ATPS

ASIA TURBOMACHINERY & PUMP SYMPOSIUM

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A FEM APPROACH TO PREDICT ACOUSTIC RESONANCE IN MULTISTAGE CENTRIFUGAL PUMP

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INTRODUCTION

CASE STUDY 1

FEM ANALYSIS OF CASE STUDY 1

CASE STUDY 2

VALIDATION OF NEW METHOD OF ANALYSIS

CONCLUSIONS

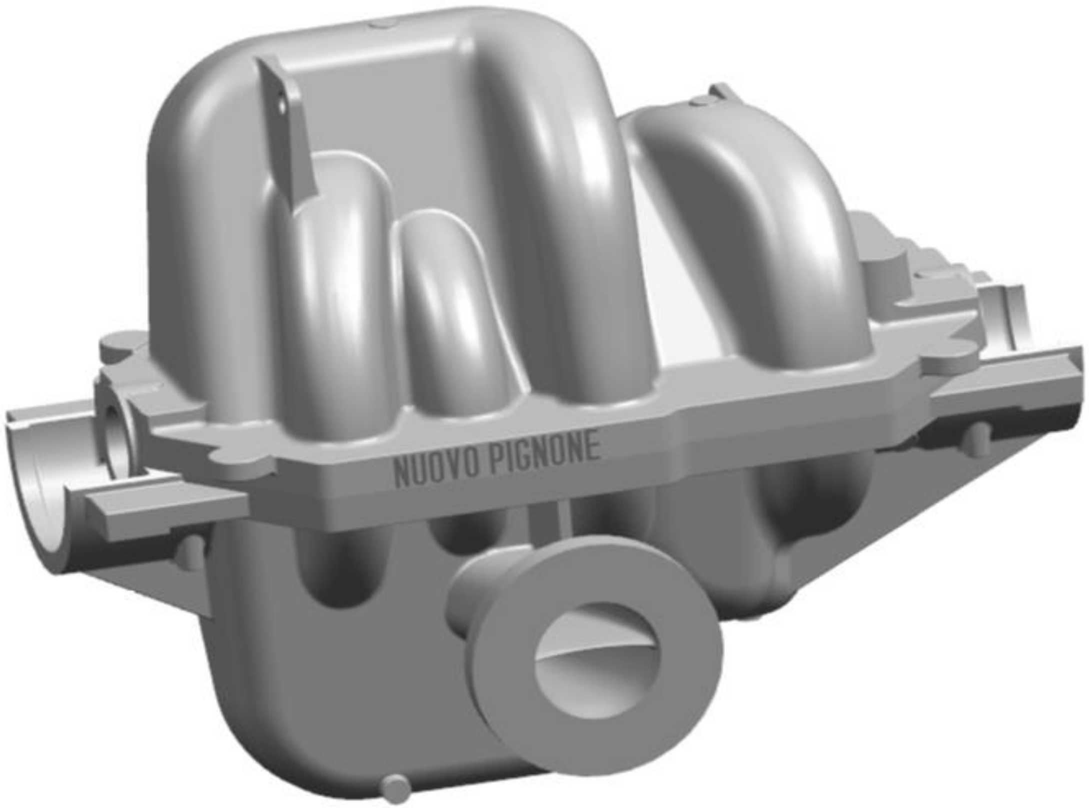
INTRODUCTION

- In the past, minimal consideration of pressure pulsation
- Experimental estimation of active length and correlation
- Wider range of velocity increased the possibility to match the natural frequencies of the system
- Low accuracy of prediction related to the uncertainties of the fluid characteristics and active length
- Small change in the working conditions can produce a significant effect

CASE STUDY 1

For an Ammonia project:

- 8x13 BB3 (Axially split, multistage, between bearing)
- double suction
- 3 stages
- 3000 rpm

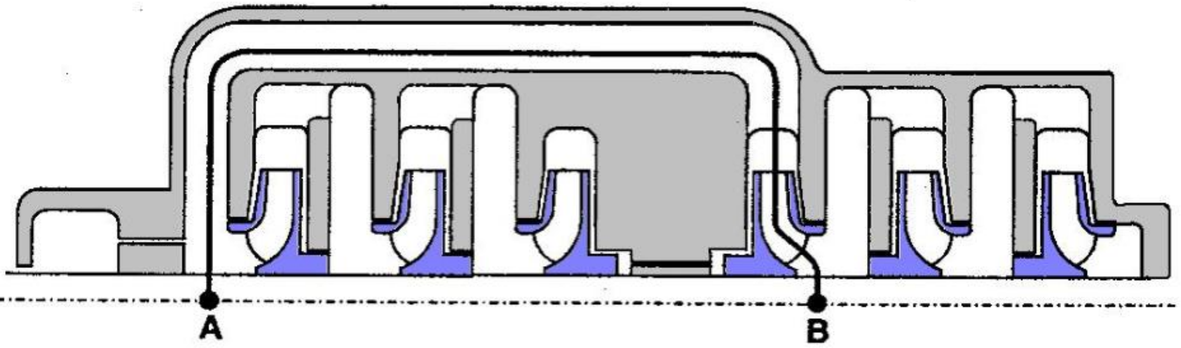


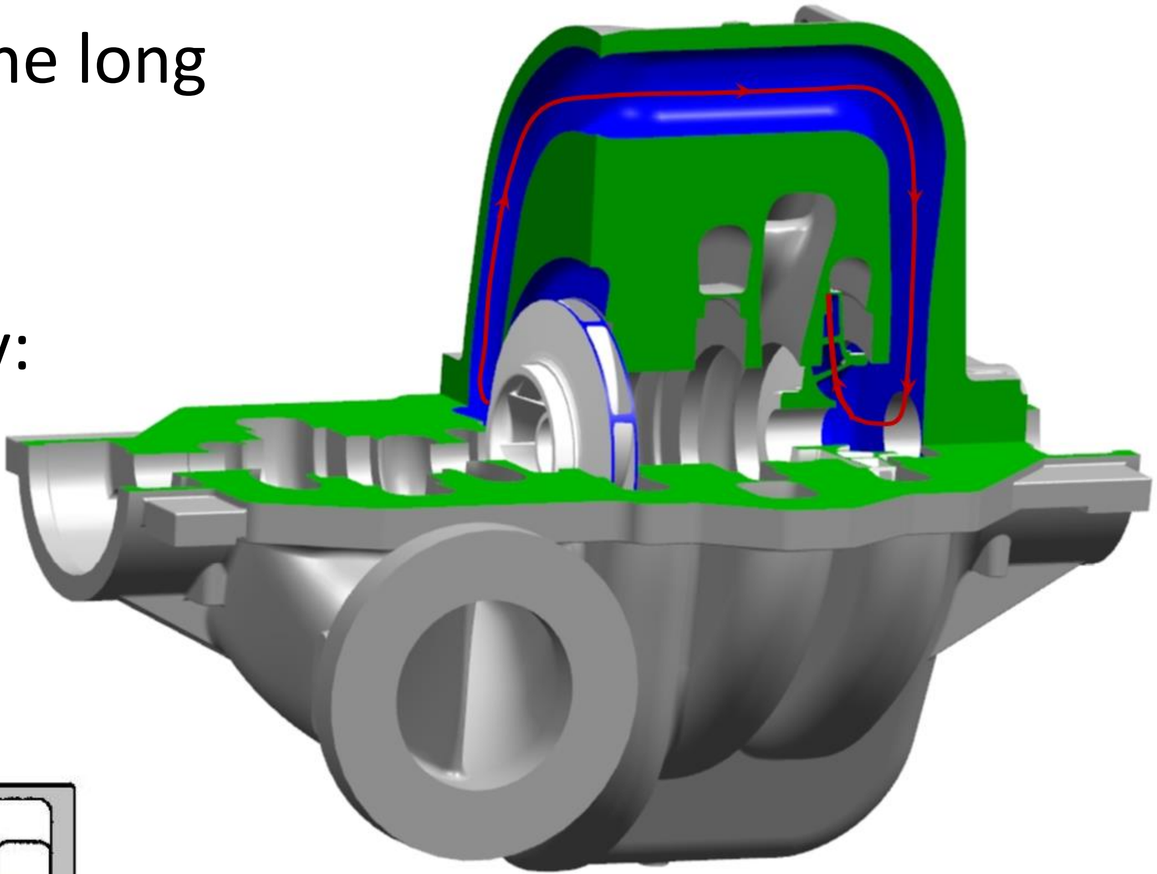
CASE STUDY 1

Estimation of Equivalent length of the long crossover channel

Acoustic Resonance frequency:

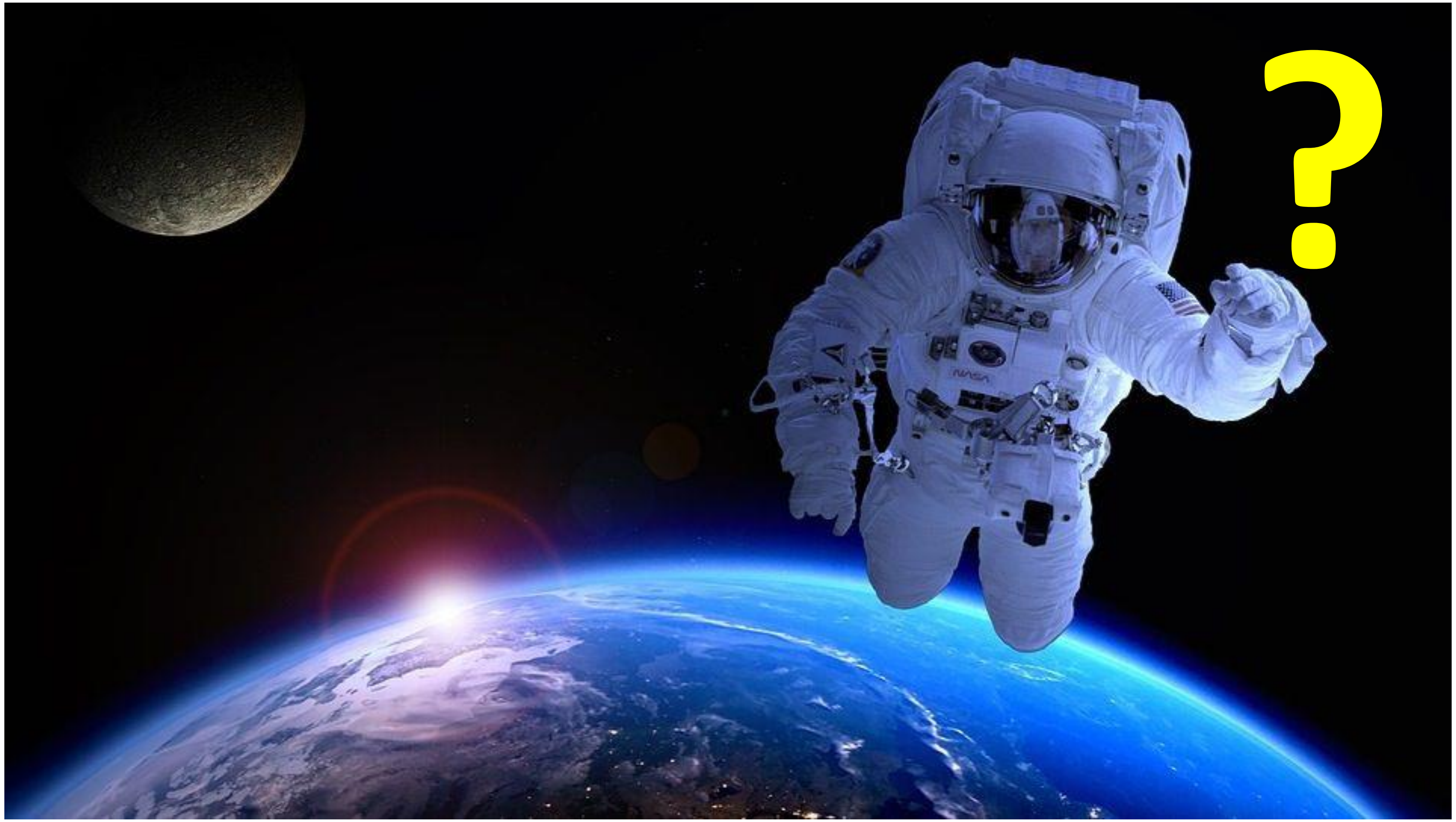
$$AR_{frequency} = \frac{sound\ speed}{equivalent\ lenght}$$





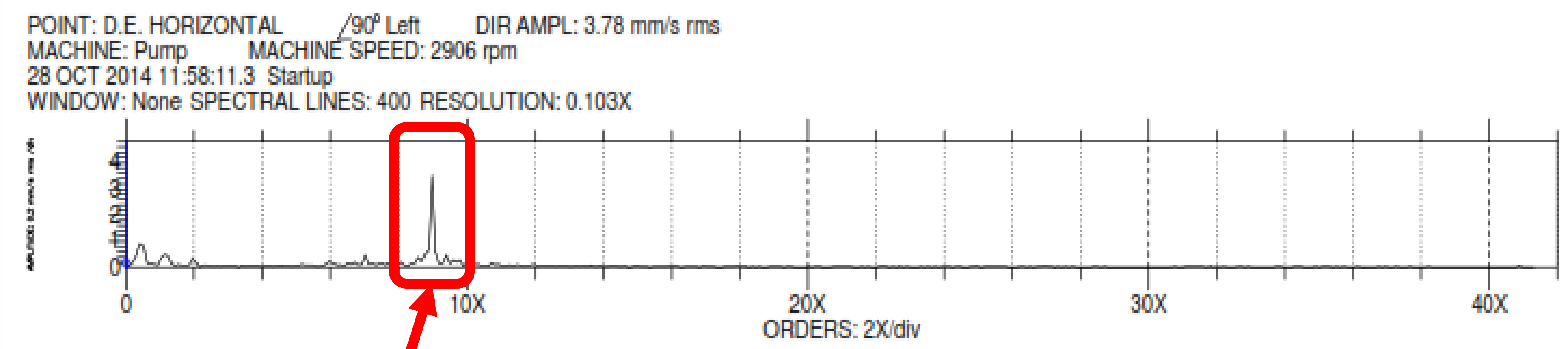
CASE STUDY 1

HOUSTON we have a problem



CASE STUDY 1

High values of the overall direct amplitude at the vertical DE at 3000 rpm.



9X → BFP

Test at higher speed (more than 3000rpm) → Vibrations in tolerance.

