Practical measurements of axle noise using torsional vibration

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- Axle noise is a persistent problem, despite many years of trying to make axles quiet.
- Cars are getting quieter so the axle manufacturers face an ever increasing challenge.

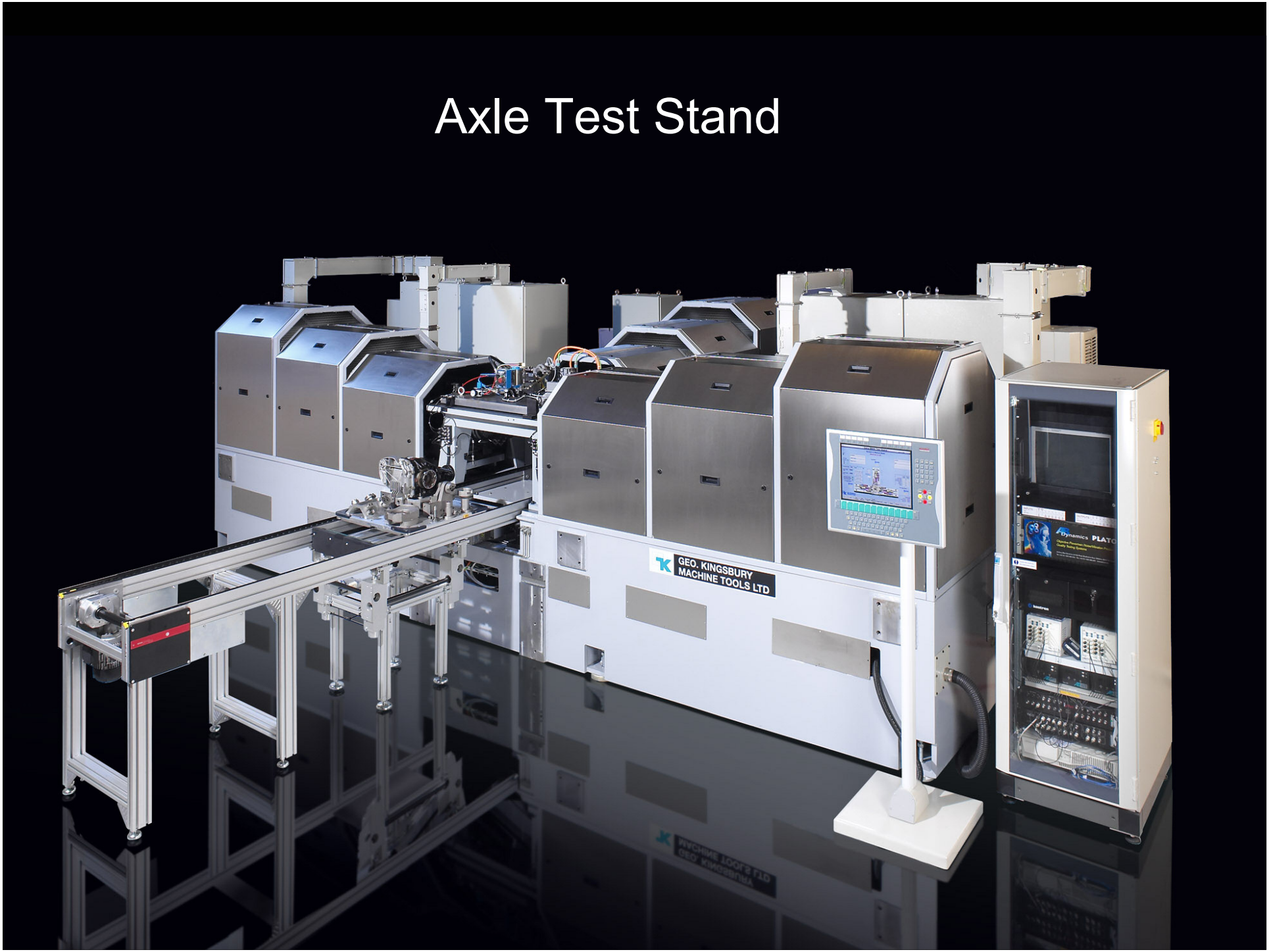
Routes for transmission of axle noise into cars

- Airborne.
- Through the axle mountings into the body shell. Vibration isolators can interrupt the axle mounting path.
- Through the shafts into the suspension - seems to be the main problem, so we measure that.

- Most axles are acceptable, but the few bad ones must be discovered before they reach the customer.

- 100% end of line noise testing is necessary.

Axle Test Stand



For gearboxes, transfer cases and axles the conventional methods are to measure

Airborne noise

or

Vibration of the casing or the test rig.

Resonances of the casing and shafts affect the results and are production variables.

IRS axles are structurally very stiff, so casing resonances are outside the frequency range of gear tooth meshing.

Possible methods of measuring shaft borne vibration;-

Torsional acceleration of shafts

Shaft torque fluctuations

Both are caused by gear tooth meshing forces,

Torsional vibration measurement challenges

- Telemetry to transmit accelerometer signals from shaft,
- Cancellation of gravity signals,
- Cancellation of signals from gross shaft movements in radial direction.

SOLUTIONS – Two accelerometers at 180 degrees + summing amps

Shaft torque fluctuation measurement challenges

- “Static” torque is high, particularly on the output shafts.
- Dynamic torque caused by tooth meshing torsional vibration is very low.

Dynamic to static ratio is up to

400,000 : 1.

Electronics noise floor must be very low to give headroom for valid measurements.

Measurements up to at least 5 kHz required.

