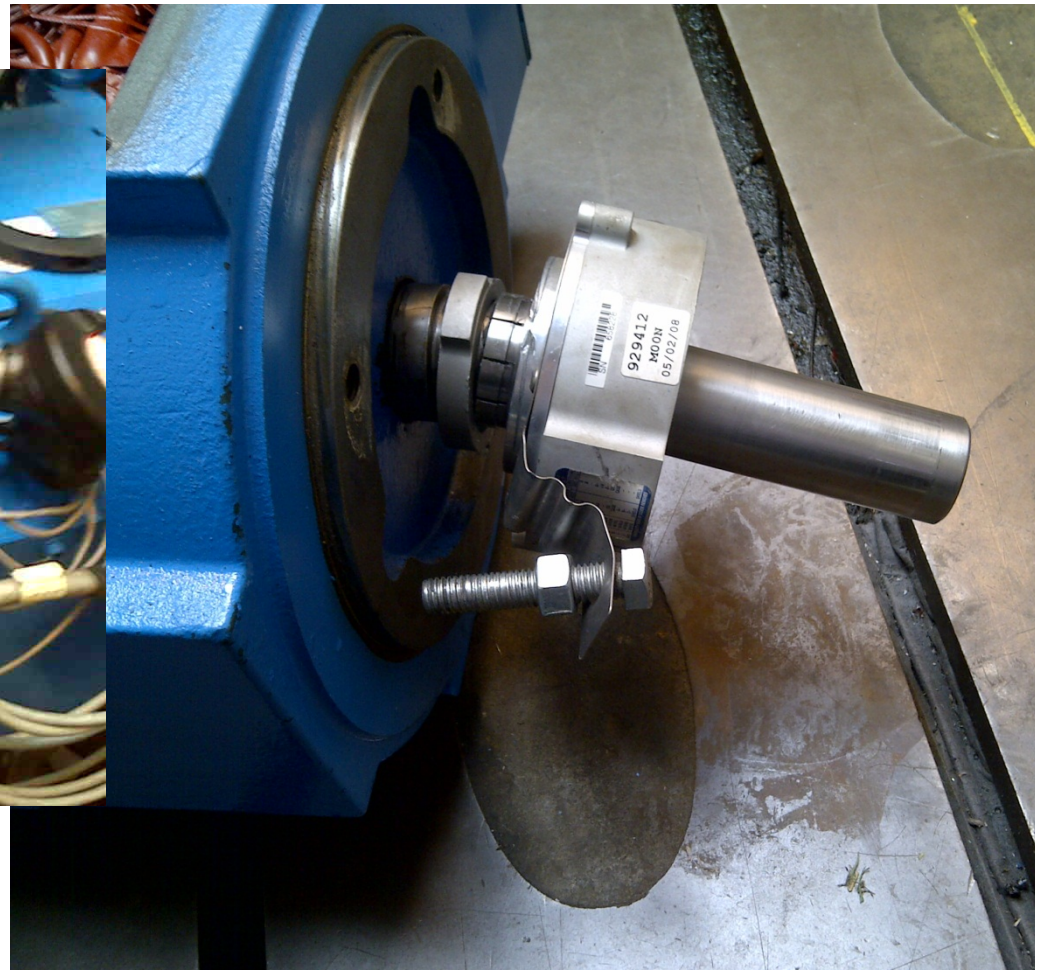
Torsional Failure of a Driveshaft of a Single Cylinder Engine