↓

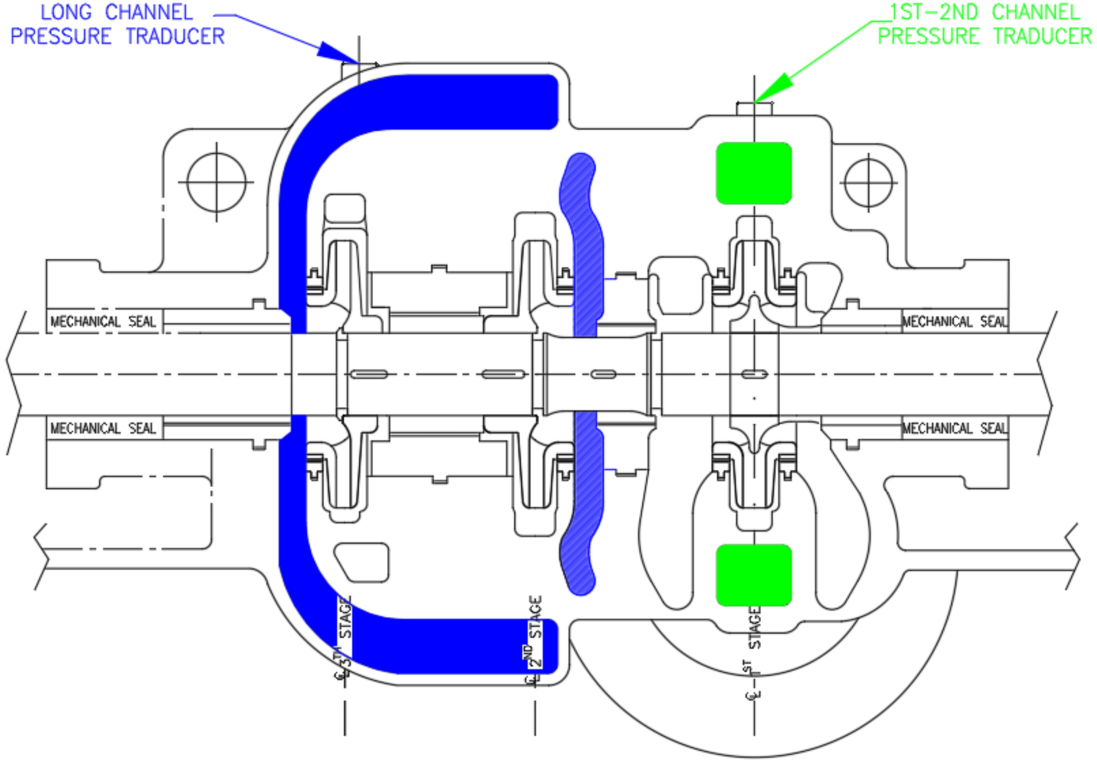
Not hydraulic alternative force

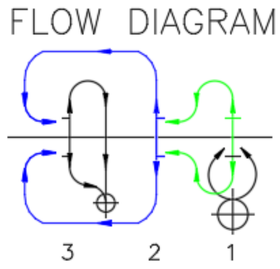
CASE STUDY 1

Dynamic transducers

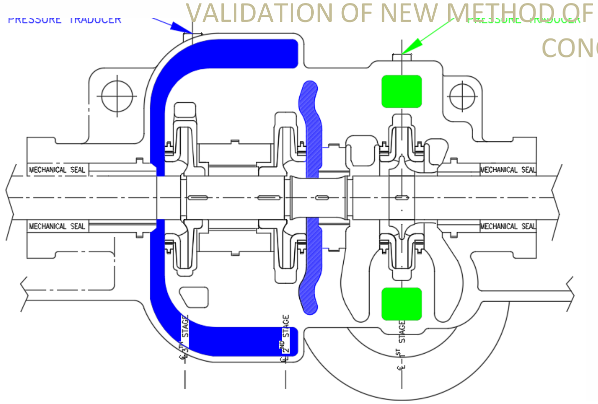
↕

acoustic phenomena in the hydraulic channels



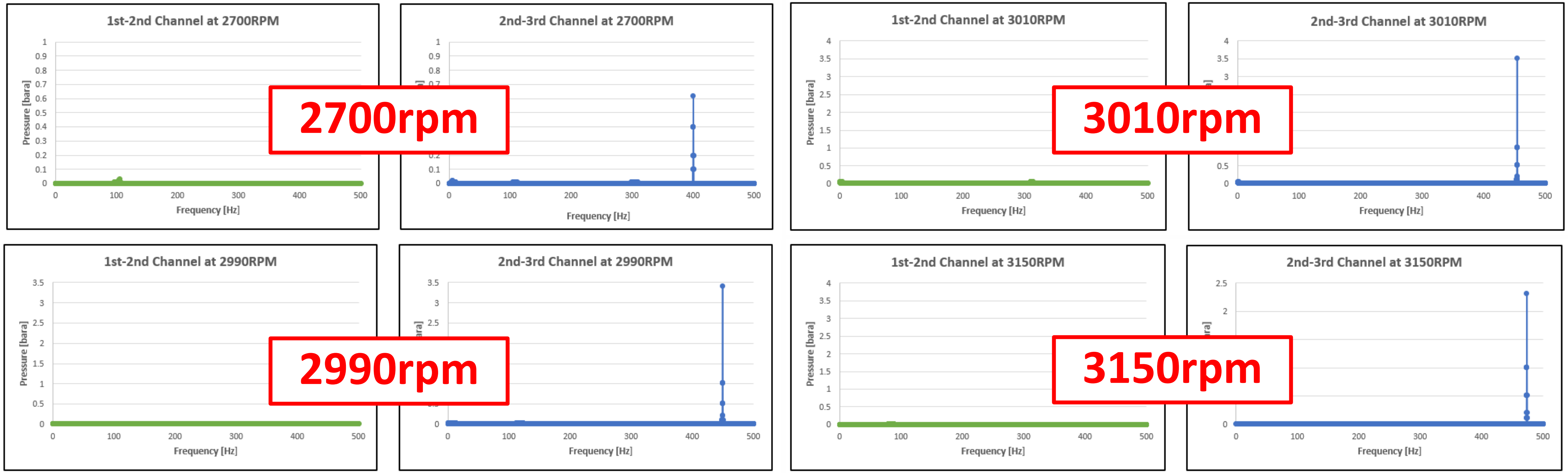


CASE STUDY 1



Peak in the long crossover channel (blue diagrams)

No peak in the first-second channel (green diagrams).



