Evaluation of Exhaust Brakes as Back Pressure Simulators on Engine Testbed

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Presentation Overview

- Introduction
- Test-bed development issue - exhaust brakes
- Resolving the issue with GT-Power
- GT-Power Results
- Summary and conclusions

Introduction

Background

- Customer project at MIRA - EMS re-calibration
- Full road exhaust must be fitted for calibration
- Exhaust development issue - design intent hardware not ready. Lead time on supply three weeks, calibration programme start one week
- Two week delay would have major impact on programme timing

Possible Solution

- Engine durability test bed installations routinely run with exhaust brakes to simulate back pressure condition. Could an exhaust brake be used to simulate back pressure for the calibration project ?
- Customer response: concerns over unrepresentative simulation of design intent exhaust system with exhaust brake
- Also, some uncertainty about actual back pressure design target

Underlying Questions

- Will an exhaust brake realistically simulate the road exhaust engine back pressure condition, at least for steady speed work ?
- For cycle mean or time-average back pressure - yes probably
- Impact on intra-cycle time pressure history at the exhaust valve - not known
- Impact on engine calibration - not known

Providing the Answers

- Could GT-Power be used to compare impact on engine performance of exhaust brake and full road exhaust systems - in principle, yes
- Practicable solution dependent on timescales - how long would the analysis take ?
- First assessment - two man days

Practicalities

- First, recognise that the question is a general one - adapt an existing model of a similar engine to save time.
- Drawings of exhaust ducting and silencer box available - construct coarse but representative models
- Limit investigation to the full load line
- Assessment methodology - examine wave profiles in the exhaust ports and impact on torque/mass flow characteristic

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Host GT-Power Model

- Calibration engine - North American V8
- Host engine for GT-Power analysis - smaller European V8. Same rated speed, similar BMEP
- Model developments/refinements:
  - > Silencer box model assembled
  - > Cam profiles and MOP timings
  - > Minor changes to exhaust manifold
  - > Minor changes to inlet system
  - > Limiting AFR provided by customer
  - > ‘Spark Advance’ provided by customer

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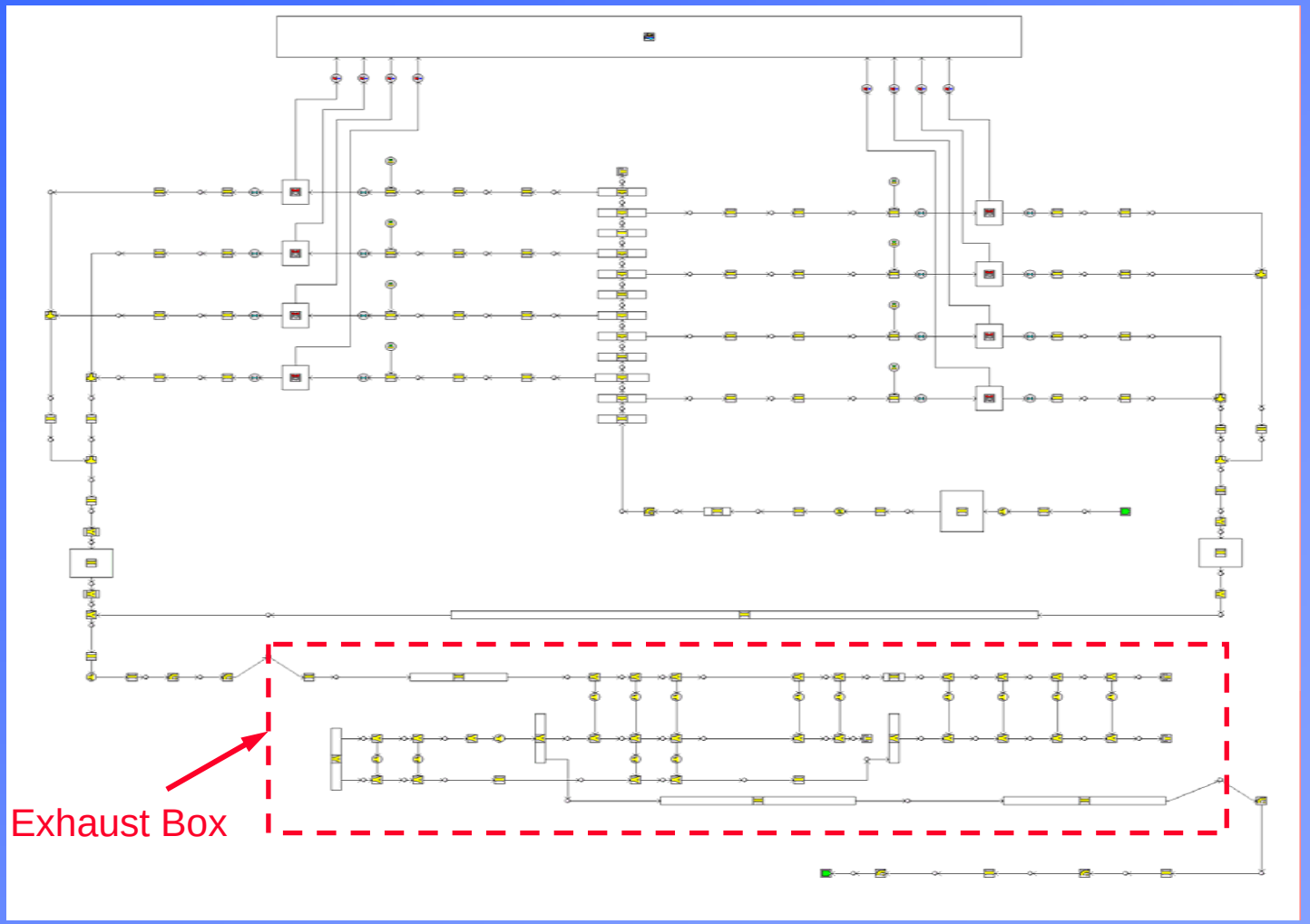
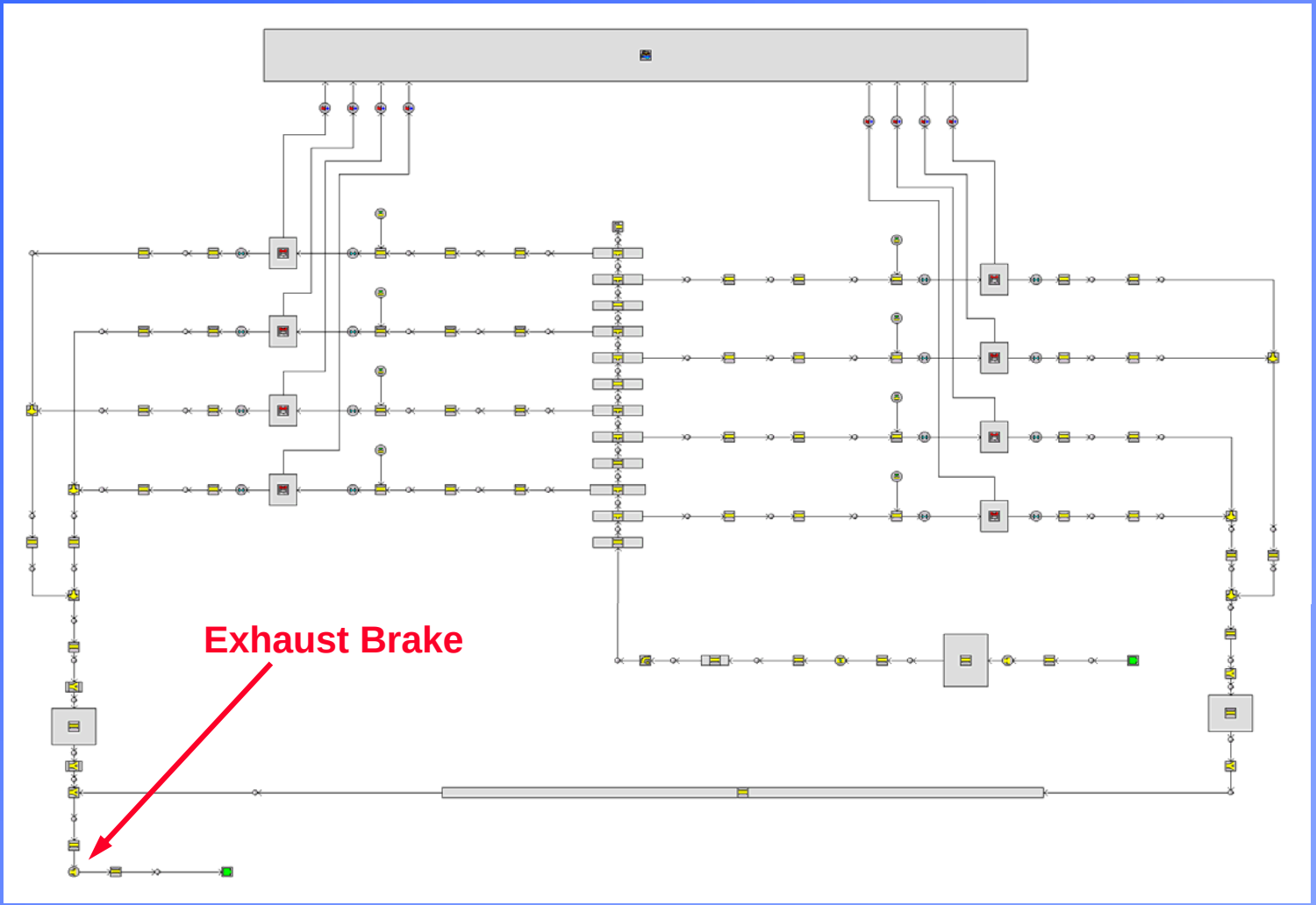
Engine With Full Exhaust