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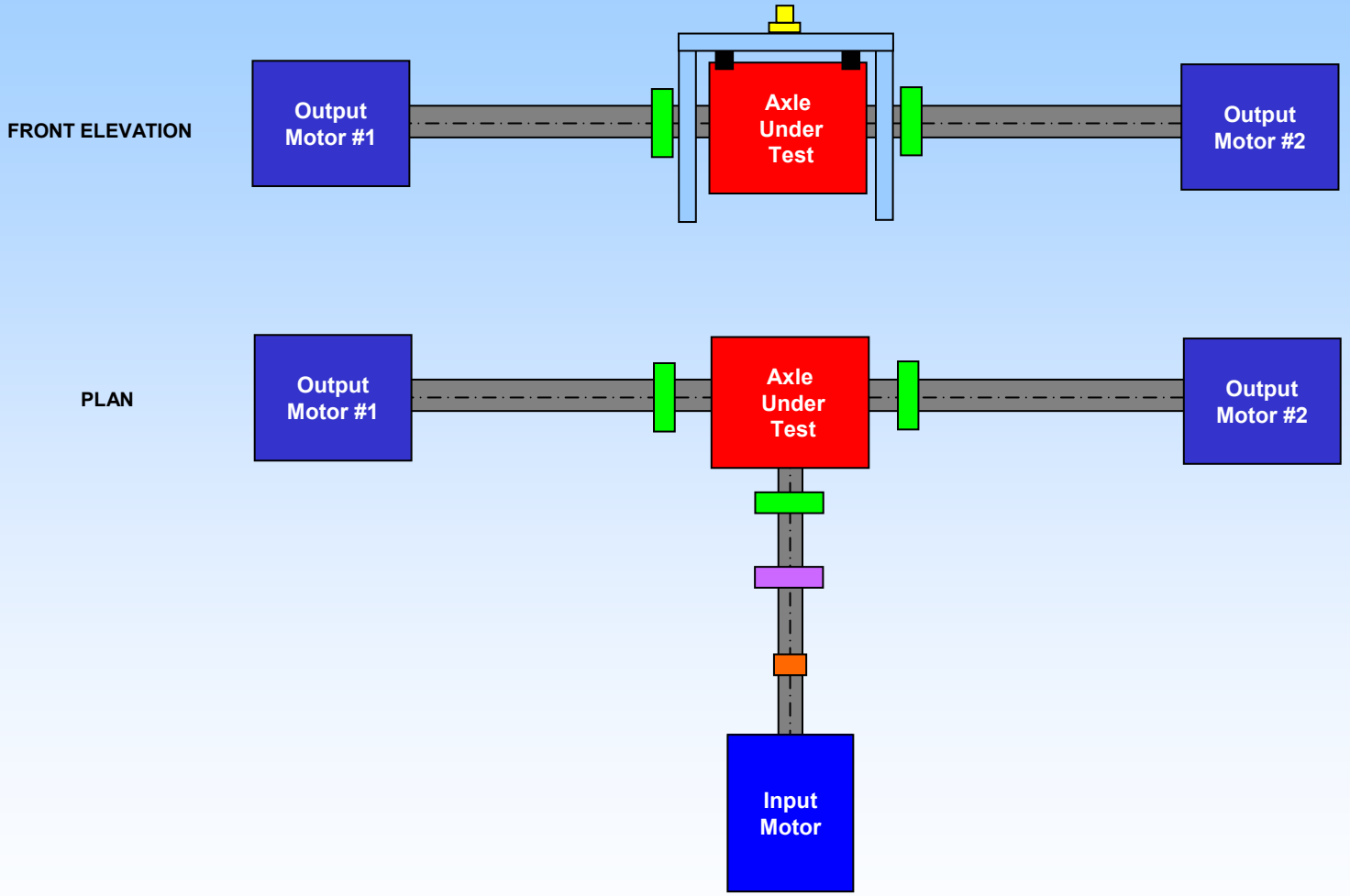
Torsional outputs from the axle are present on the input and output shafts of all axles, upstream and downstream of the source, relative to the mechanical power flow.

Potentially any of the shafts could be used to measure vibration, but the signals may be influenced by the inertias of the shafts and associated components.

- There is a high potential for the dynamics of the test rig to influence the results of measurements, due to torsional resonances of the drive line.
- The results are likely to specific to each test rig.
- This may not prevent valid comparisons between axles, but extra care is necessary.

Fundamentals of a simple axle test rig



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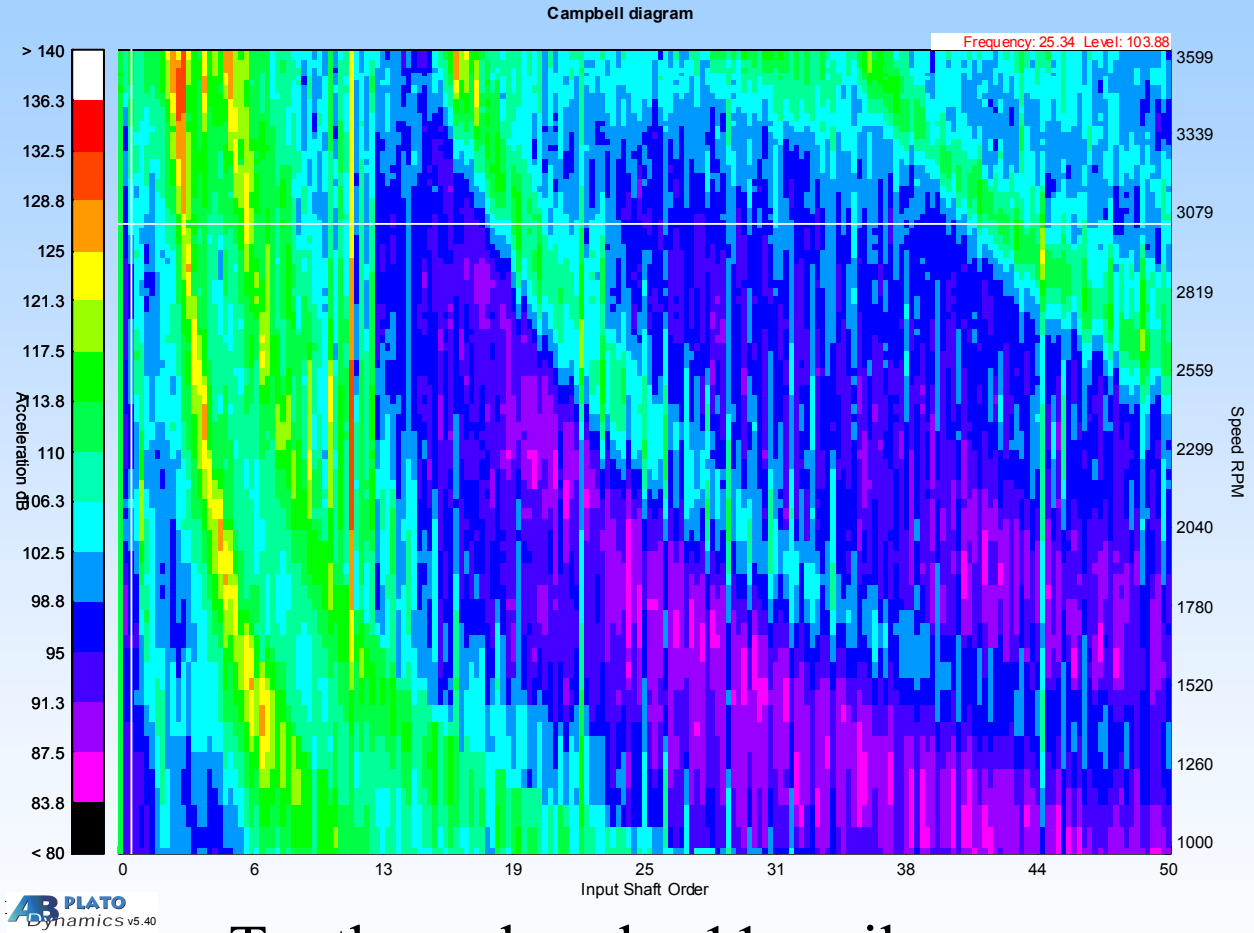
Rig considerations.