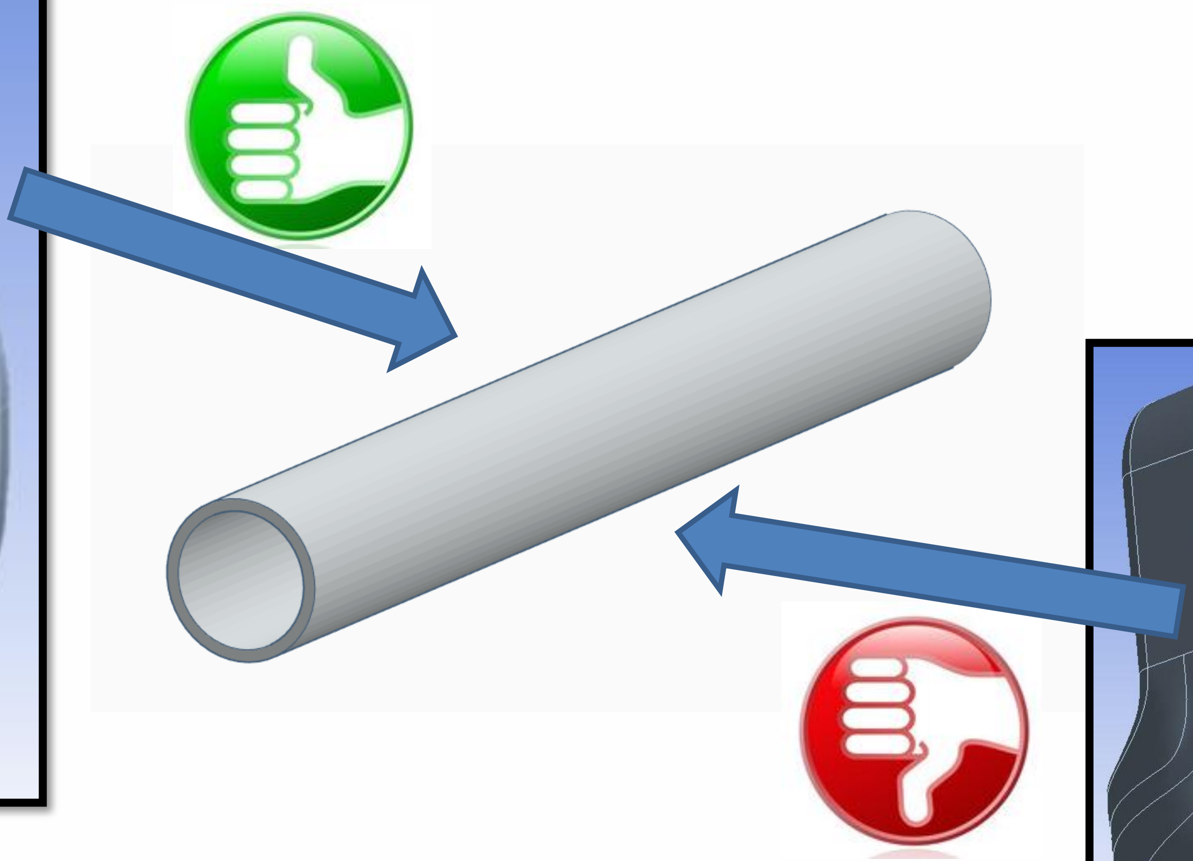
CASE STUDY 1

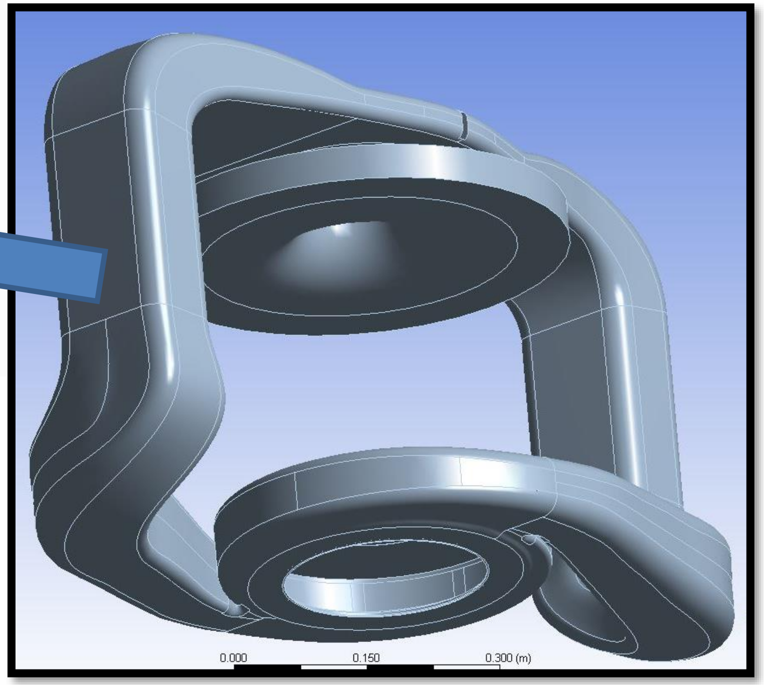
Speed close to the nominal speed → greater amplitude of pressure peak

The AR frequency of the channel is close to the nominal speed.

Speed [RPM]	BPF (2^{nd}stage Impeller) [Hz]	Pressure Peak-to-peak [bara]
2700	405	0.6
2990	449	3.4
3010	452	3.5
3150	473	2.3