Engine With Exhaust Brake

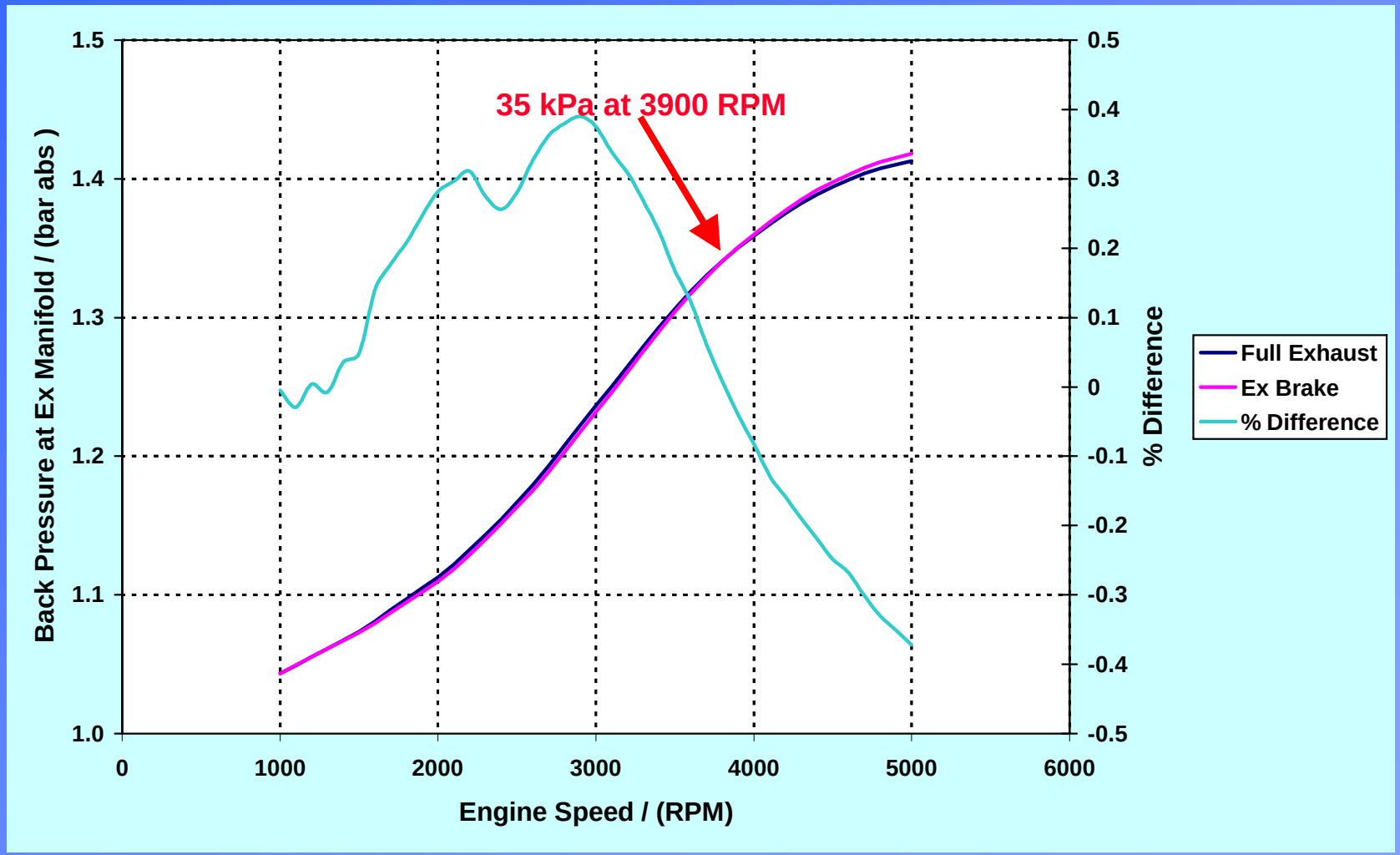


GT-Power Analysis

Exhaust Brake Sizing

- Back pressure target quoted as 35 kPa at 3900 RPM full load, upstream of catalyst
- Not known exactly where or which cylinder bank - available information vague/ambiguous
- Full exhaust and exhaust brake GT-Power models ‘tuned’ to meet 35kPa target

Exhaust Manifold Back Pressure



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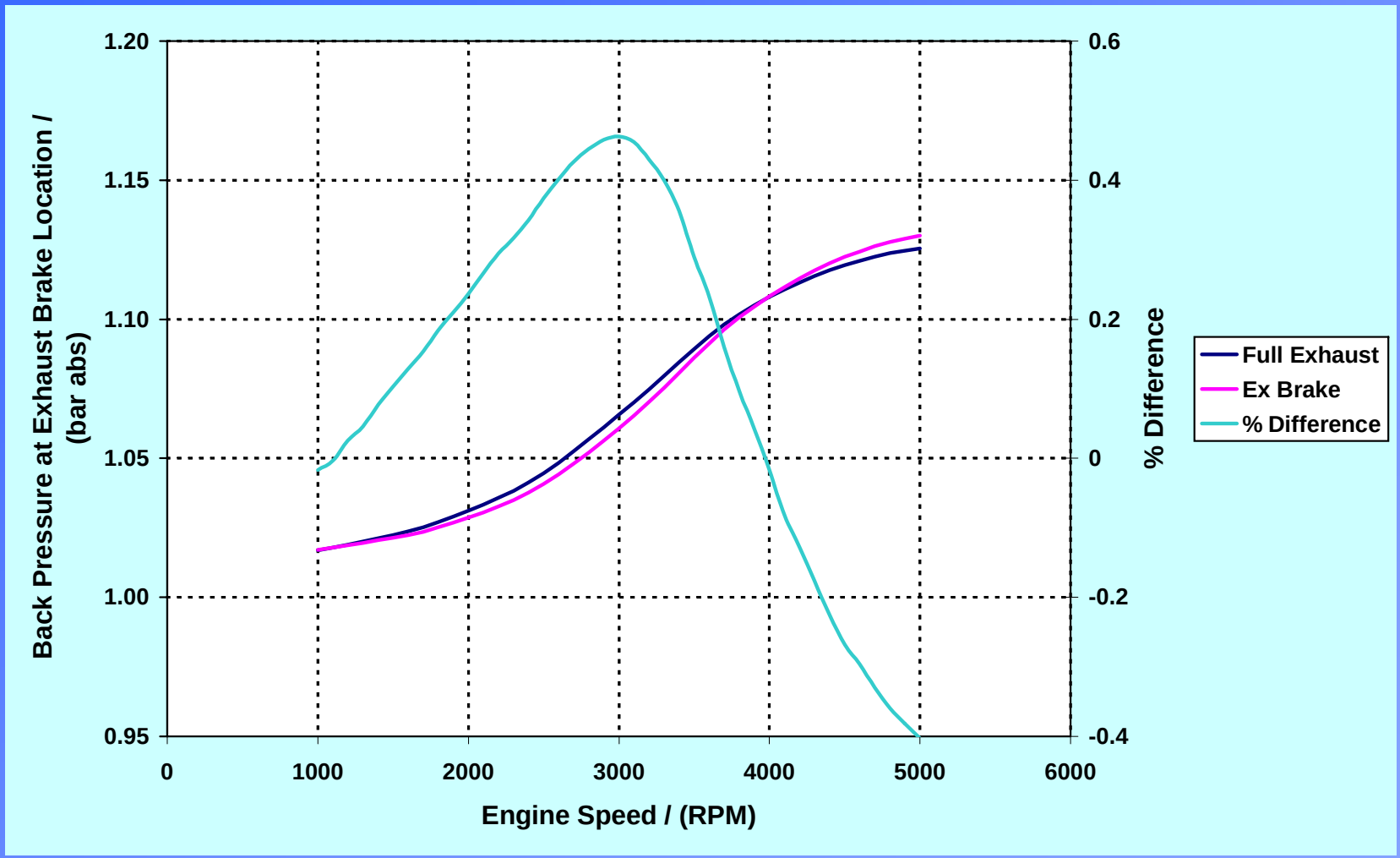
Exhaust Brake Back Pressure