Torsional measurements have a potential problem if the input shaft velocity is not smooth.

Velocity or torque ripple may affect the results.

Consider motor control systems and inertias.

Overview of torsional acceleration test result - input shaft



Tooth mesh order 11 easily seen and not greatly influenced by resonances at 155 and 300 Hz

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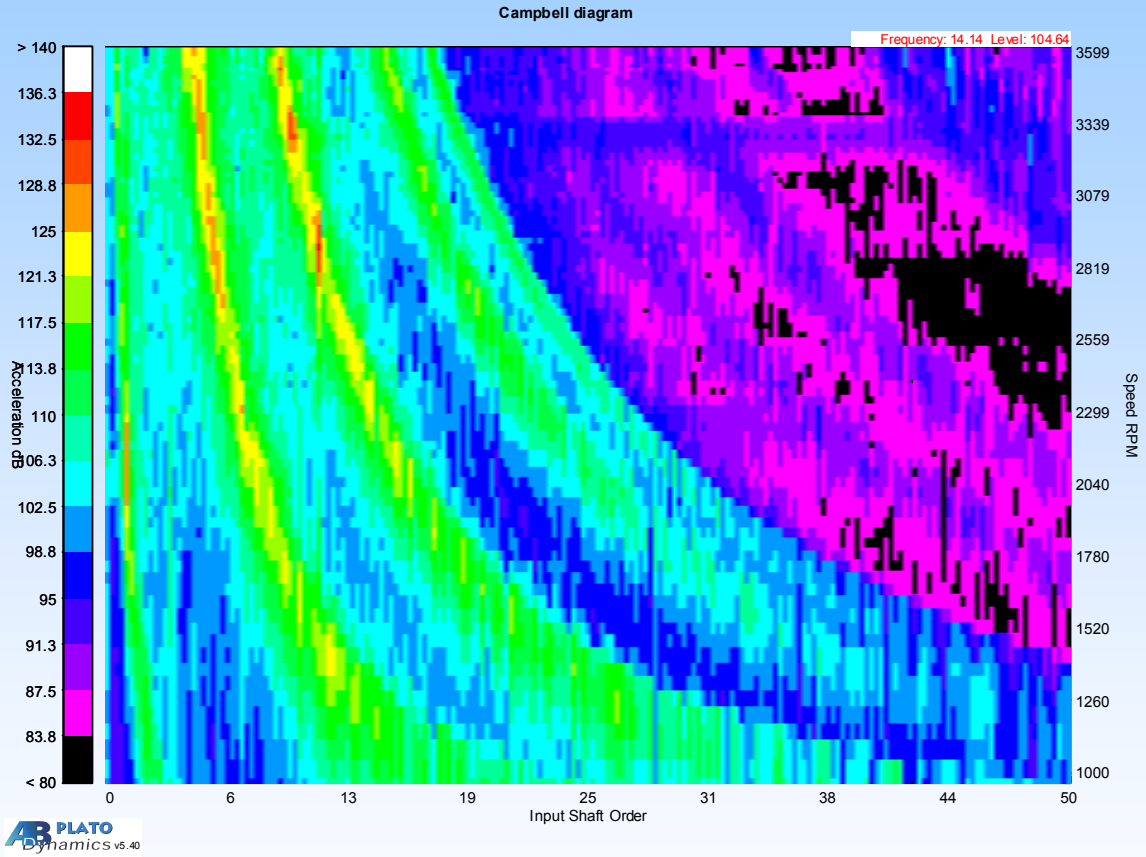
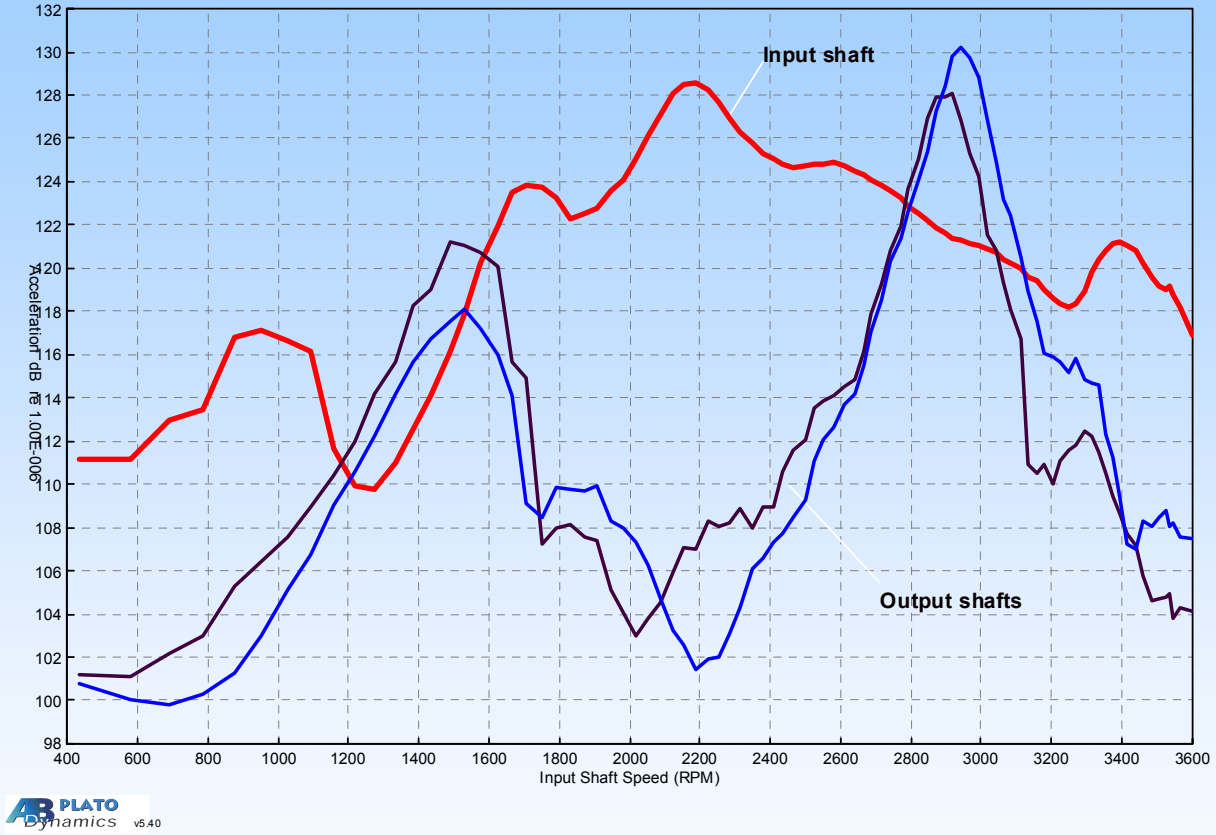
Overview of torsional acceleration result – output shaft



Output shaft signals are dominated by resonant response at 270 and 530 Hz.