Typical Failures

Torsional Failure of a Driveshaft of a Single Cylinder Engine





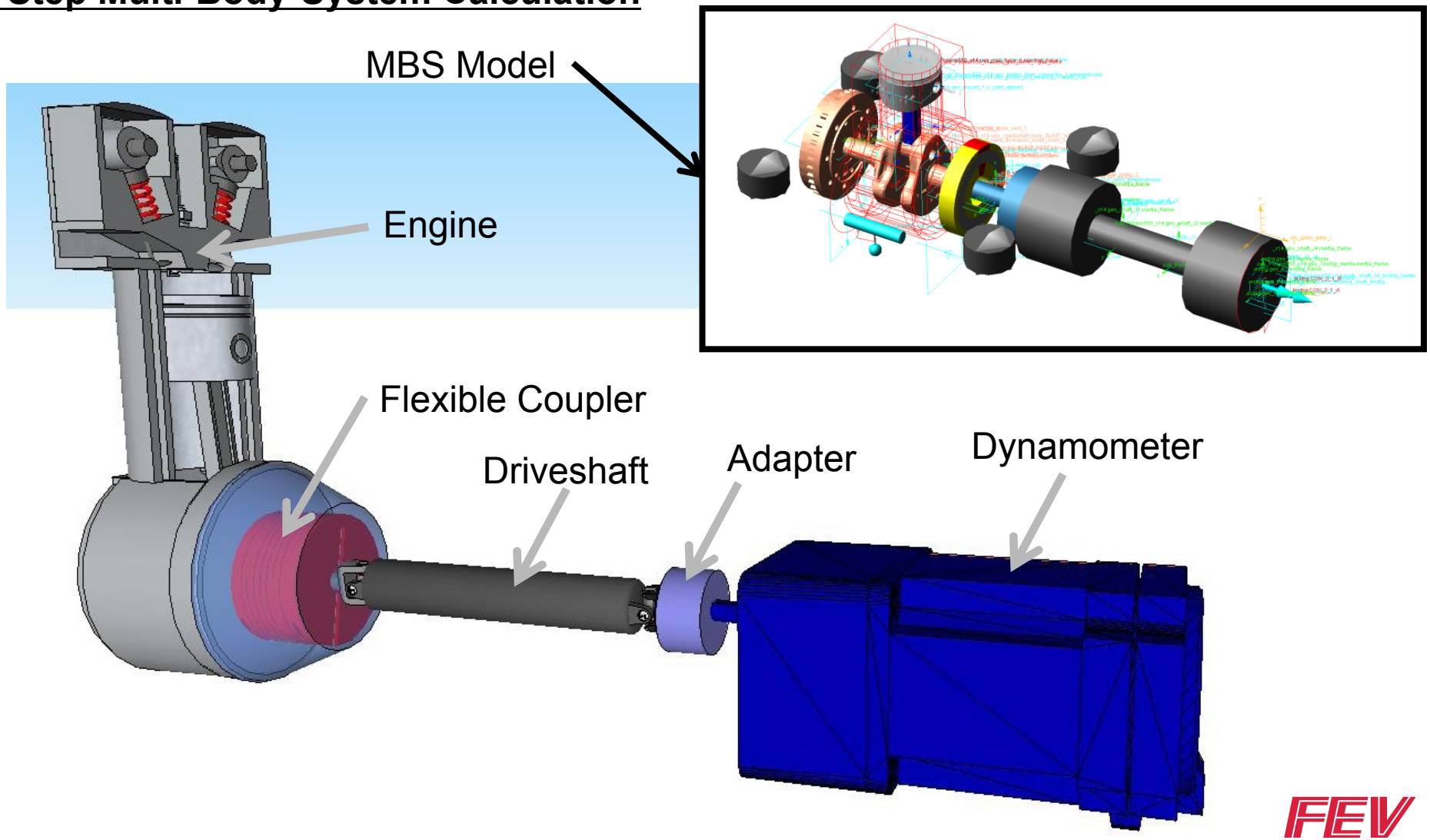
Typical Failures

Torsional Failure of a Power Generator

Source: Diesel and Gas Turbine Worldwide, November 2011

Traditional Approach

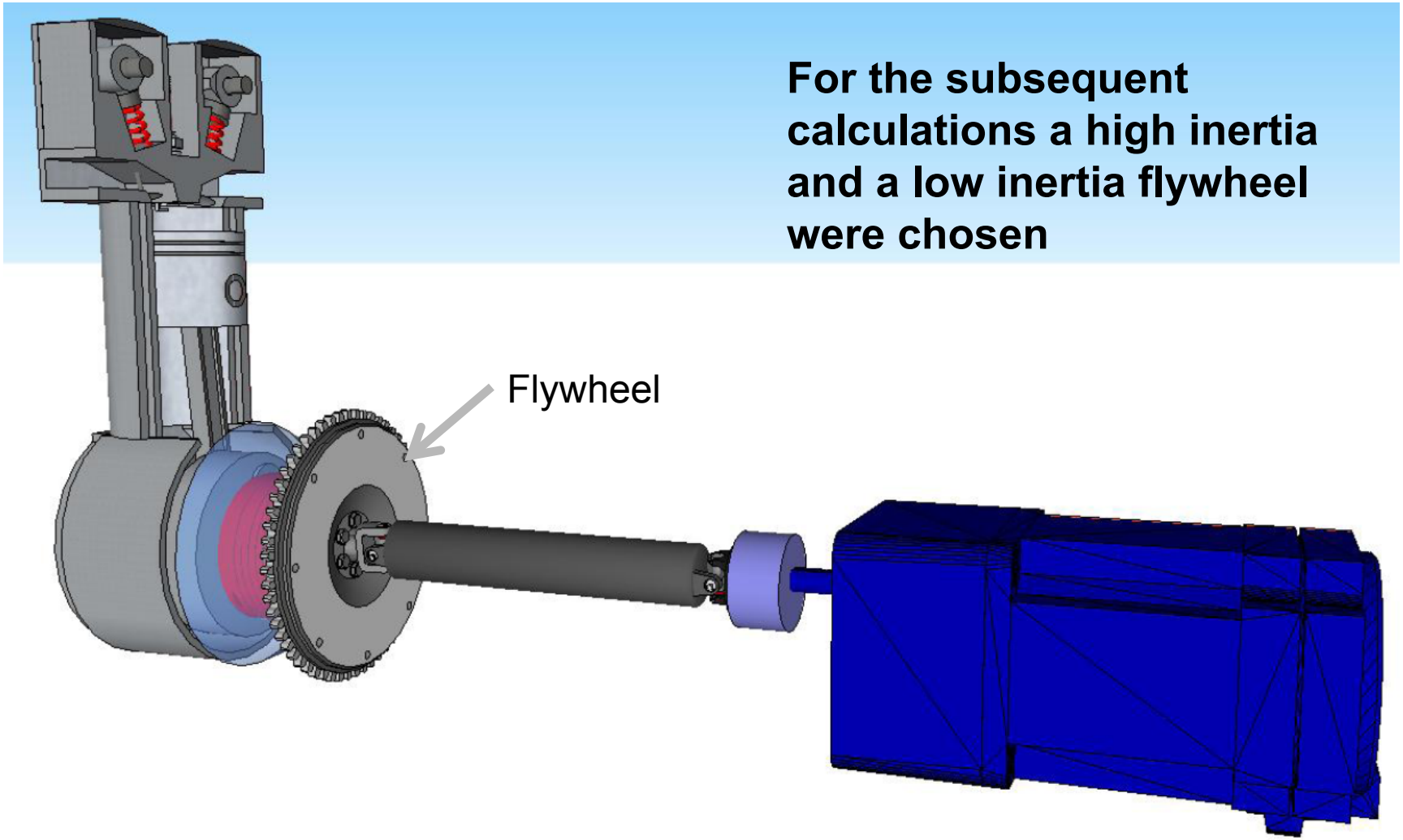
Multi-Step Multi-Body-System Calculation