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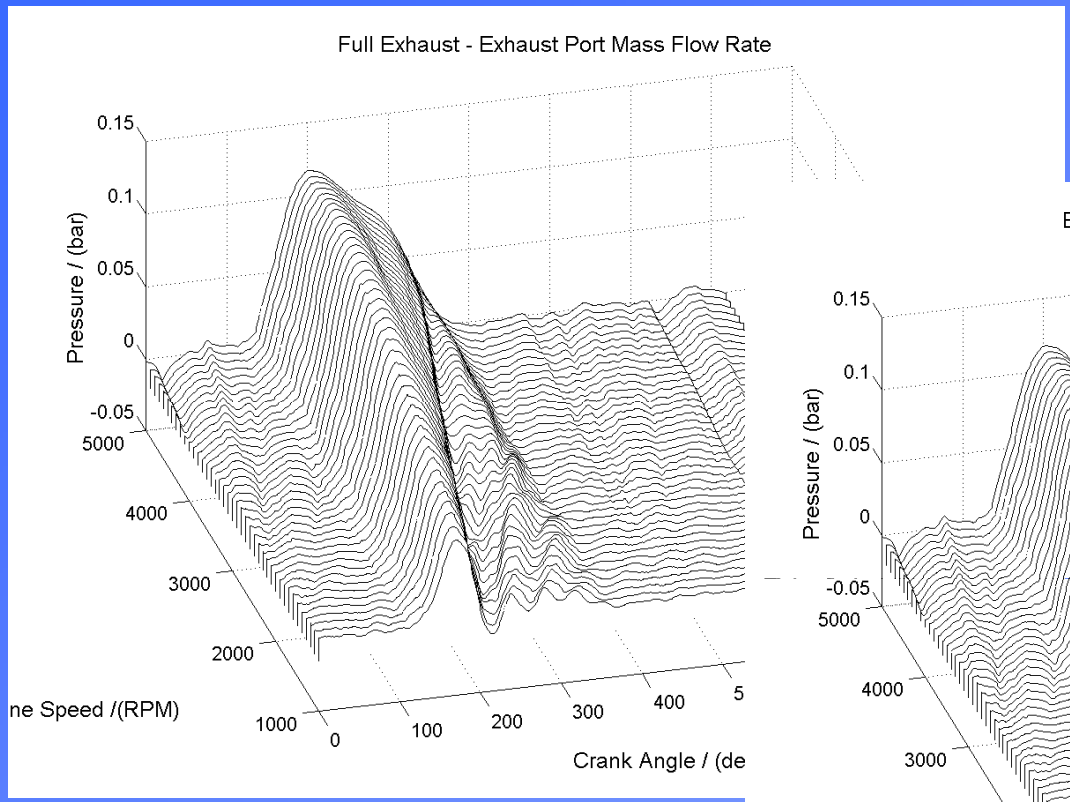
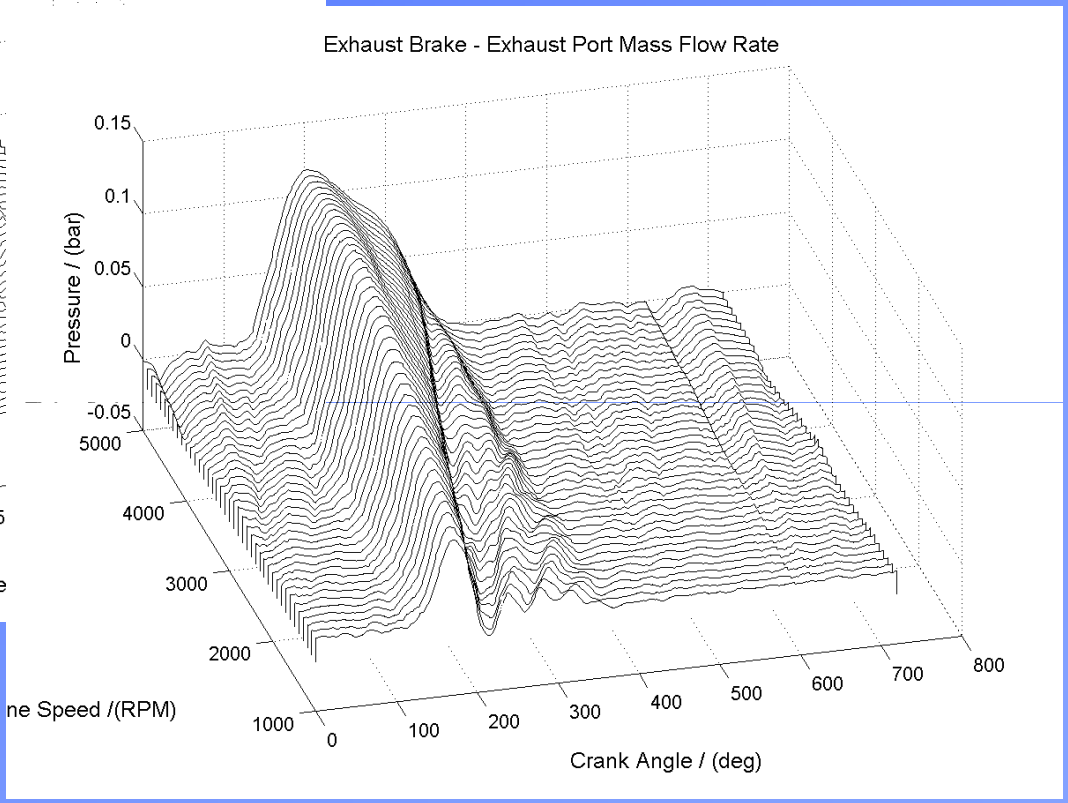
GT-Power Runs

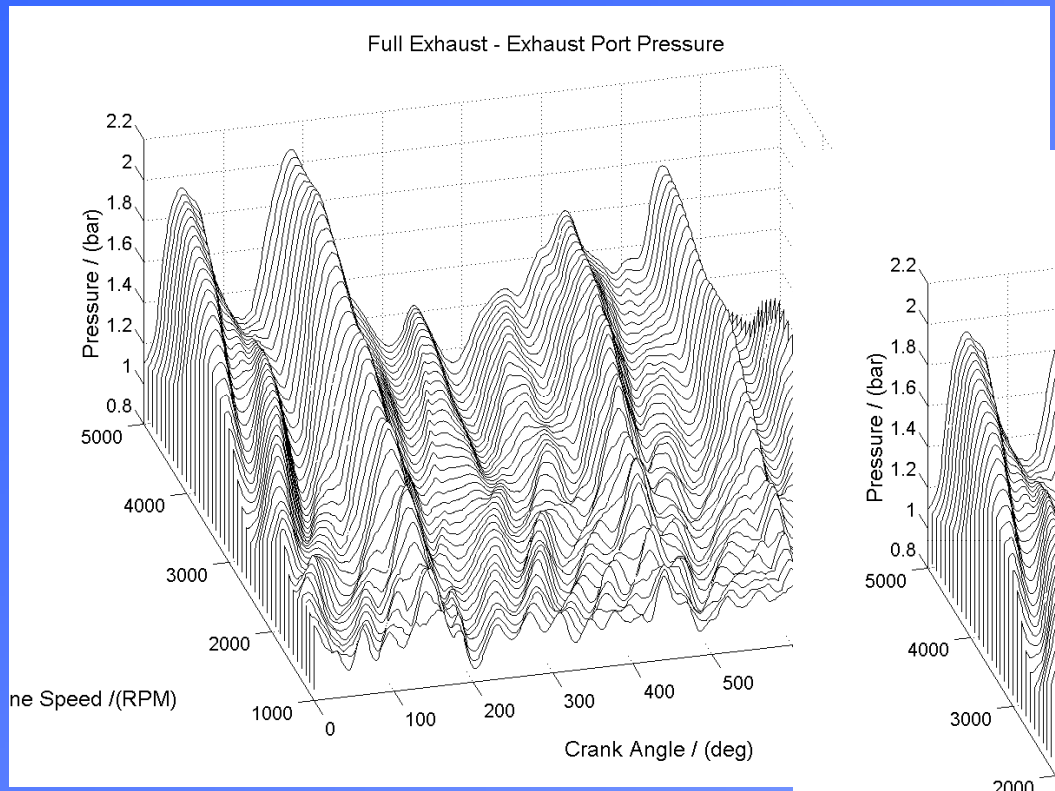
- Both models run over full-load speed range at 100 RPM intervals
- Crank angle based pressures and mass flows output at all speeds
- Selected cycle-averaged performance parameters also output
- So, let’s first of all have a qualitative look at the results