Tooth mesh order 11 is not well resolved

Torsional acceleration data at tooth mesh order measured on the rig input and output shafts.



Simultaneous measurements during acceleration test, drive side loading.

Different test rig effects on input and output.

Output shaft response dominated by resonances

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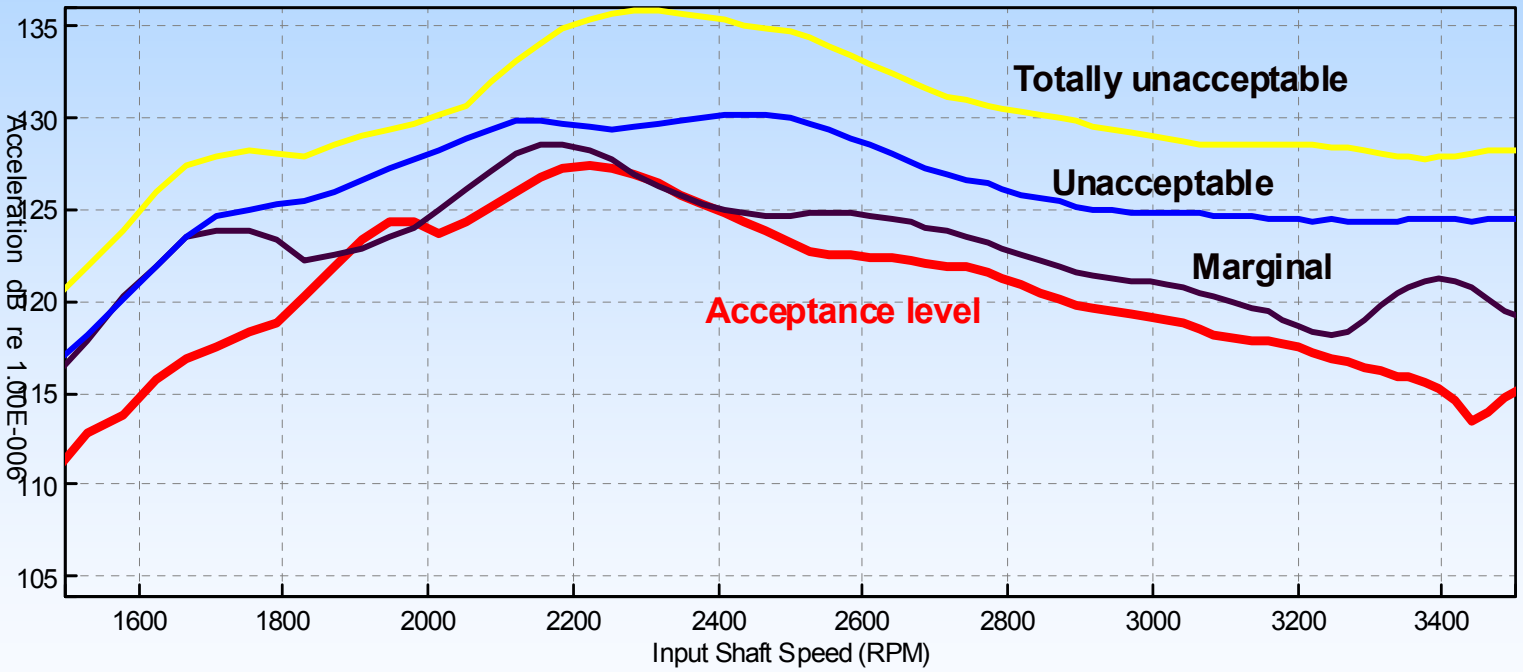
Torsional vibration- input shaft, tooth mesh order. - Comparison of subjectively unacceptable axles with production acceptance level.



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Production acceptance level was derived from the envelope of results of axles which were subjectively acceptable in a vehicle.

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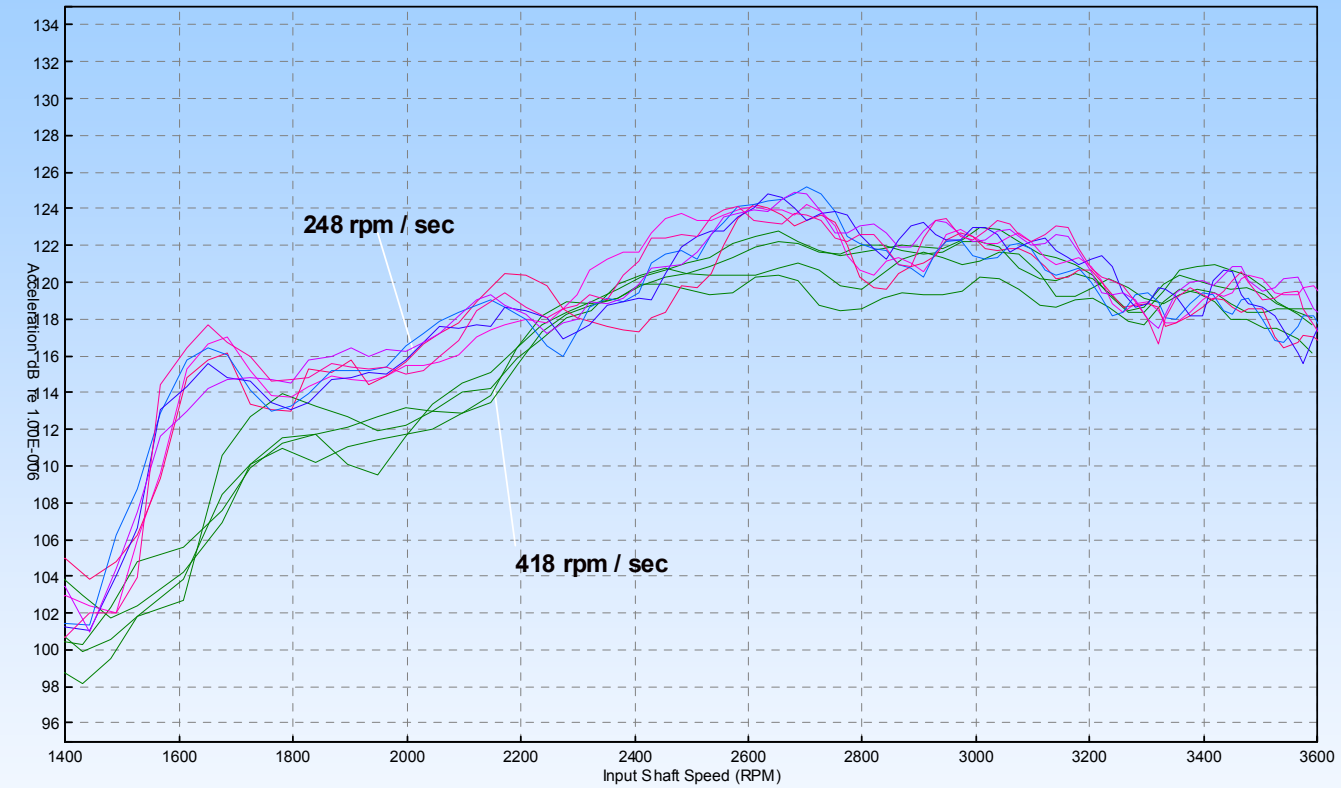
Torsional vibration – Effect of test time