Traditional Approach

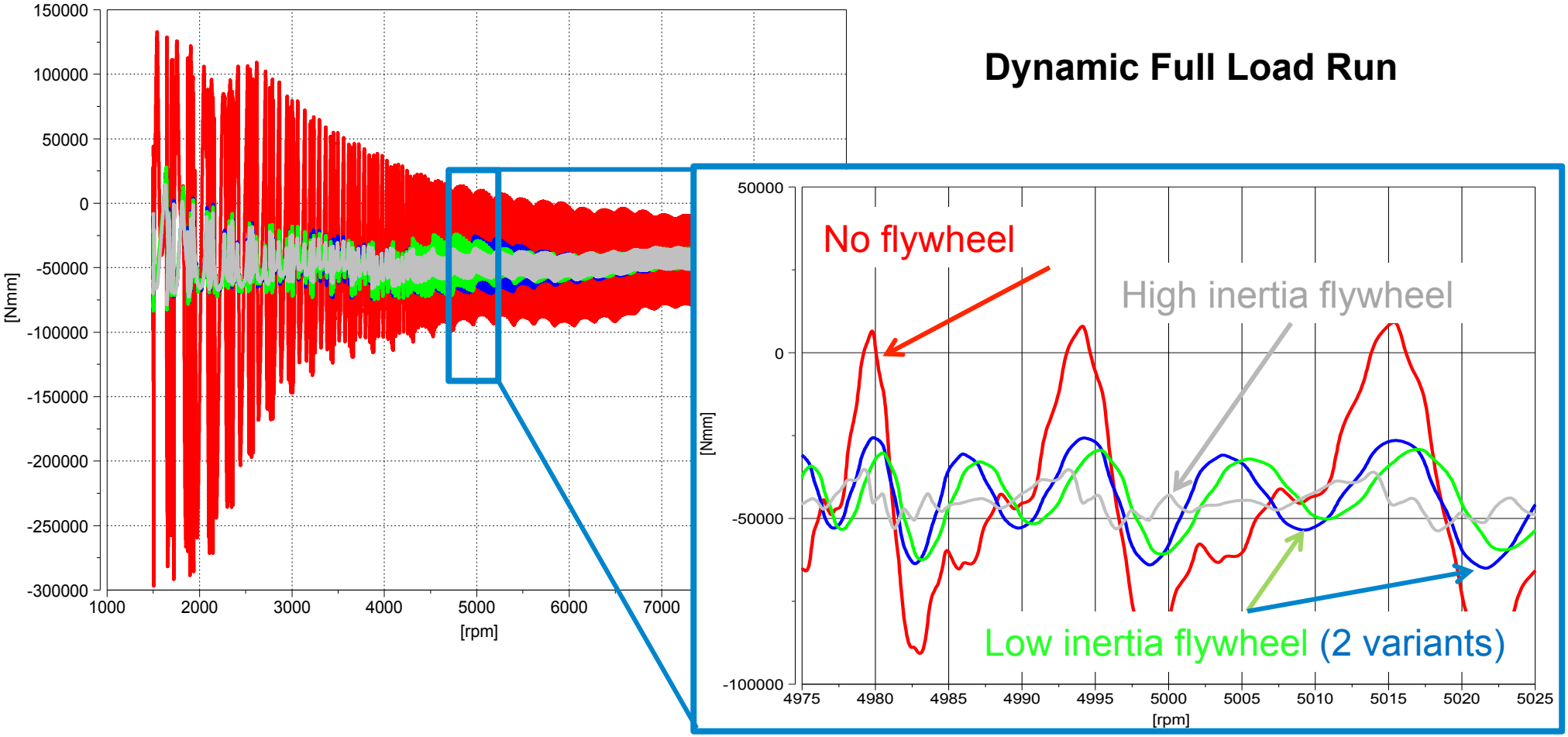
Multi-Step Multi-Body-System Calculation

For the subsequent calculations a high inertia and a low inertia flywheel were chosen