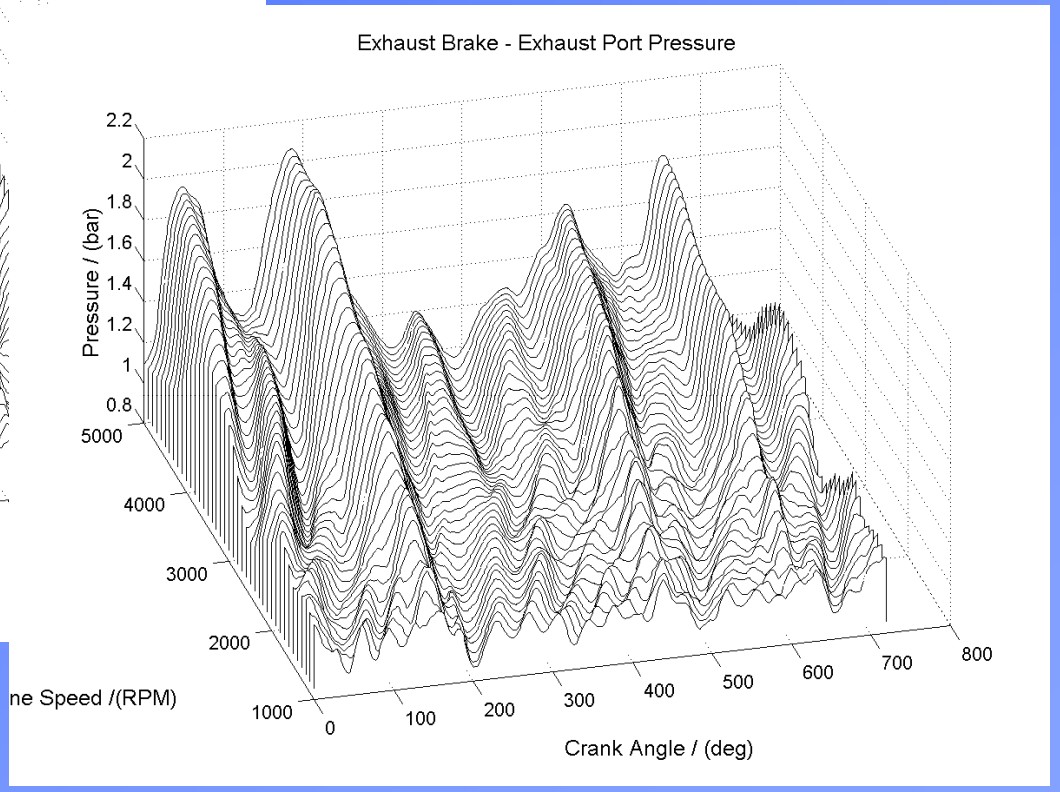
Exhaust Port Mass Flow





Exhaust Port Pressure





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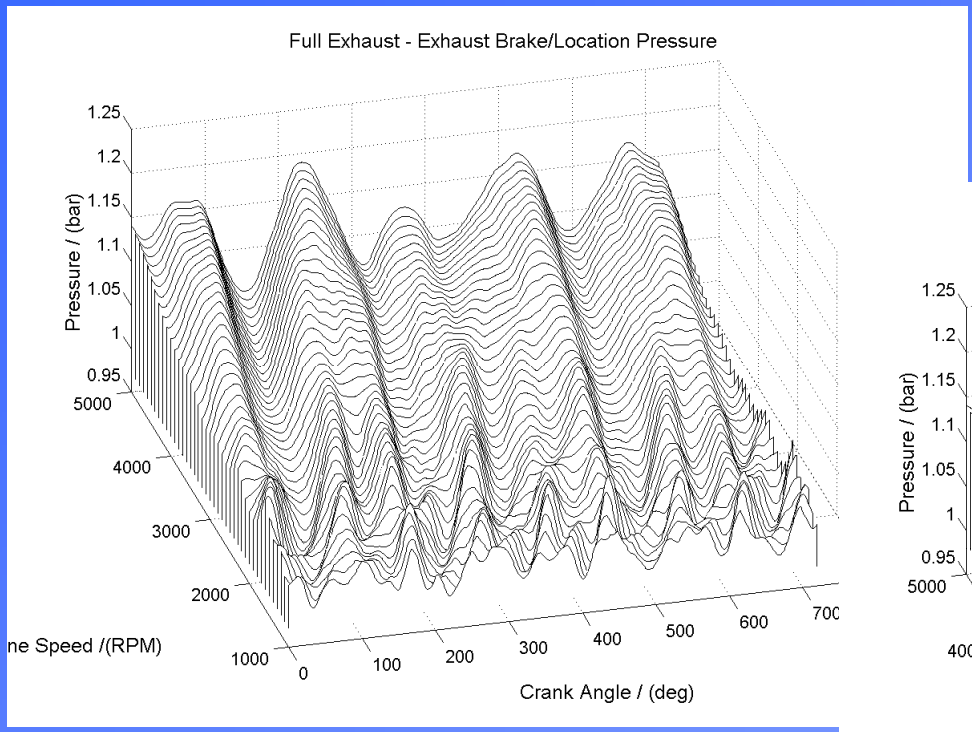
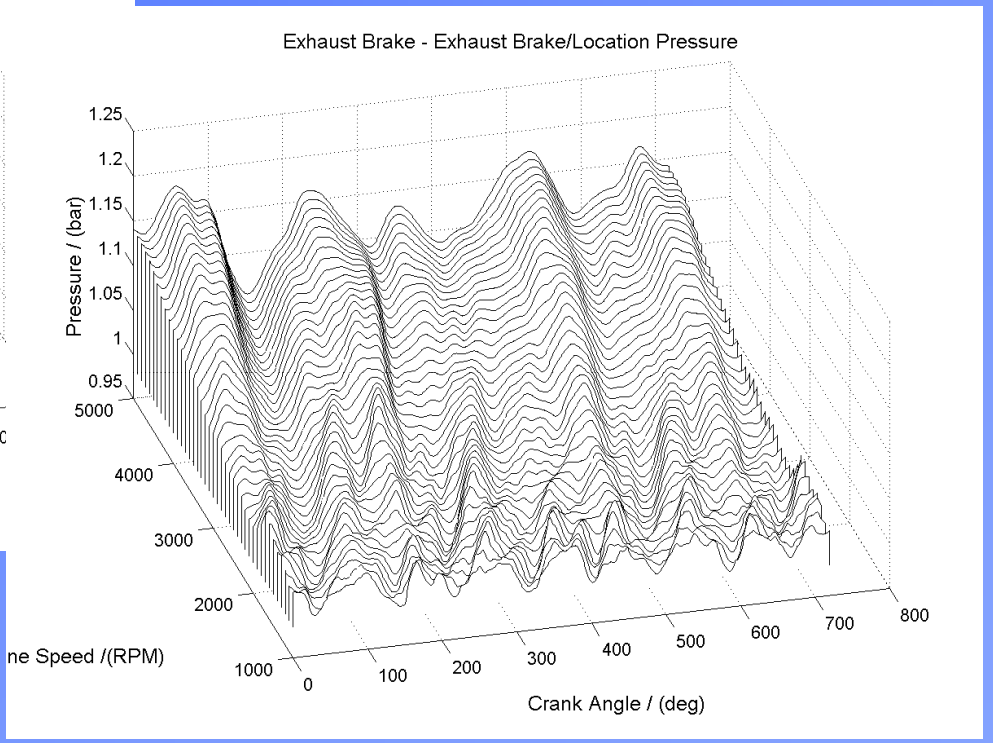
Exhaust Brake Pressure