248 rpm/sec = 12.5 seconds test time

418 rpm/sec = 5.5 seconds test time

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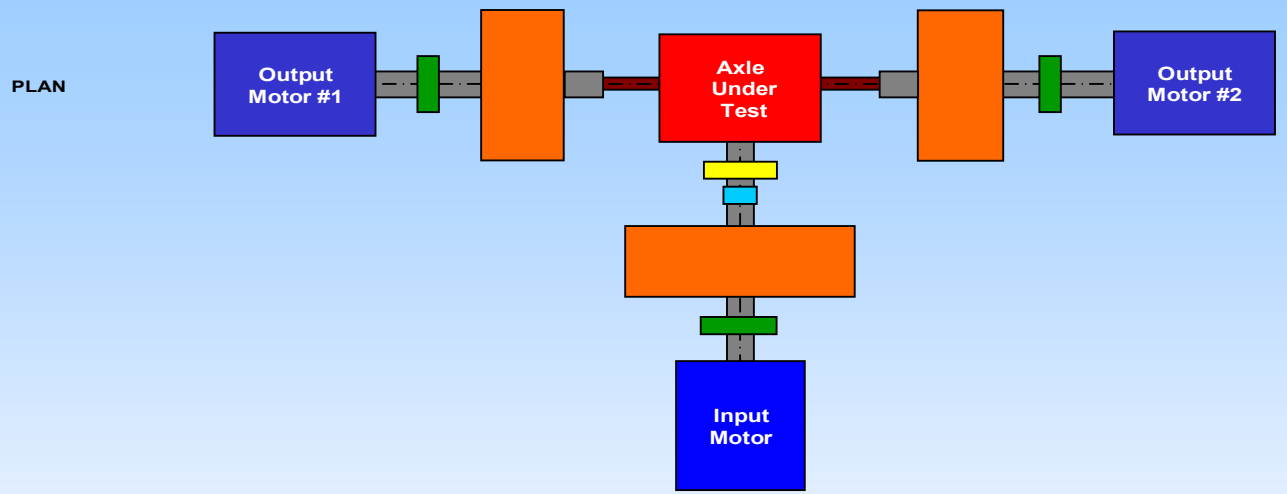
Torsional oscillations induced by motors are undesirable – rig design to isolate them from the axle.

Torque Fluctuation Measurement



Cannot operate below lowest torsional resonance of the system

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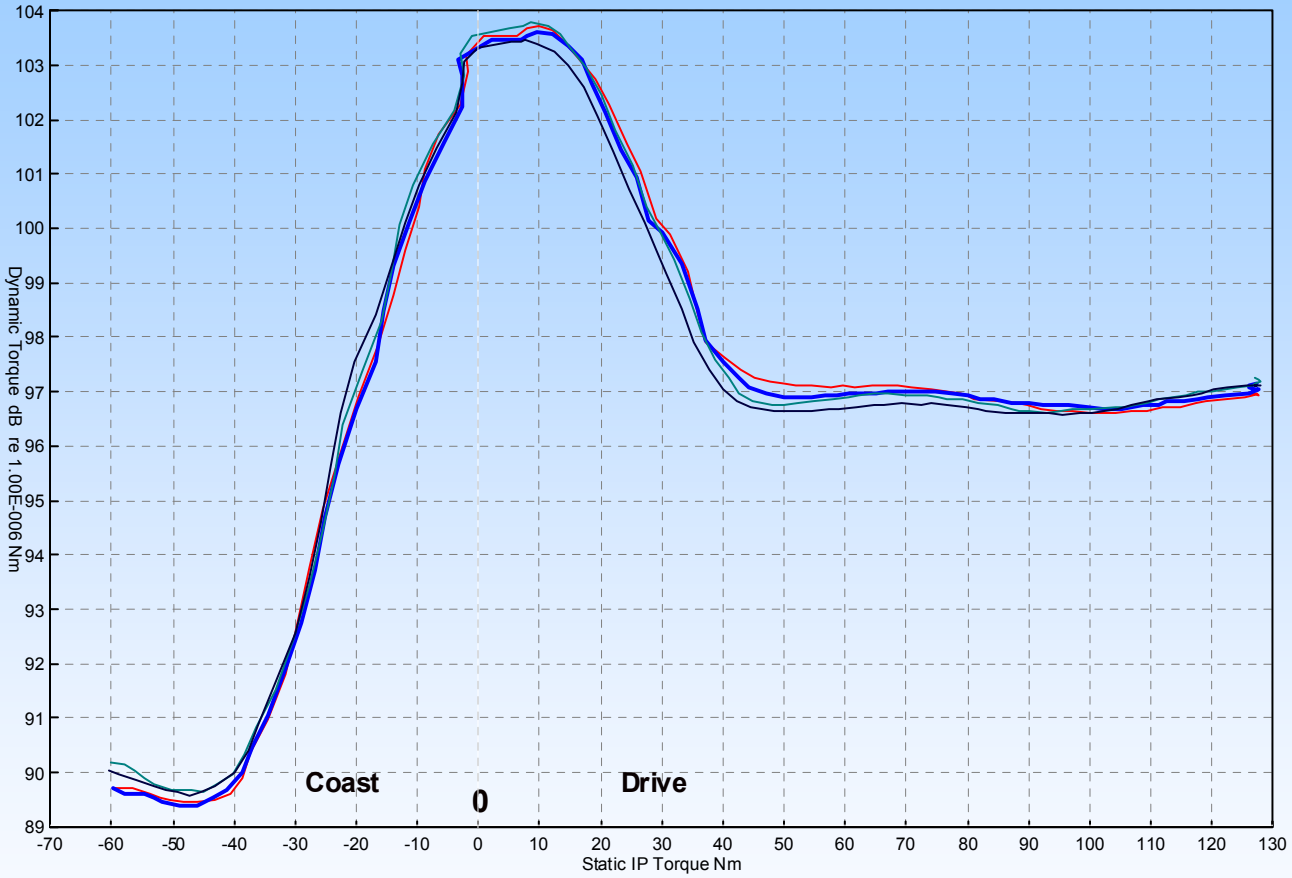
Test rig design.