FEM ANALYSIS OF CASE STUDY 1

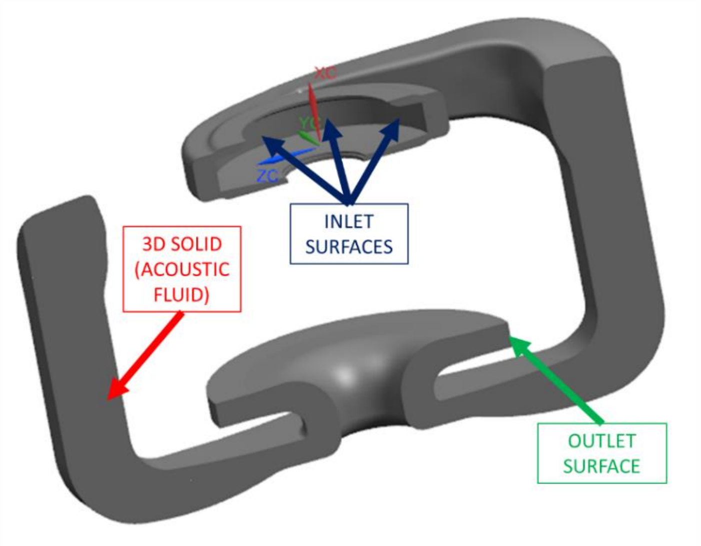


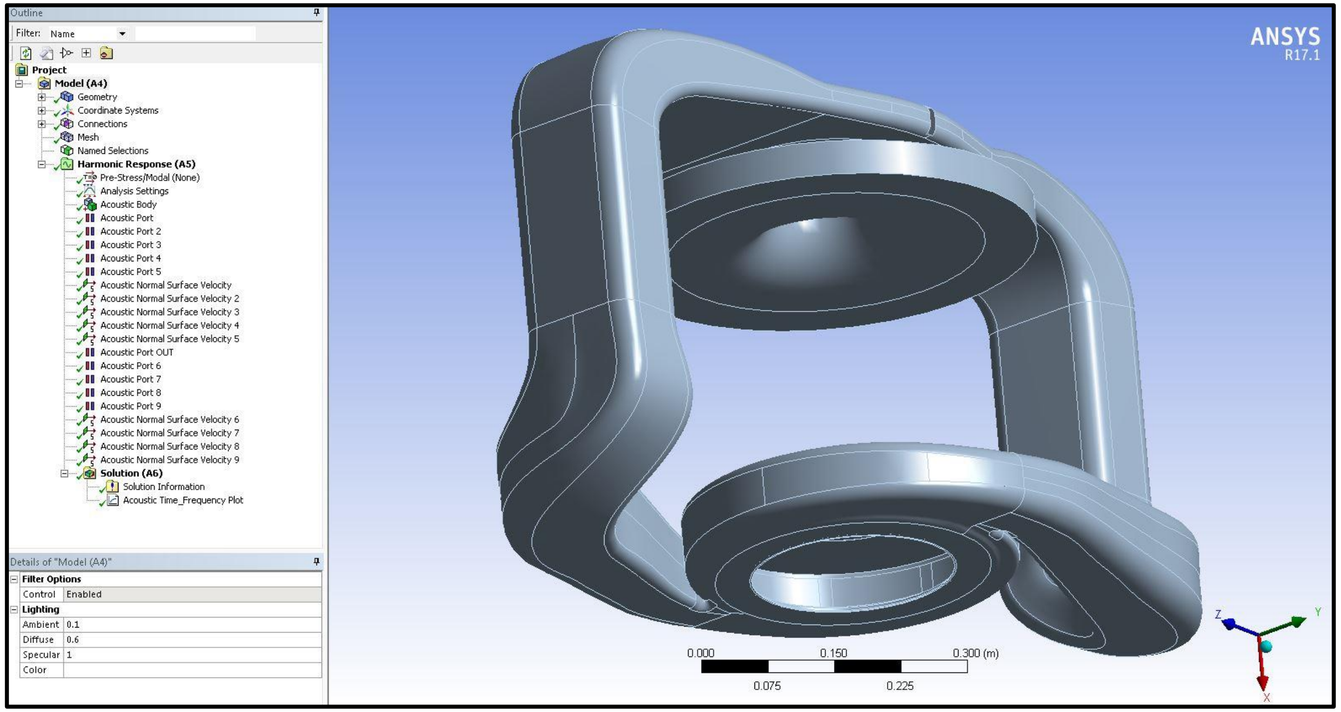


3D geometric complexity cannot be simplified with a linear cylindrical duct

FEM ANALYSIS OF CASE STUDY 1

3D modeling + FEM analysis + Ansys® acoustic model

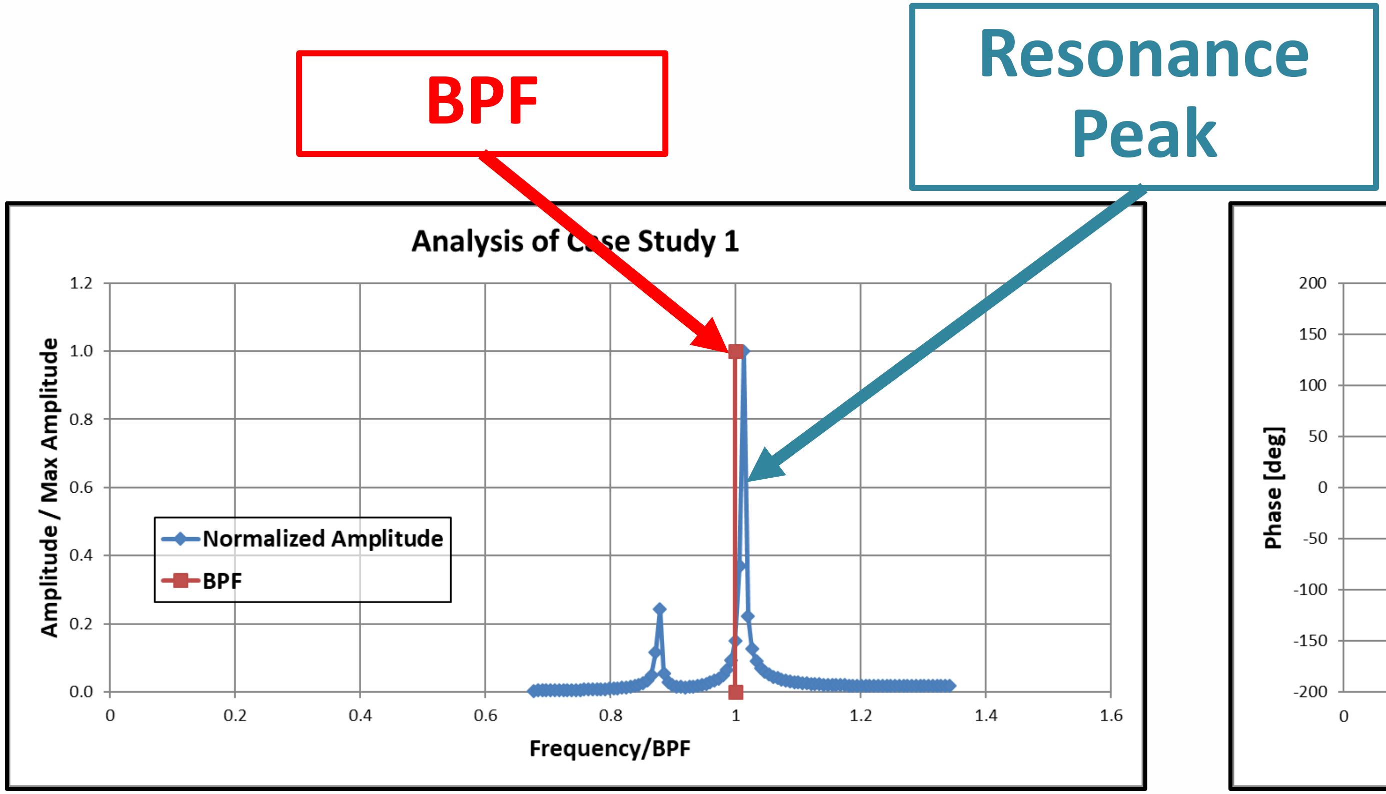


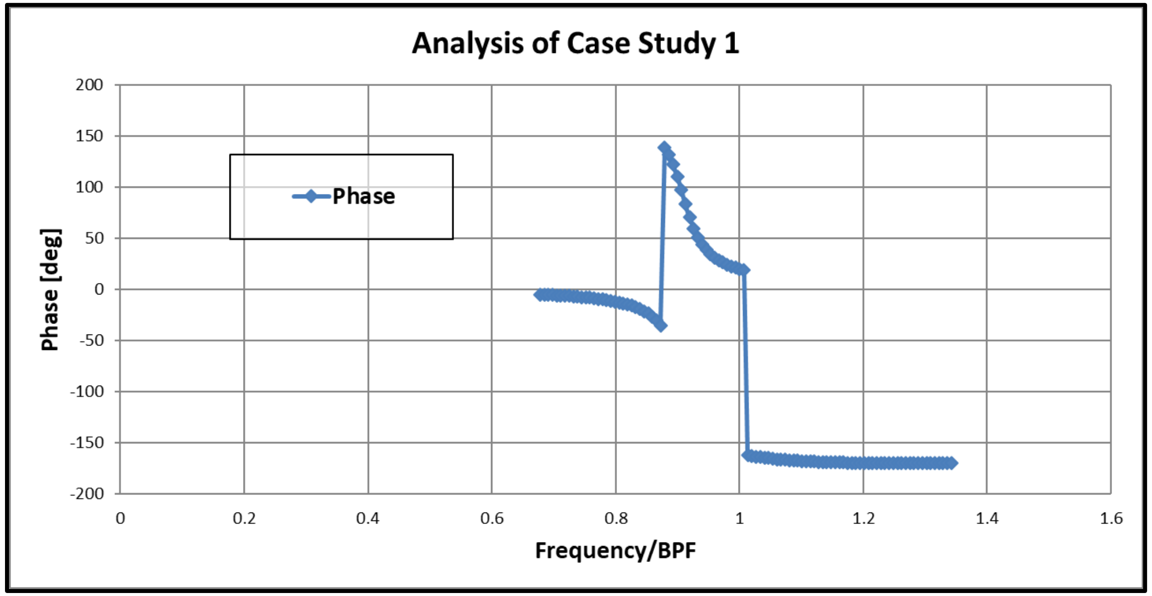


- small pressure changes respect to mean pressure
- rigid wall boundary

FEM ANALYSIS OF CASE STUDY 1

Resonance peak of resonance very close to the BPF





CASE STUDY 2

New pumps to be tested ←→ Procedure validation

AR close to the BPF for a new BB5 4x11/7 stages

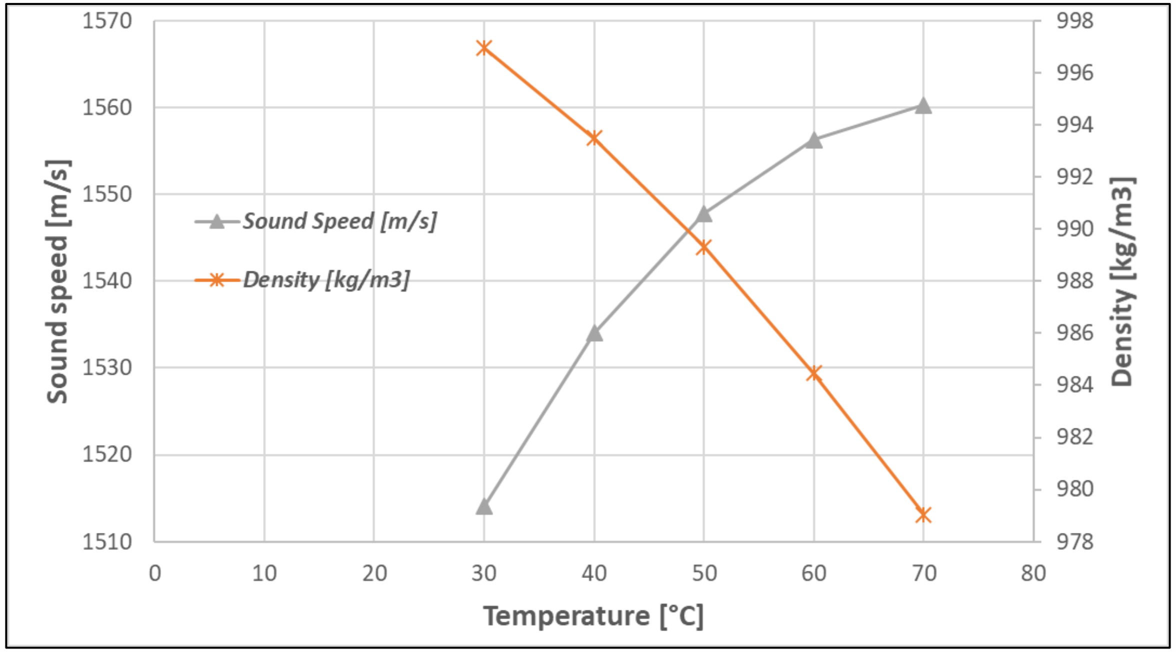
Test with interception between BPF AR in two ways:

1. varying the rotation speed;
2. varying the resonance frequency by the fluid sound speed.

CASE STUDY 2

The fluid (water) sound speed is function of the temperature:

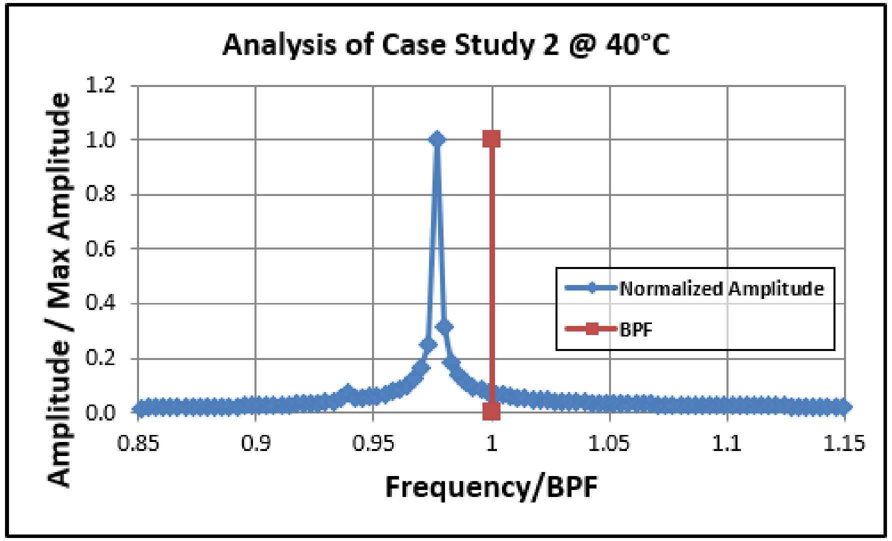
Temperature [°C]	Pressure [bar]	Density [kg/m3]	Sound Speed [m/s]
30	30	996.94	1514.1
40	30	993.48	1534
50	30	989.3	1547.8
60	30	984.46	1556.3
70	30	979.04	1560.3

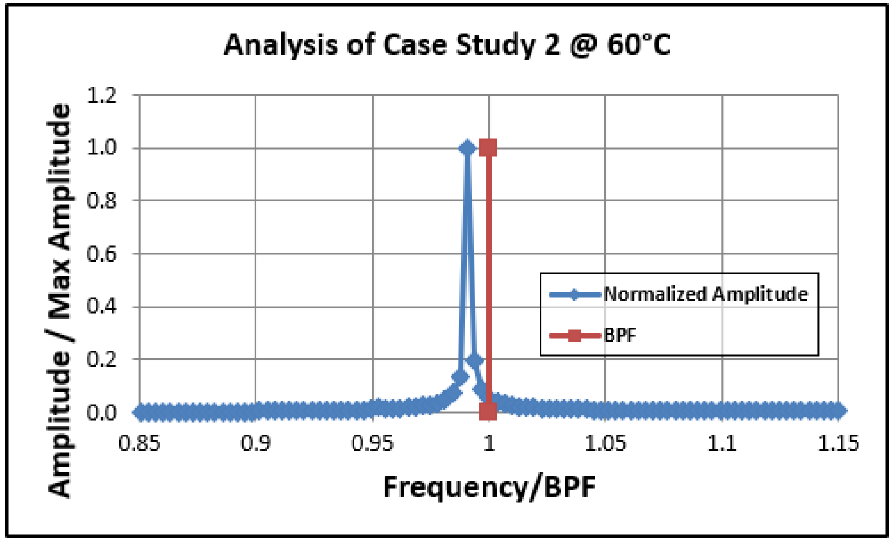


CASE STUDY 2