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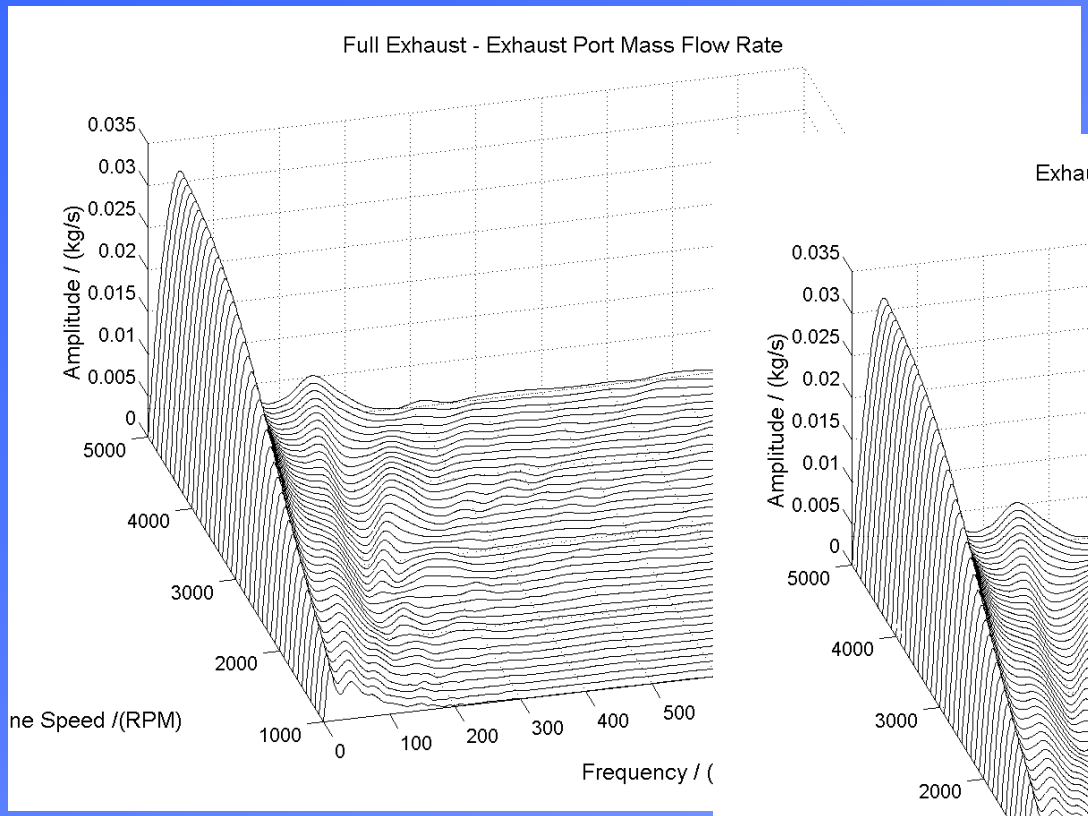
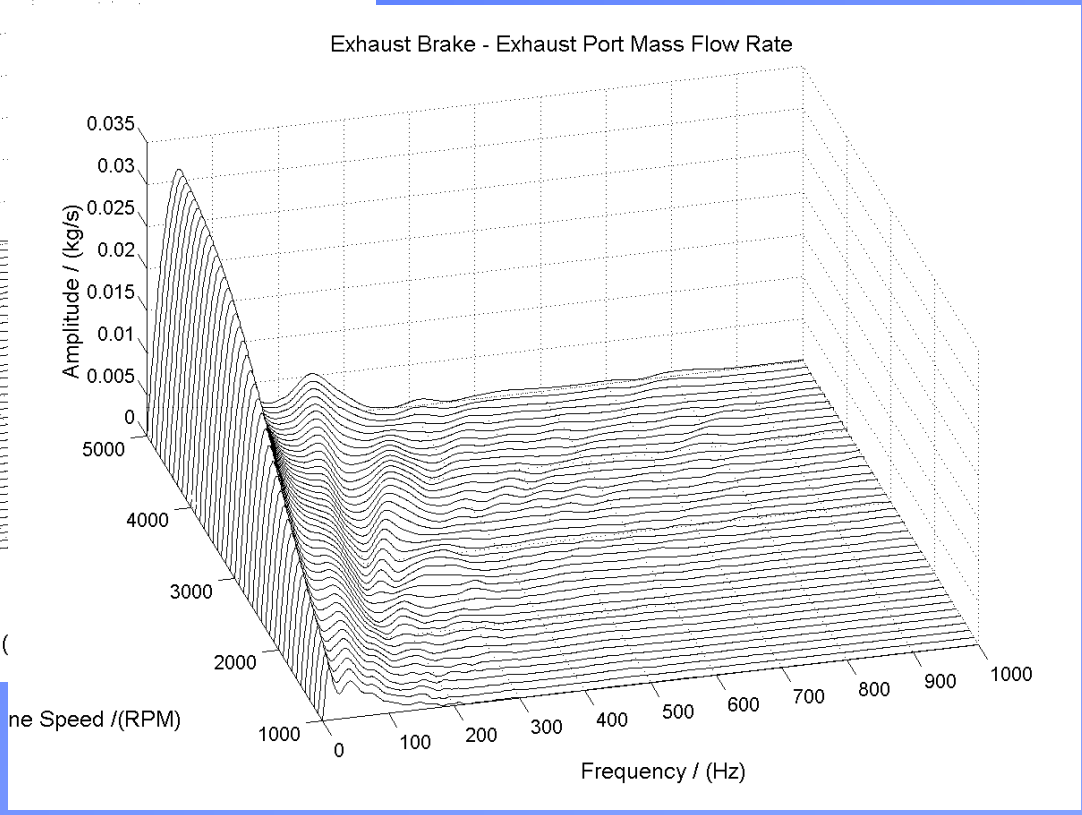
Frequency Domain Analysis

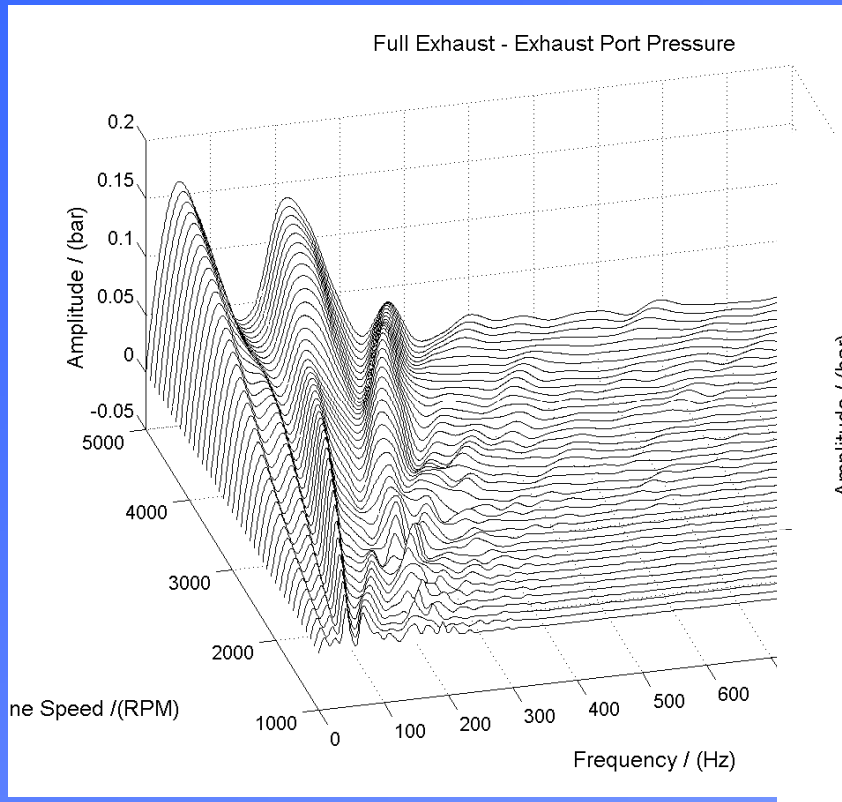
- Useful tool for qualitative and quantitative analysis of wave data
- Improved sensitivity - differentiation of results
- Steady speed engine operation produces periodic waveforms, no need for ‘windowing’, no risk of spectral ‘leakage’
- Reveals engine order based information