- The results which follow are from test rigs which were specifically designed to minimise the effects of torsional resonances within the speed range of interest.
- Few test rigs for transmission noise are analysed at the design stage for torsional resonances.

Dynamic torque results at tooth mesh order – input shaft torque repeatability



Dynamic torque against static torque at constant speed when the torque is swept from coast to drive.
Repeatability within +/- 0.5 dB

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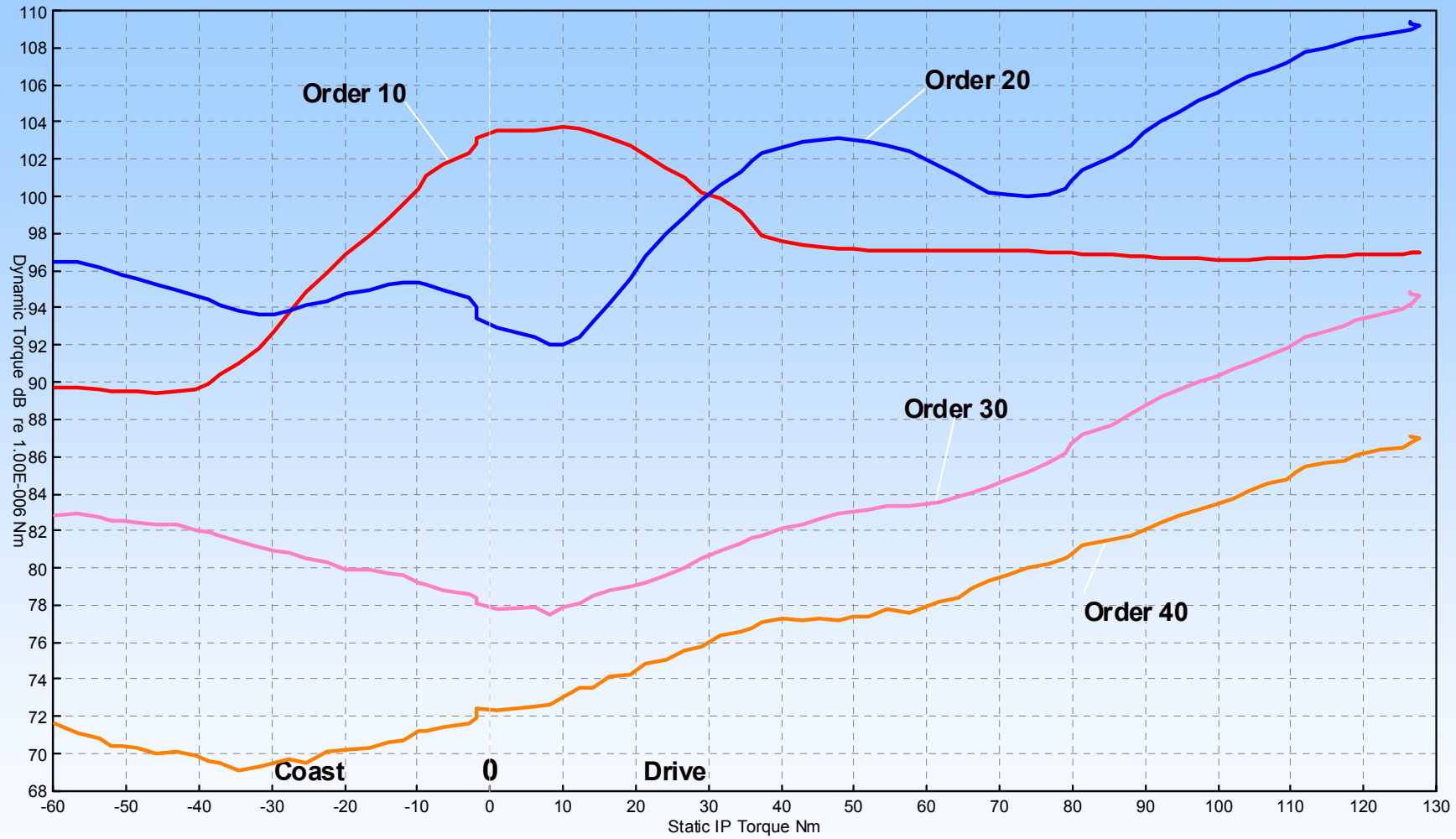
Harmonic content of dynamic torque signal



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Input shaft results.
To interpret these you need to know how important the harmonics are