Traditional Approach

Torsional Vibration Comparison – High-Fidelity MBS Calculation



Traditional Approach

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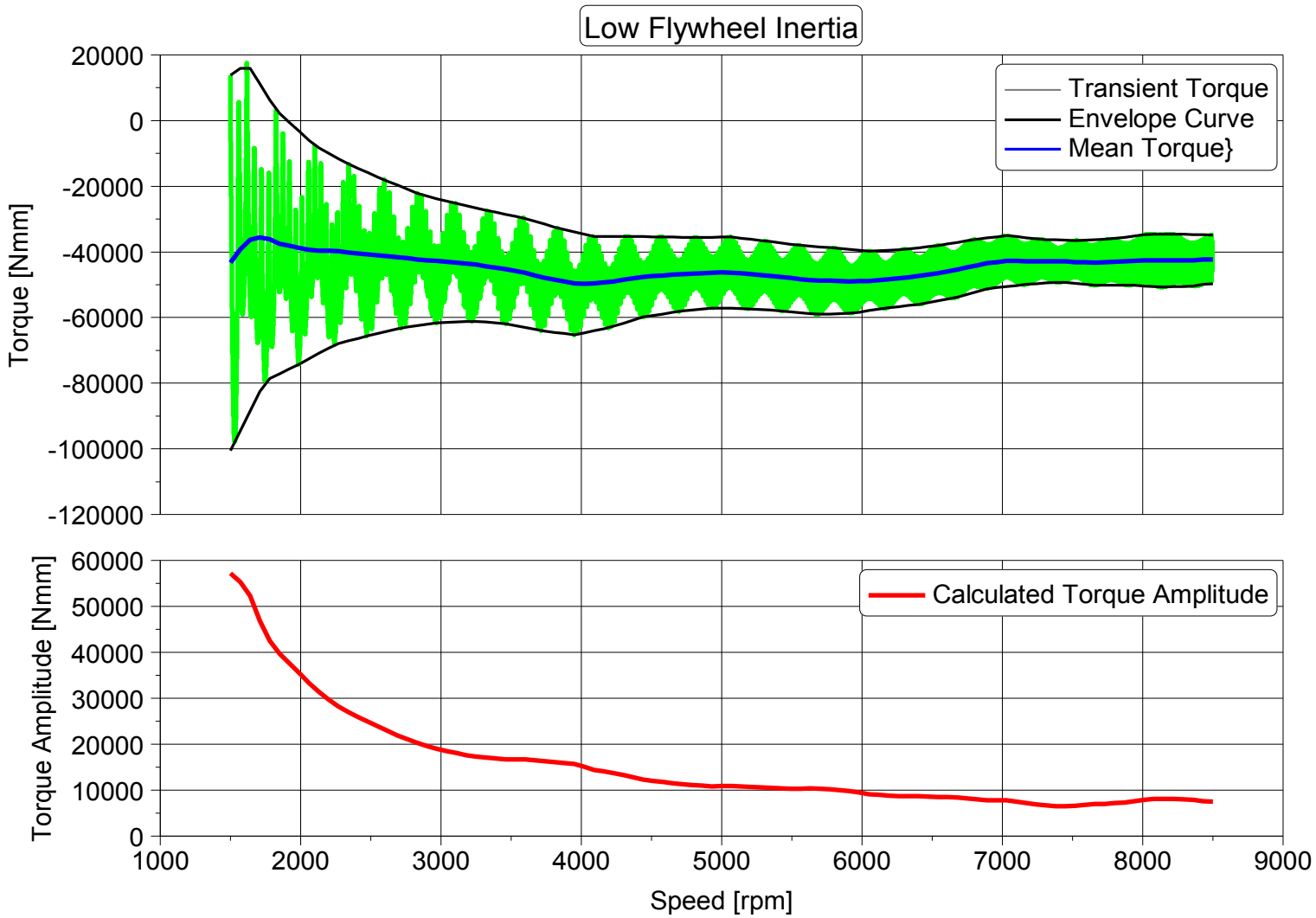
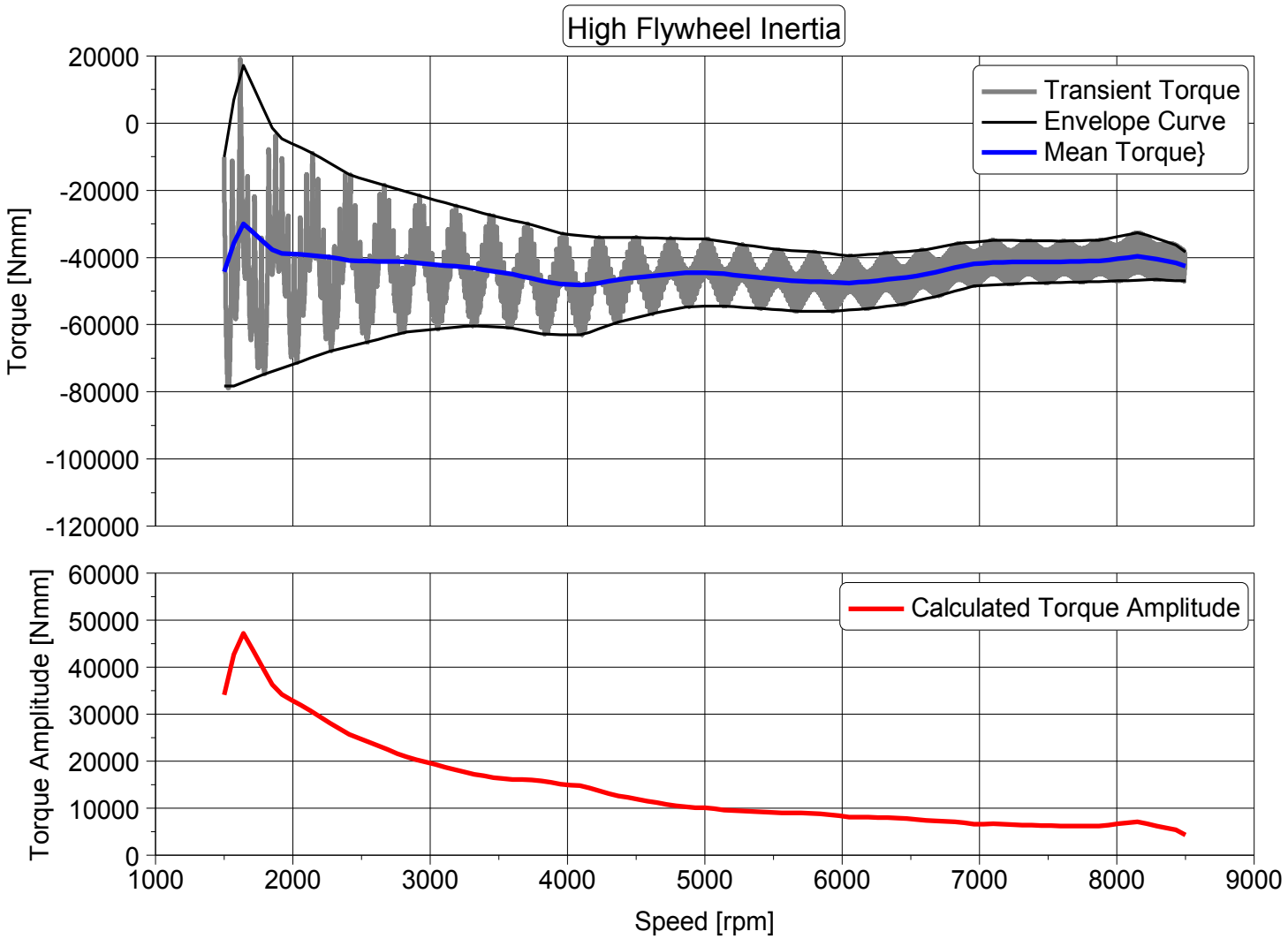