FEM Analysis → AR frequency in long channel approaches to the BPF

No pressure transducers on channel but only vibration probes on the bearings.





The resonance was highlighted with the variation of the vibration levels.

VALIDATION OF NEW METHOD OF ANALYSIS

Analysis of older tests pumps from database

	Testing issue	Analysis issue	API Pump	Peak Frequency / BPF	Speed [rpm]	Nr of blades	L3/L2 %	L/Deq
Test 3	NO	YES	BB3/7 Stages	1.035	2915	7	6.0	61
Test 4	NO	NO	BB3/4 Stages	1.427	1490	7	14.0	27
Test 5	NO	NO	BB3/10 Stages	0.861	5700	6	0.1	110
Test 6	YES	YES	BB3/6 Stages	0.972	2980	7	12.0	34
Test 7	NO	NO	BB3/6Stages	0.893	2985	7	7.0	50
Test 8	NO	NO	BB3/4 Stages	1.273	1490	8	12.0	30

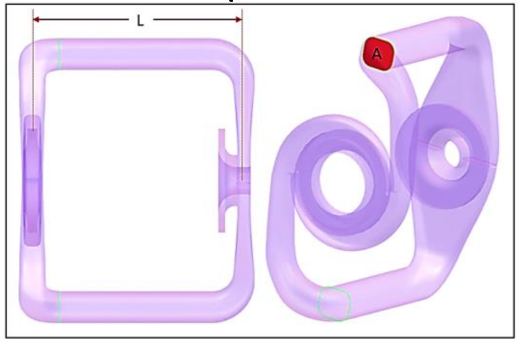
Deq: diameter of a circular section with area A calculated as

$$D_{eq} = \sqrt{\frac{4A}{\pi}}$$

L2: equivalent length calculated using the 1-D method

L3: equivalent length calculated using the 3-D method

L: interstage channel length



VALIDATION OF NEW METHOD OF ANALYSIS

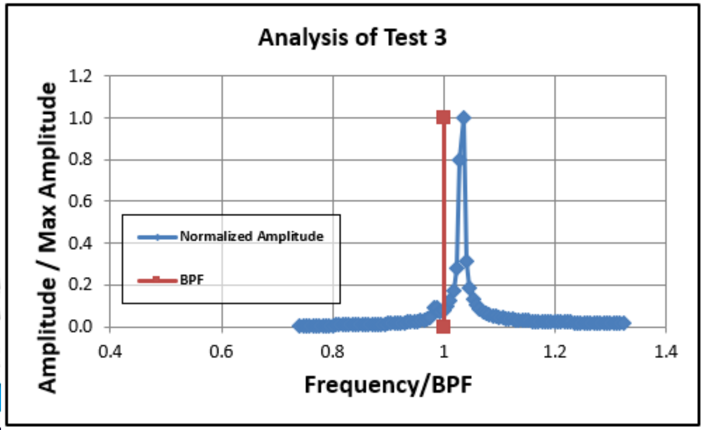
	Testing issue	Analysis issue	API Pump	Peak Frequency / BPF	Speed [rpm]	Nr of blades	L3/L2 %	L/Deq
Test 3	NO	YES	BB3/7 Stages	1.035	2915	7	6.0	61