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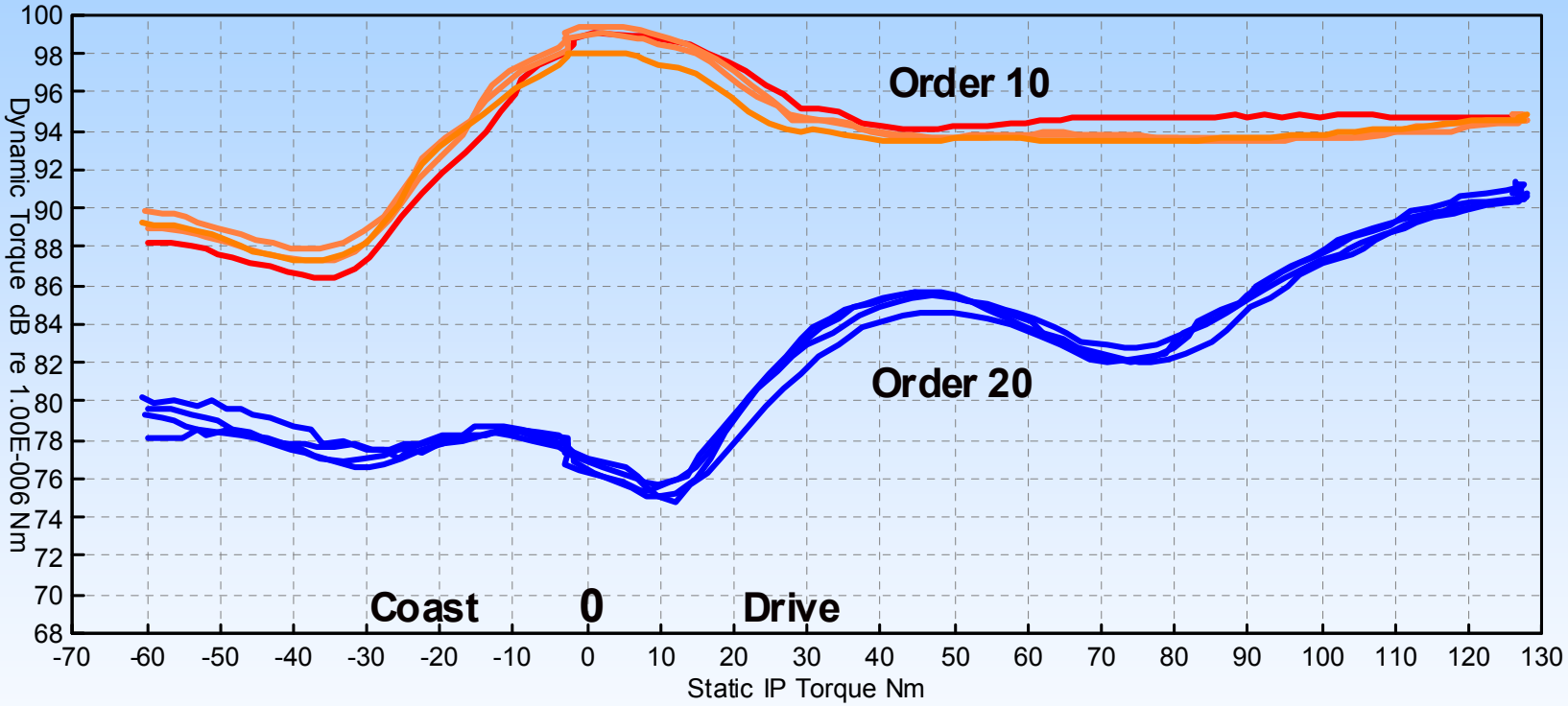
DYNAMIC TORQUE REPEATABILITY – OUTPUT SHAFT



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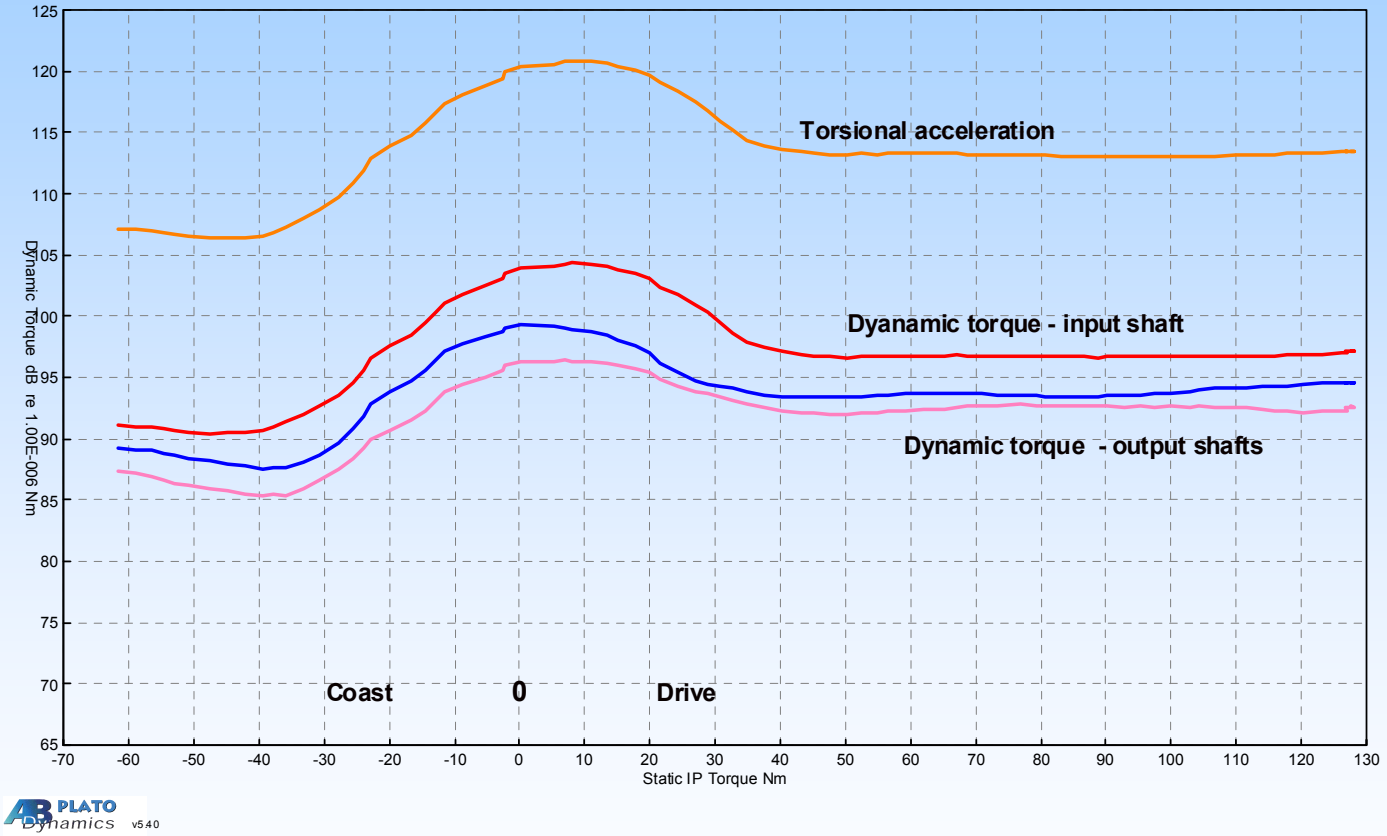
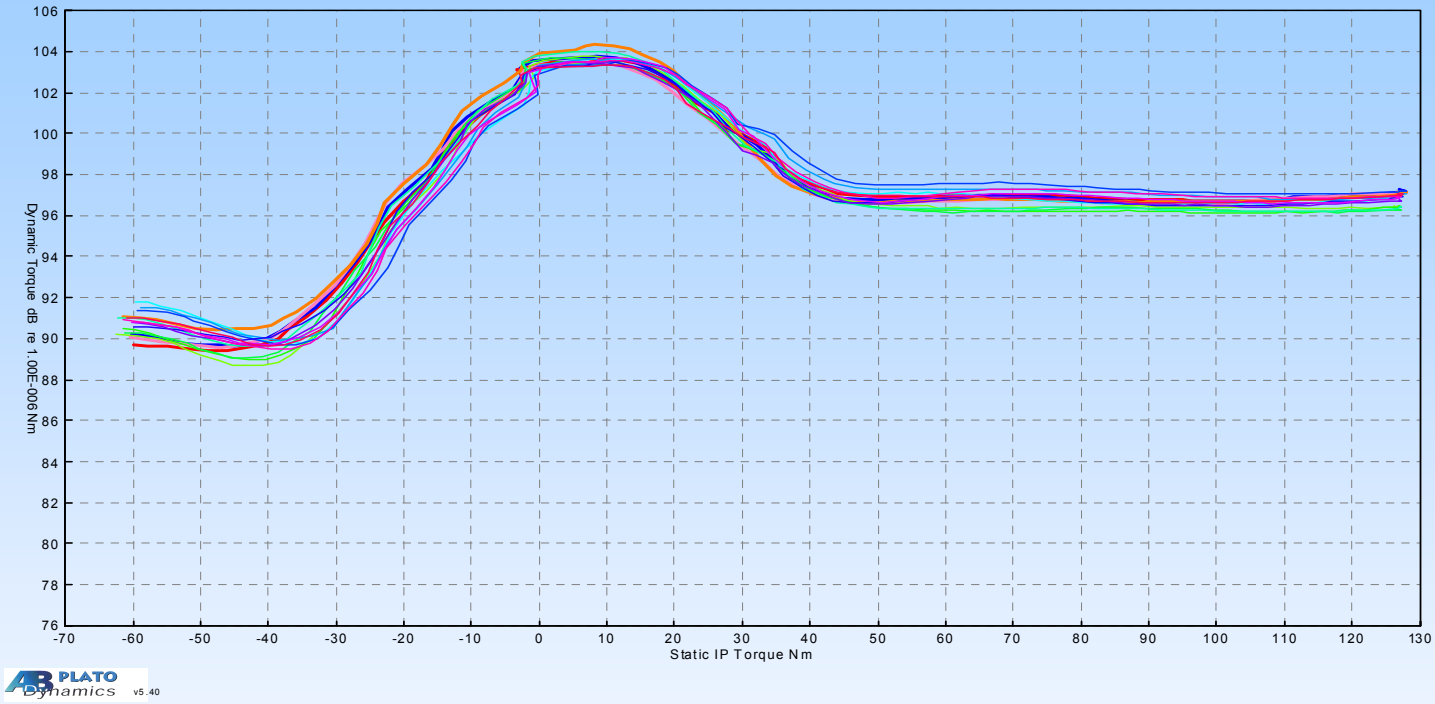
Comparison of dynamic torque and torsional acceleration results