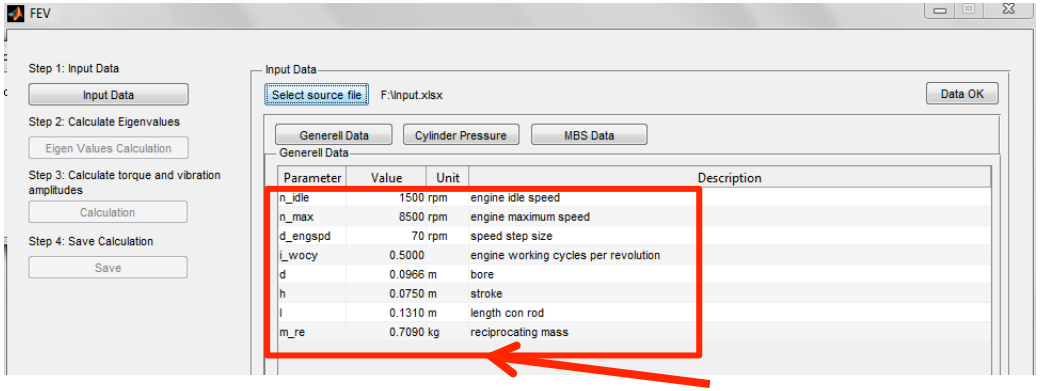
Traditional Approach

Torsional Vibration Comparison – High-Fidelity MBS Calculation

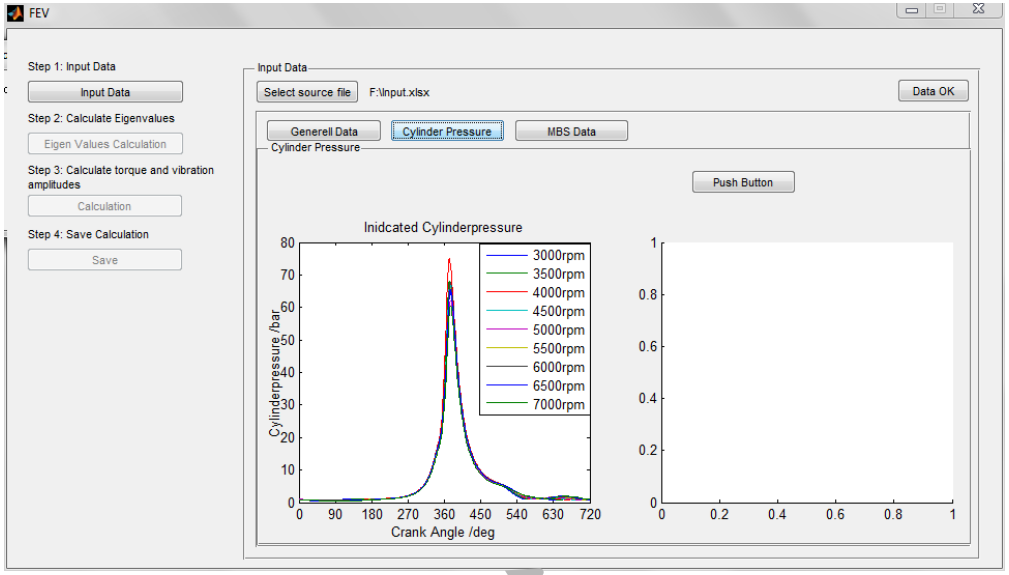


Alternative Approach

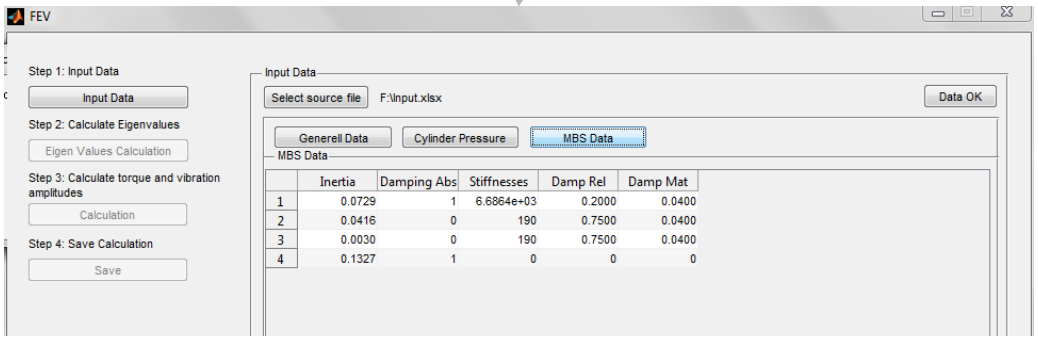
Low Fidelity MBS – Software Layout



Basic engine data



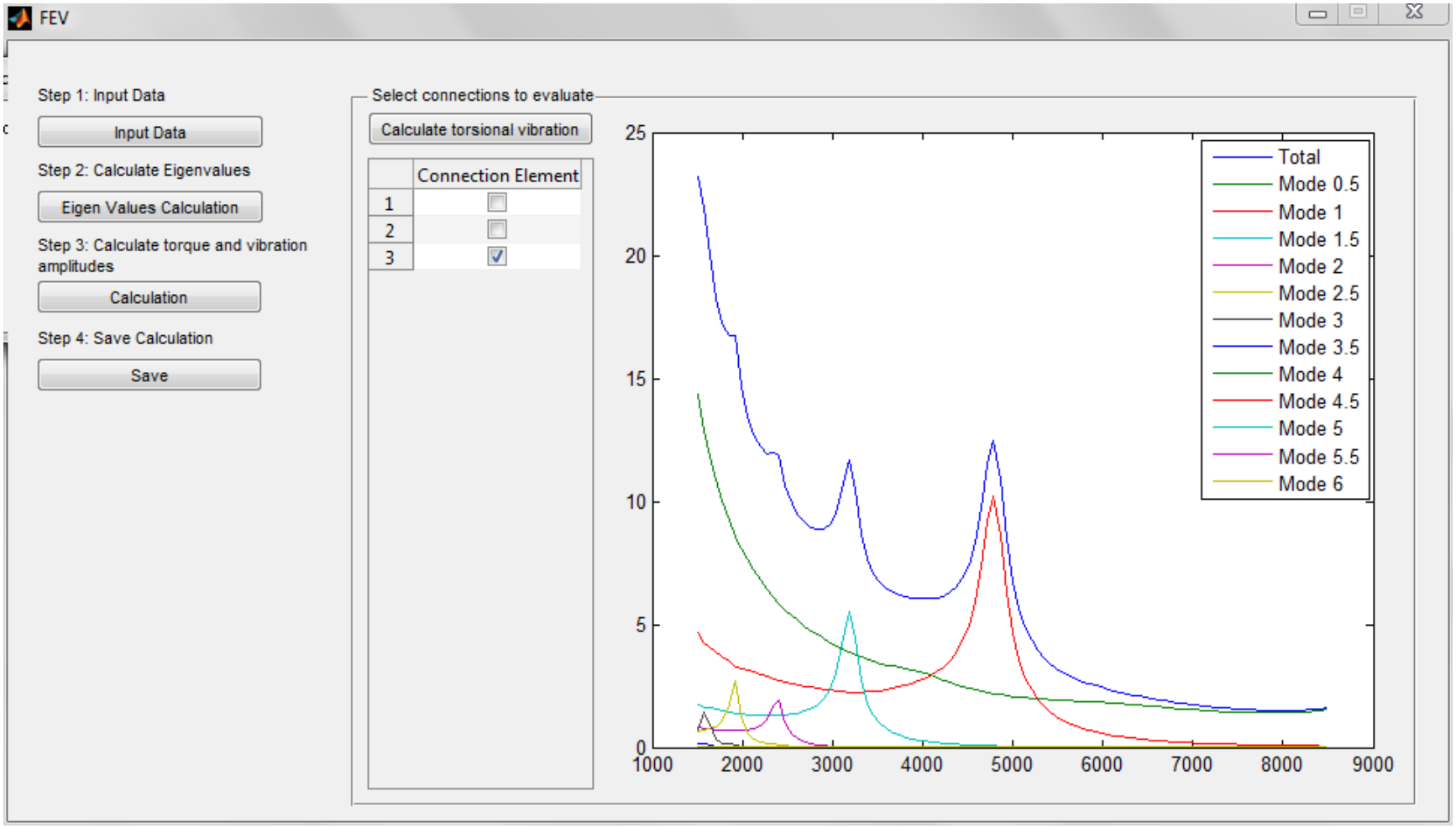
Basic component data (if this data is not available, a database can be consulted offering scatterbands from known engines with similar design characteristics)



Cylinder pressure data (if pressure traces are not available, a function generator will create pressure traces using a provided peak cylinder peak