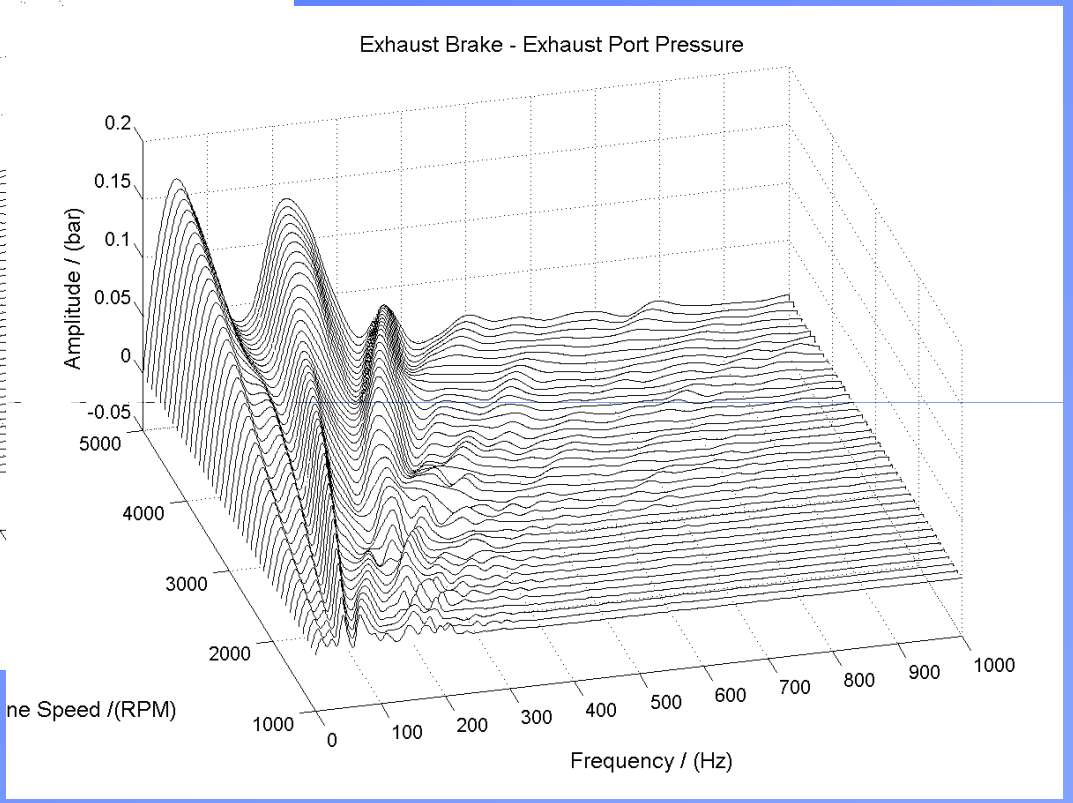
Exhaust Port Mass Flow



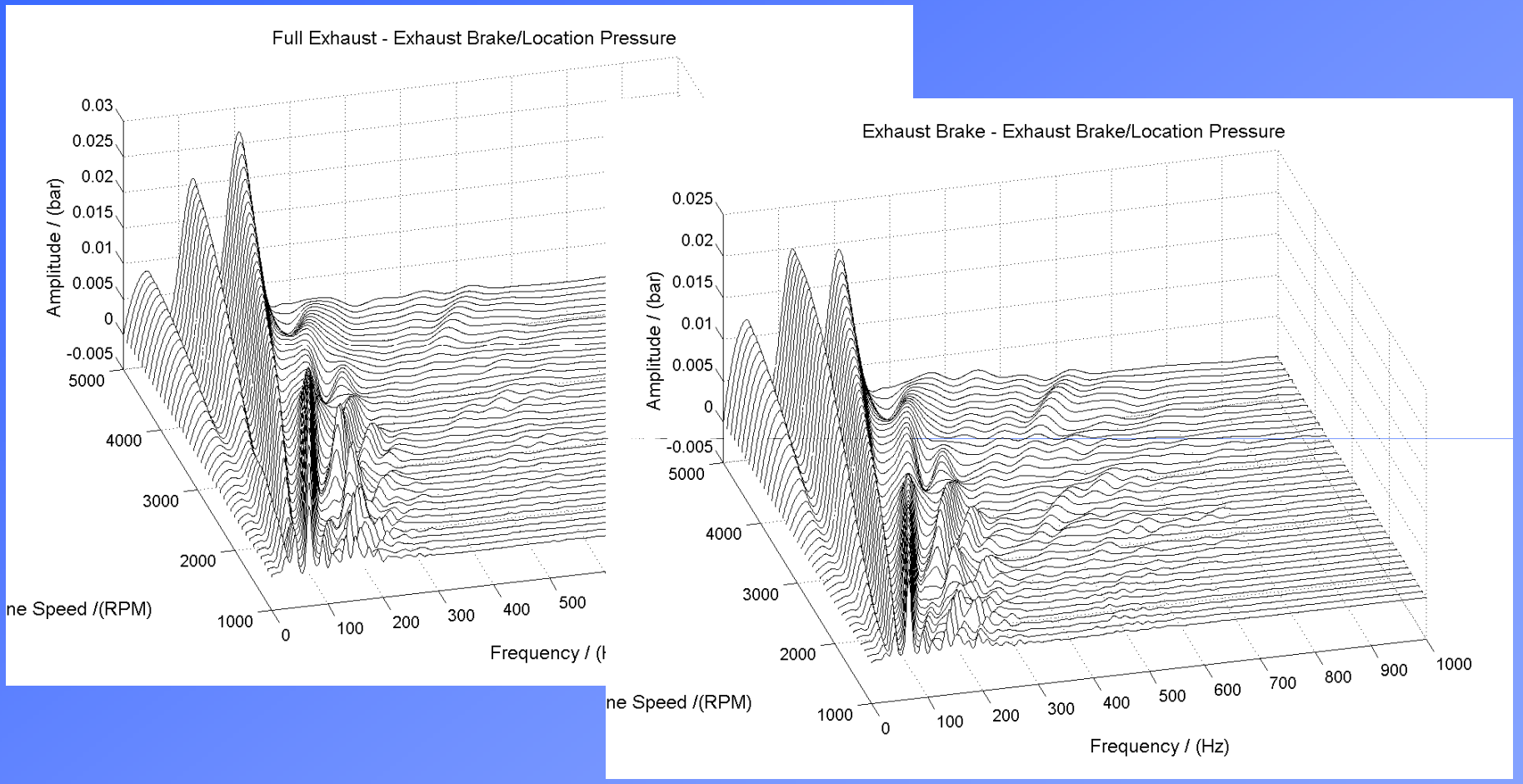


Exhaust Port Pressure

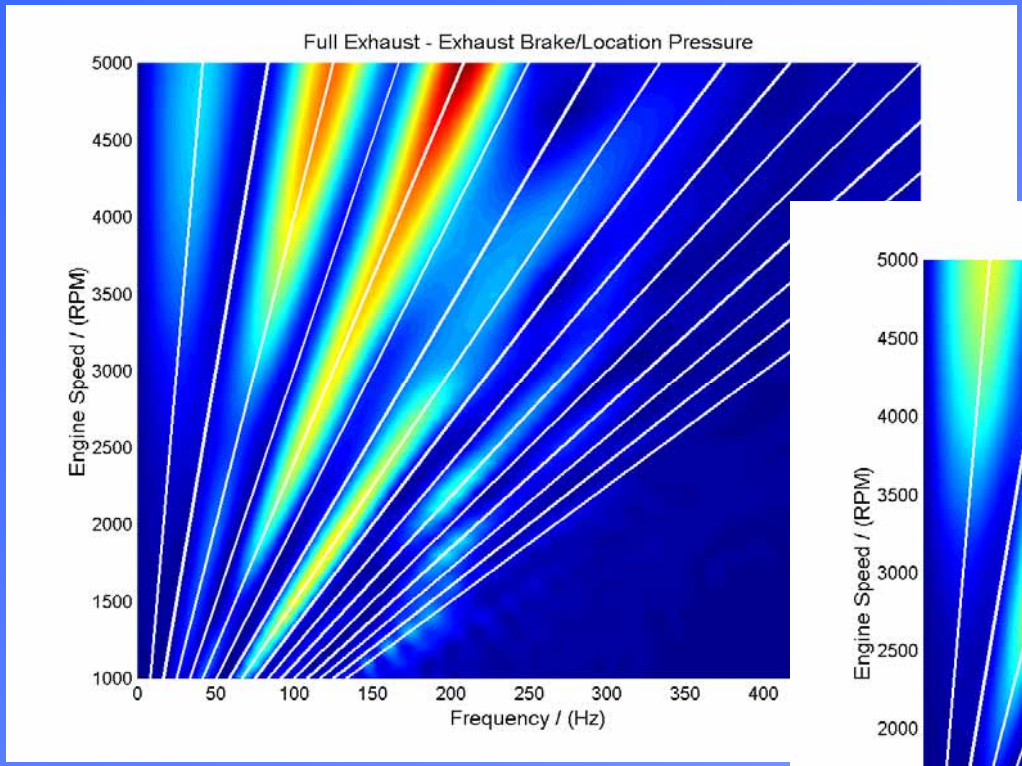


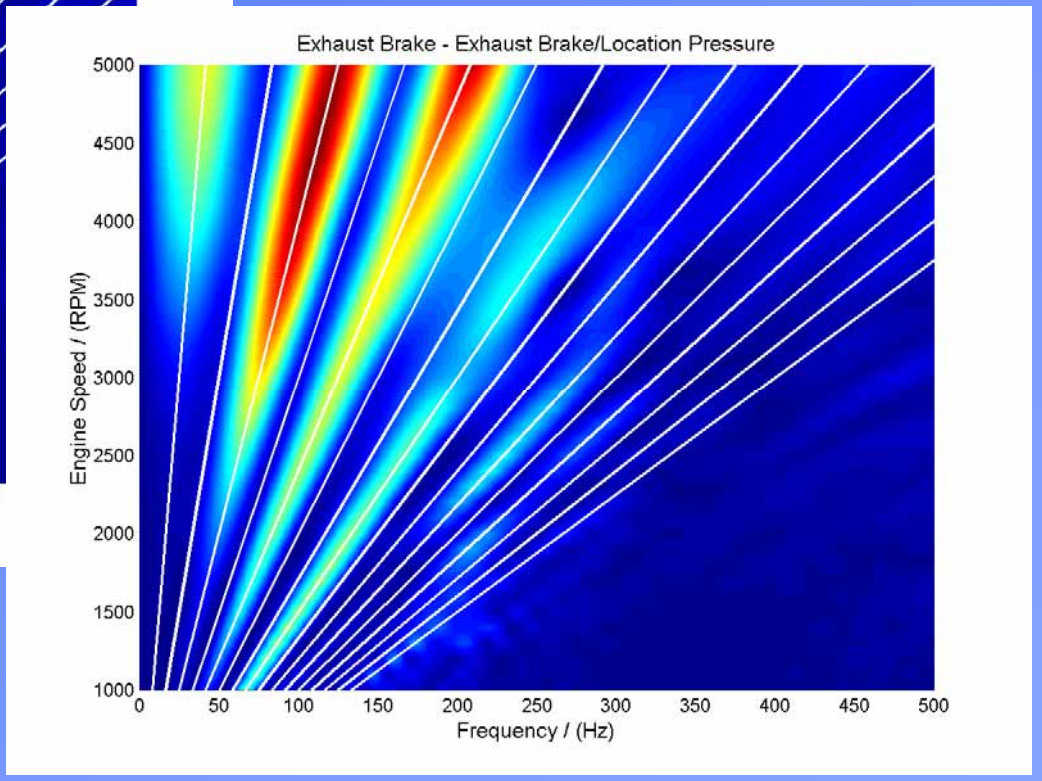


Exhaust Brake



Campbell Plots - Exhaust Brake