On a good rig any of the torsional parameters can be used

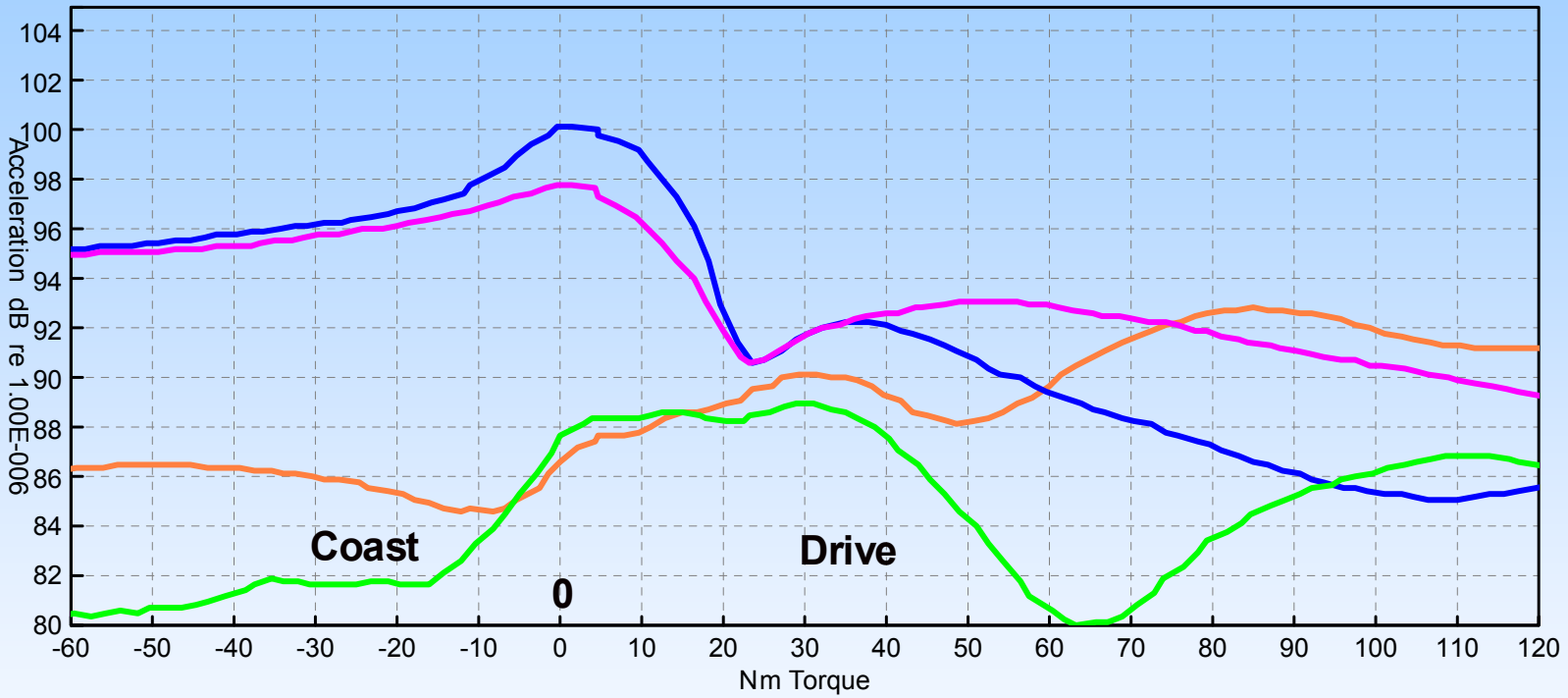
How robust is the process across test rig fixtures?



Same axle tested on 16 fixture configurations
All results were within +/- 1 dB range

Same axle tested on 3 test machines with 16 fixture combinations.
All results were within +/- 1.5 dB range

Range of results from torsional measurements - dynamic output shaft torque.



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Extreme results from production, showing 15 dB range and necessity of testing on both drive and coast.

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Conclusions

- Torsional measurements of vibration of axle shafts on test rigs are successful for end-of-line noise quality control.
- Torsional results on a rig correlate with subjective assessments in vehicles.
- Torsional acceleration or dynamic torque can be measured, to predict axle noise.
- Test rig design can have a large influence on the results.
- On well designed test rigs consistency across rigs and fixtures is excellent.

Visit stand 4430 in Hall 4 for further information.

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