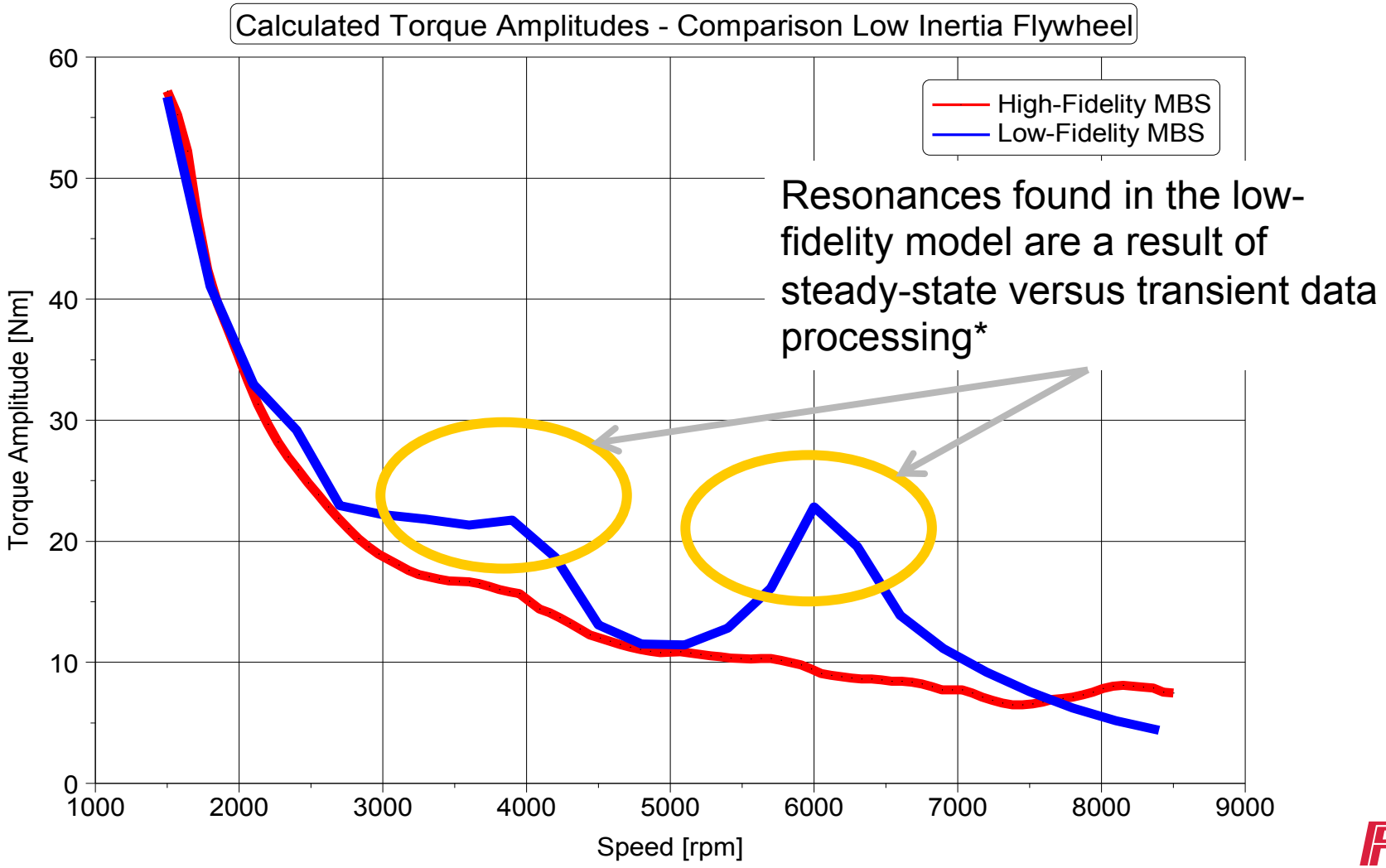
Alternative Approach

Low Fidelity MBS – Software Layout – Output



Results

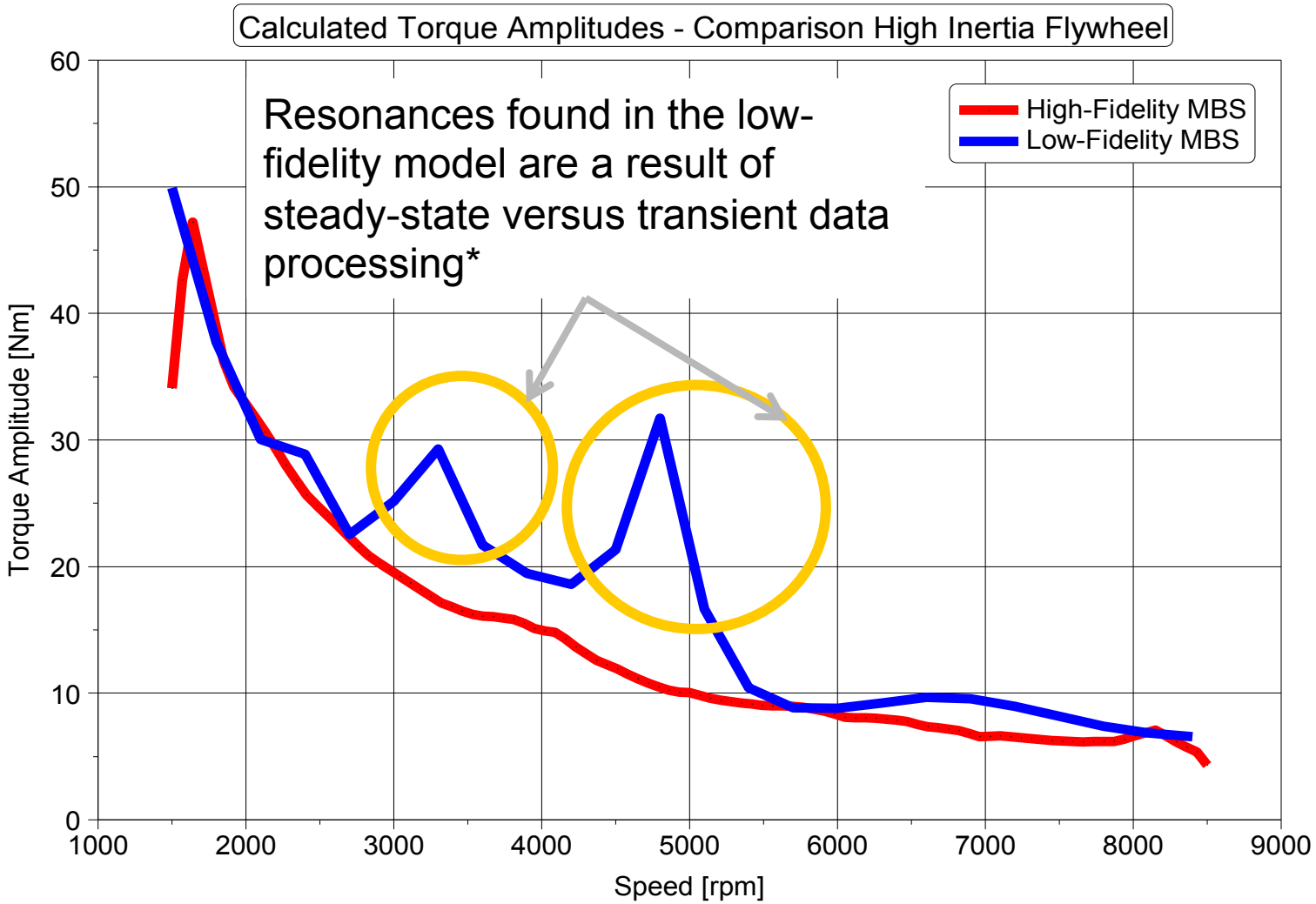
Comparion High-Fidelity versus Low Fidelity MBS