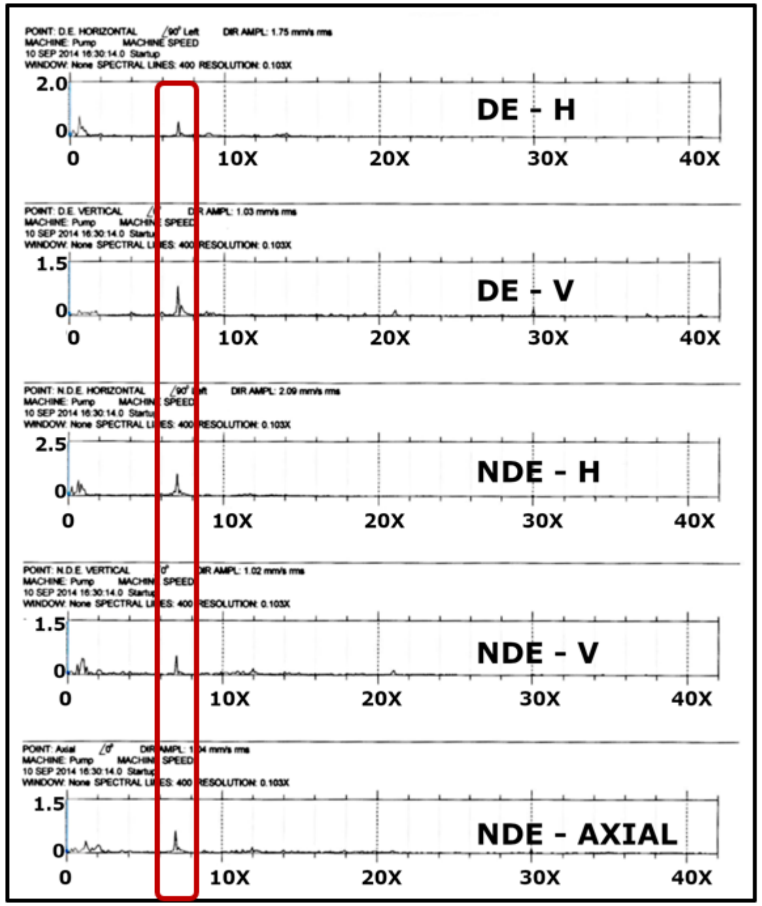
FEM Analysis:

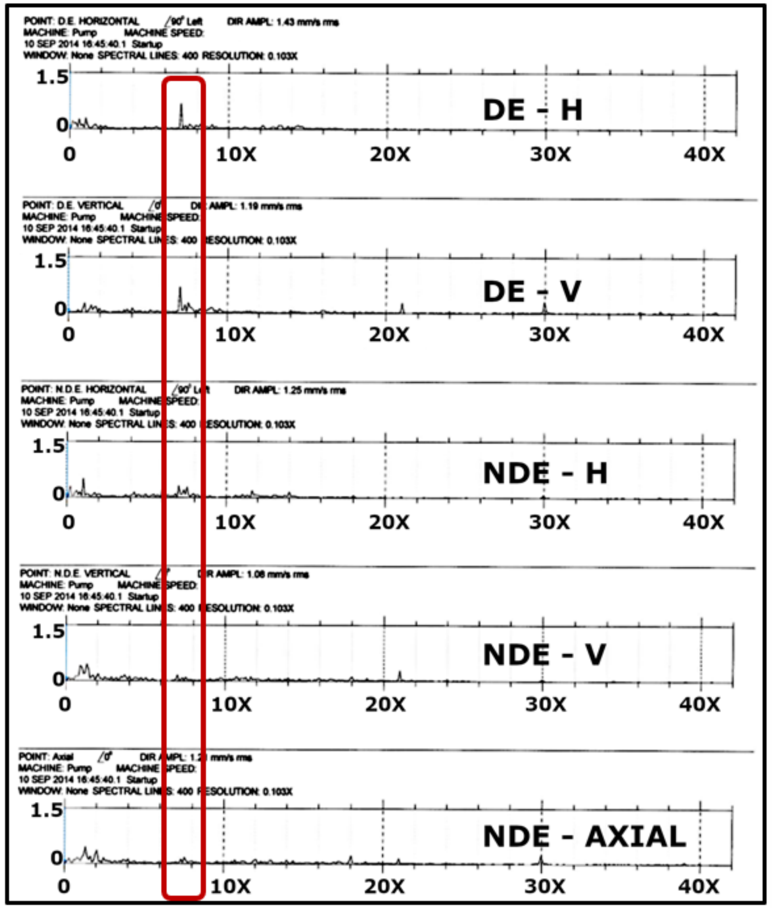
acoustic resonance for the Test 3

Tests:

vibrations below the limits(damping effect)