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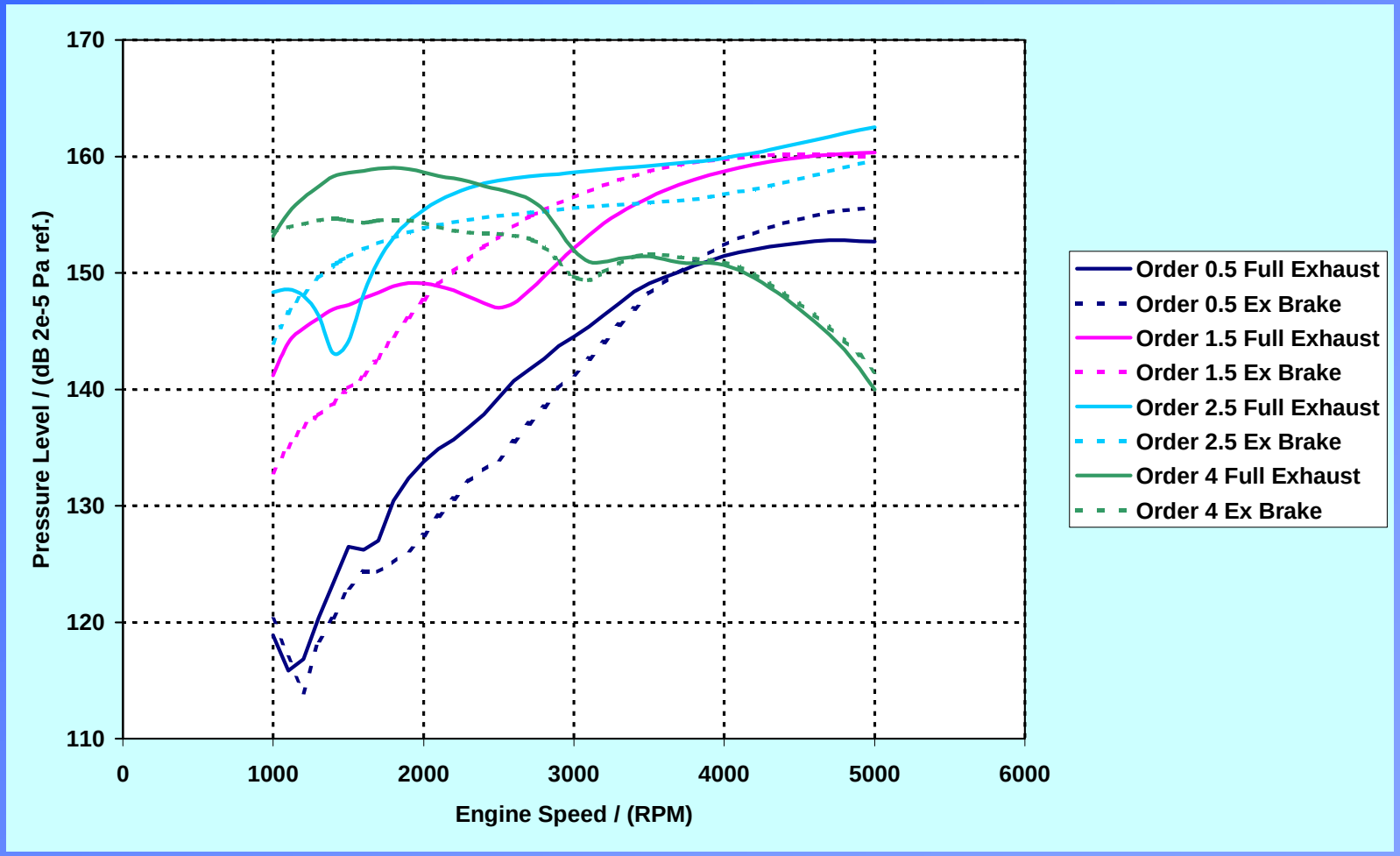
Order Cut Comparisons



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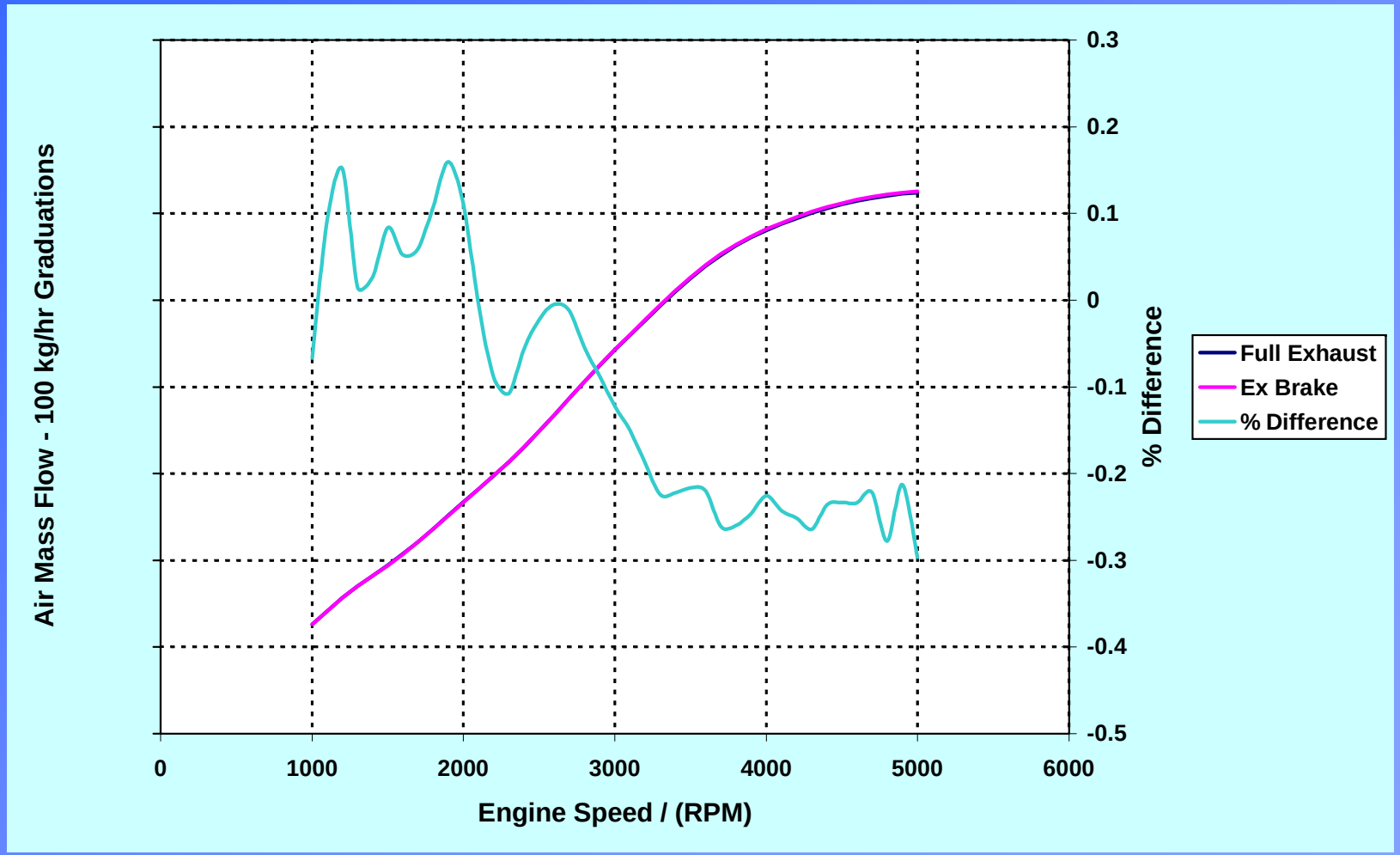
Impact on Engine Performance ?