* These resonances would actually occur under real-world steady-state conditions

Results

Comparion High-Fidelity versus Low Fidelity MBS

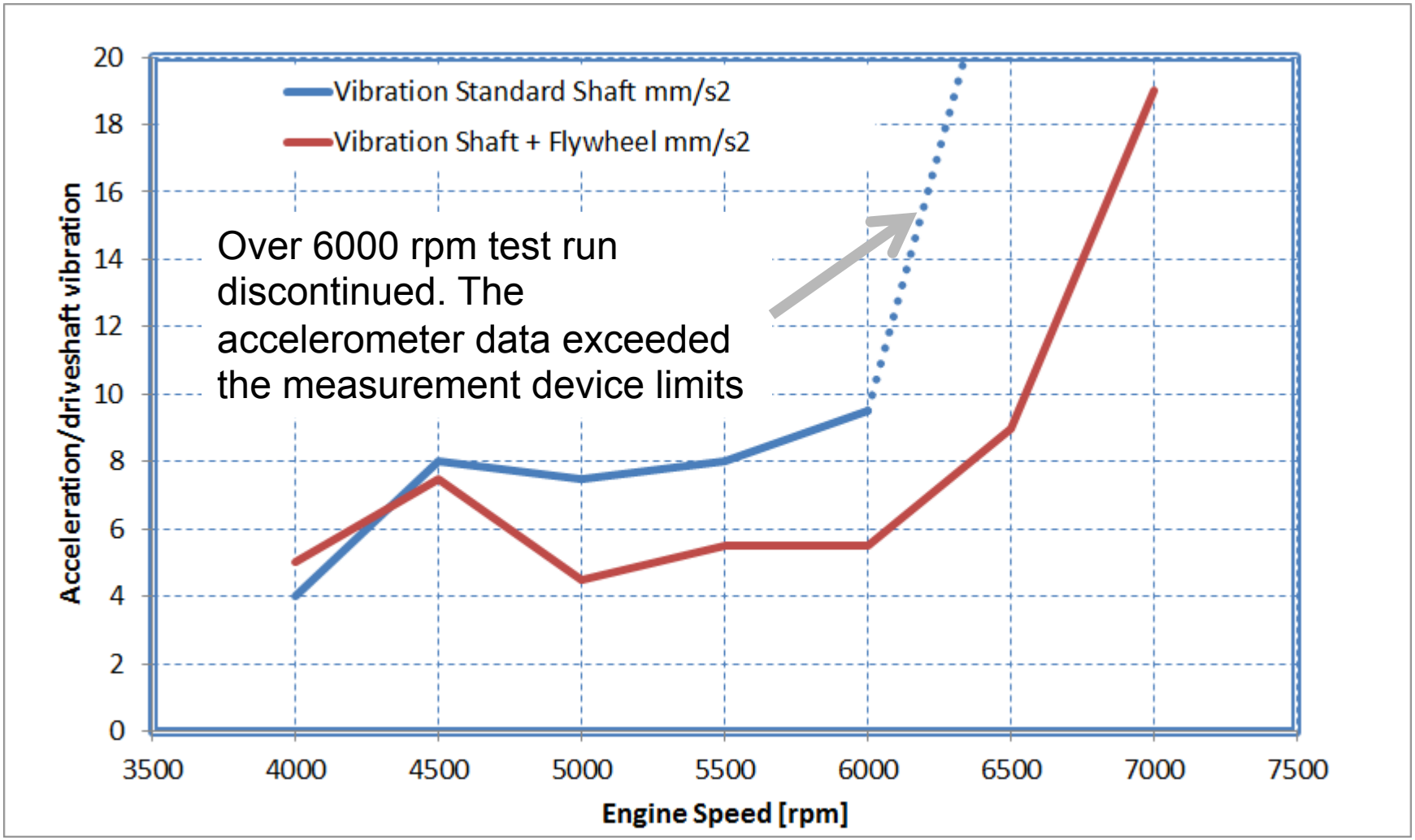


* These resonances would actually occur under real-world steady-state conditions

Results

Driveshaft Vibration Comparison

Accelerometer placed on shaft end of the dynamometer



Outlook

- An alternative approach to high-fidelity MBS calculations proves to offer reliable data to design robust test cell driveline systems for low cylinder count engines in test cell environment
- Contrary to conventional MBS calculations the low-fidelity software does not require specialized system knowledge and can be operated by operations engineering staff after brief training/introduction
- Low-fidelity software allows to generate results very quickly resulting in substantial time/cost savings during test cell setups
- Low-fidelity system is not a replacement or substitution for high-fidelity systems – it represents a shortcut to allow quick and safe test cell setup and operation
- The alternative approach was verified in multiple projects and proved to provide robust and reliable results
- Database with existing main parameters allows to process engine configurations with no existing data or information

Thank you for your attention