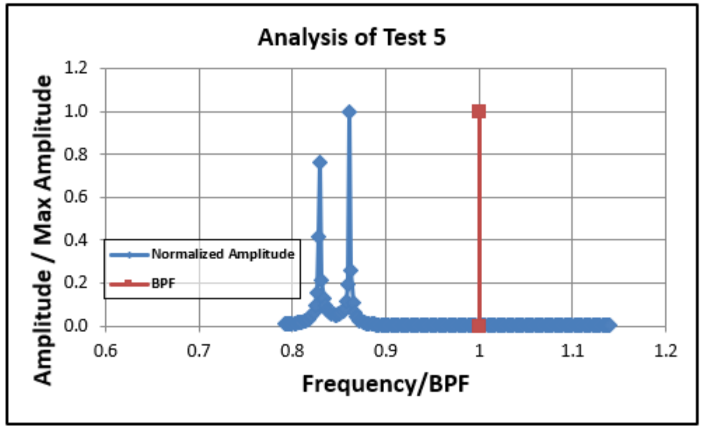


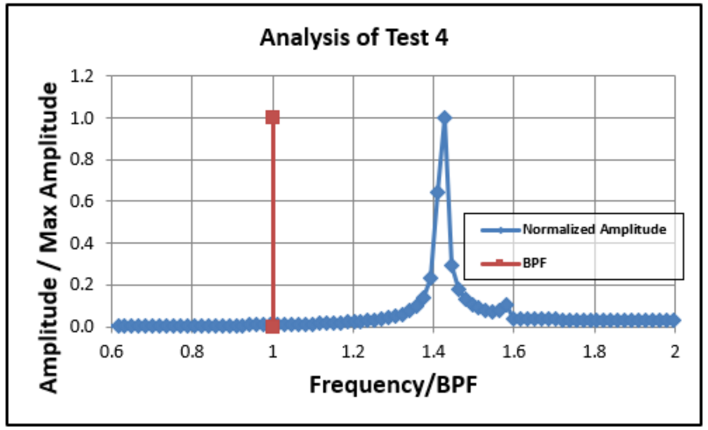
VALIDATION OF NEW METHOD OF ANALYSIS

Test 4, 5, 7 and 8

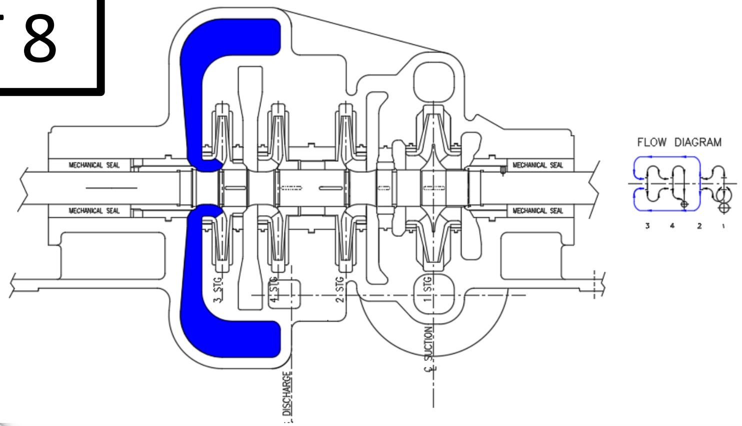
AR frequency far from the BPF

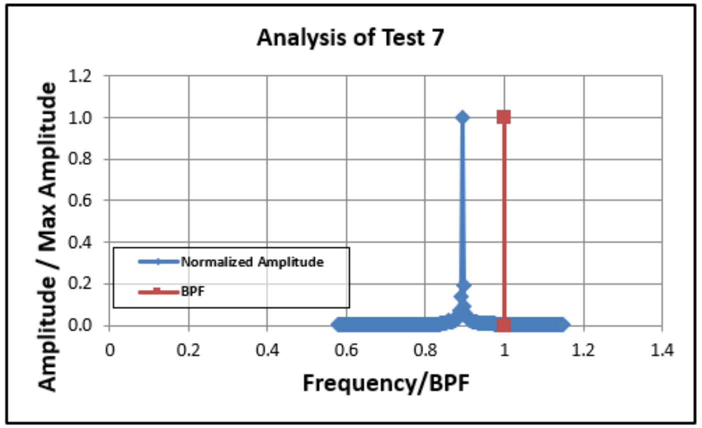
	Testing issue	Analysis issue	API Pump	Peak Frequency / BPF	Speed [rpm]	Nr of blades	L3/L2 %	L/Deq
Test 4	NO	NO	BB3/4 Stages	1.427	1490	7	14.0	27
Test 5	NO	NO	BB3/10 Stages	0.861	5700	6	0.1	110
Test 7	NO	NO	BB3/6Stages	0.893	2985	7	7.0	50
Test 8	NO	NO	BB3/4 Stages	1.273	1490	8	12.0	30

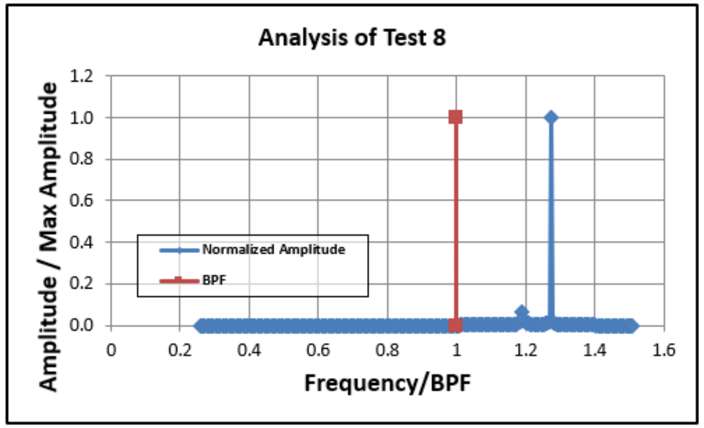




TEST 8



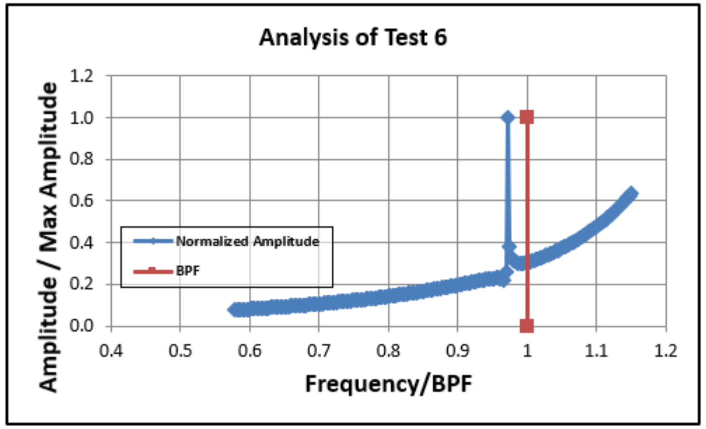


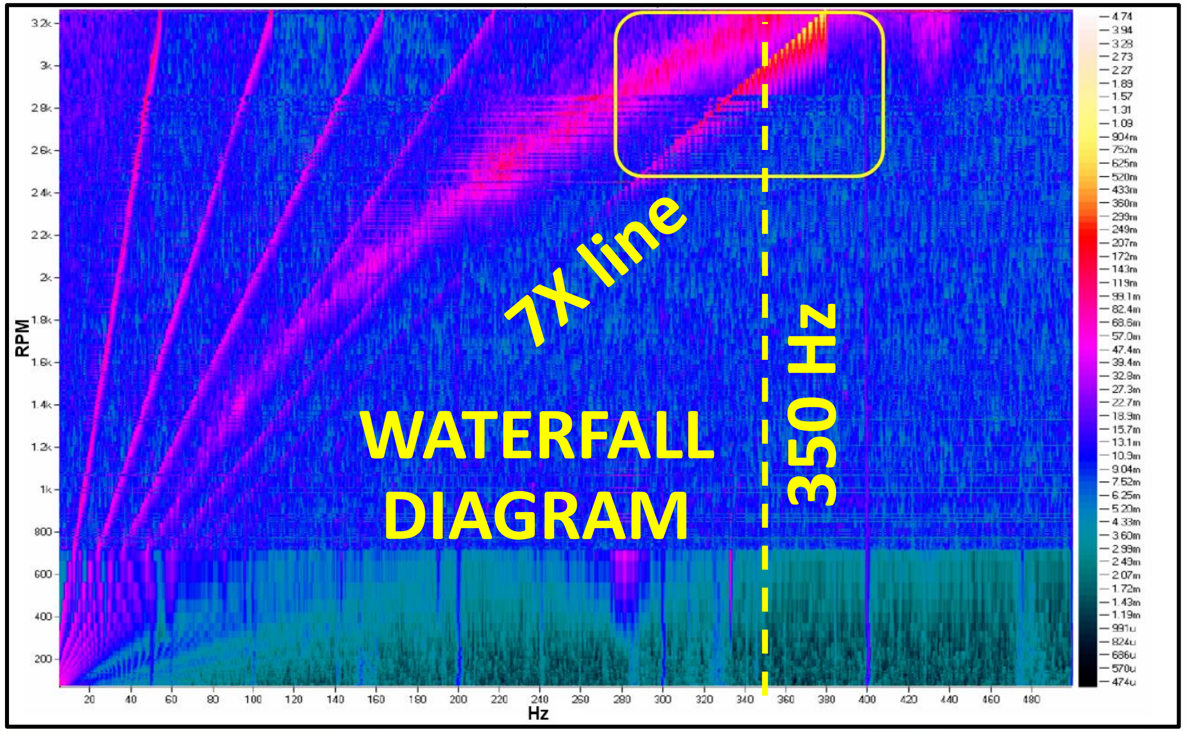


VALIDATION OF NEW METHOD OF ANALYSIS

FEM Analysis → peak of AR for **Test 6**
Waterfall diagram → peak on line 7X close to 350Hz (7 x 50Hz)

Rotation speed = 2985 rpm (~50Hz)
Nr of blades = 7





CONCLUSIONS

- Necessity of improve the design procedure for a possible issue on field
- New method for AR prediction in complex 3D geometries
- New procedure validation with tests and simulations
- The error in length calculation is related to the ratio L/Deq
- Computational capacity
- Updating of design procedure after new method validation

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