- So, there are differences in the spectral content of the manifold waveforms. But, what is the impact on engine performance, if any ? Let's look at three parameters:

- Air mass flow rate
- Brake torque
- PMEP

Air Mass Flow Rate



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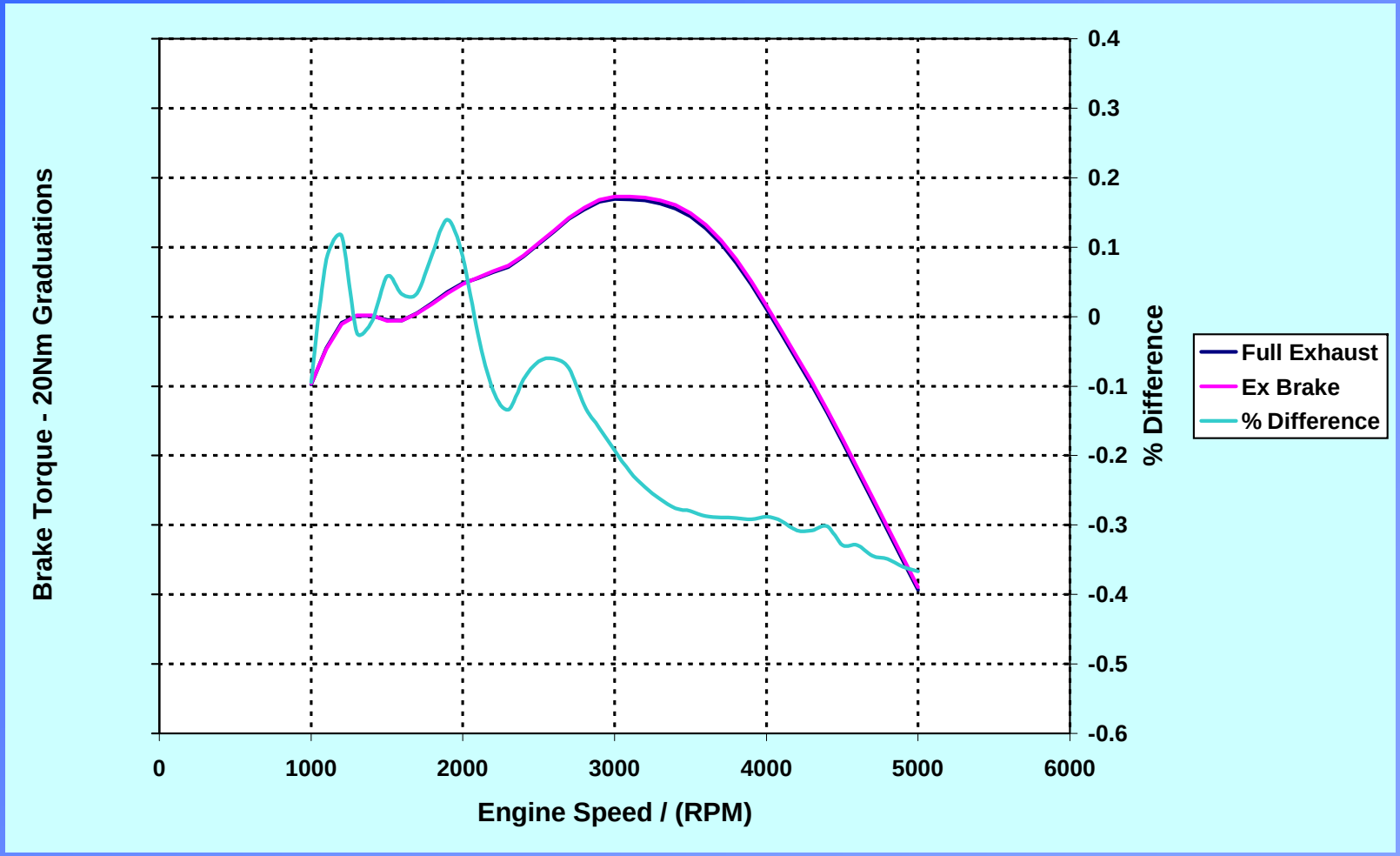
Brake Torque



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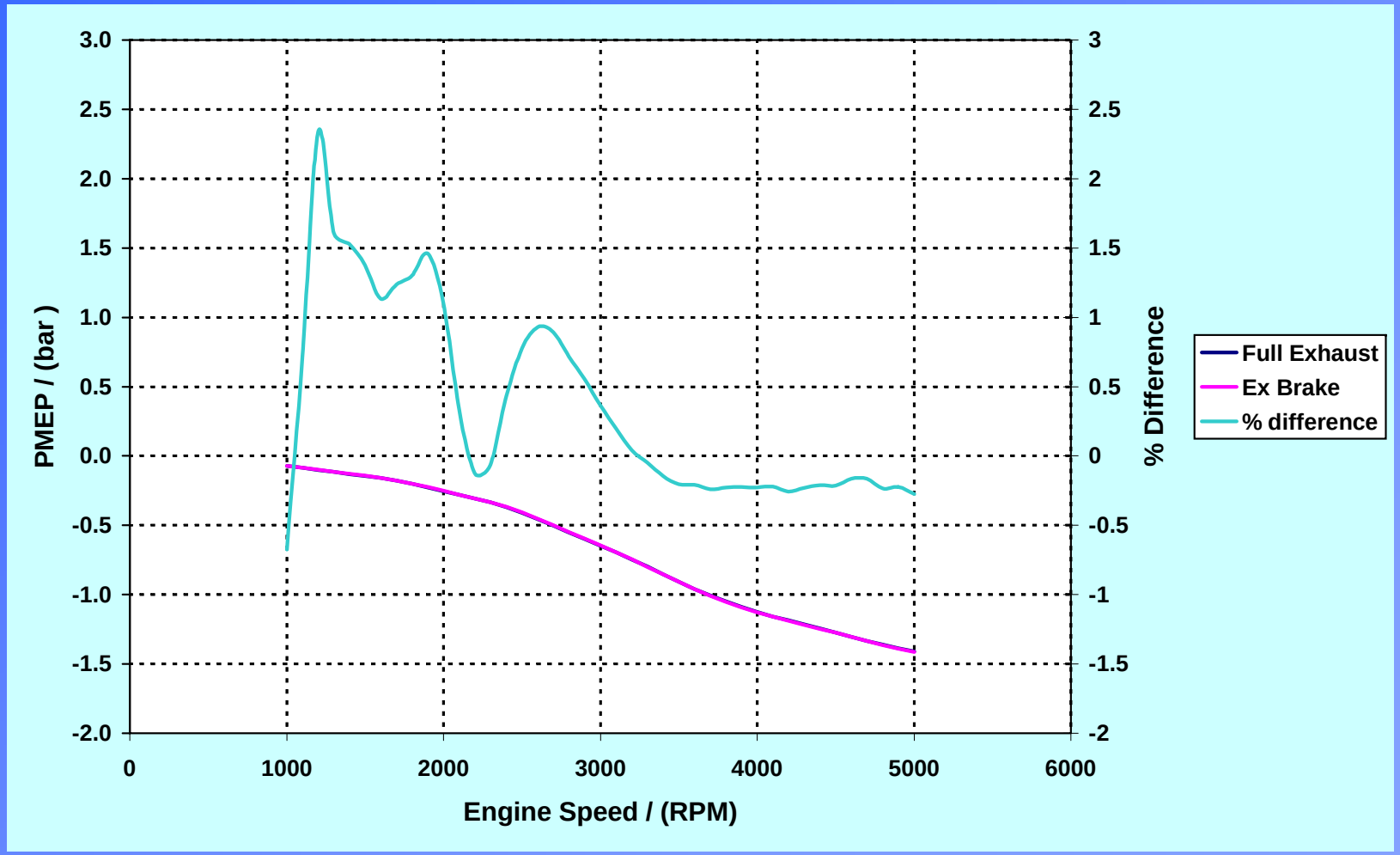
PMEP


PMEP / (bar)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
-1.0
-1.5
-2.0
% Difference
3
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
0
1000
2000
3000
4000
5000
6000
Engine Speed / (RPM)
Full Exhaust
Ex Brake
% difference

Epilogue

- Based on the GT-Power analysis the customer calibration programme was able to commence prior to the arrival of the exhaust hardware
- Valuable programme time was saved
- Subsequent revisiting of calibration sites on the engine maps after the road exhaust had been fitted showed no significant deviation in repeatability of engine performance

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Summary and Conclusions

- Exhaust brakes can be used on test bed to realistically simulate full road exhaust systems
- The value of GT-Power as a rapid evaluation tool for engine performance assessment has been demonstrated
- The case study presented is a typical example of the way in which state-of-the-art analysis tools are applied by MIRA in it’s consultancy activities