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Design of Semi-Active Vibration Control Device for Commercial Pump Systems

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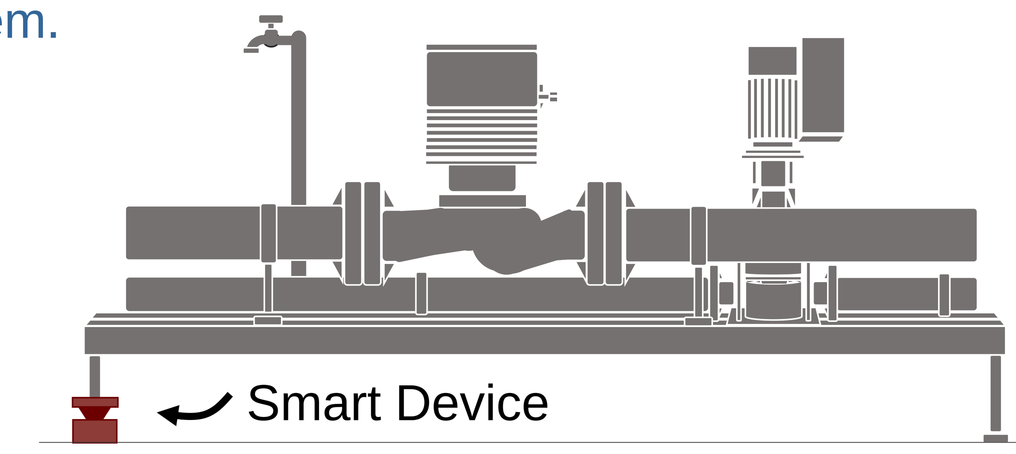
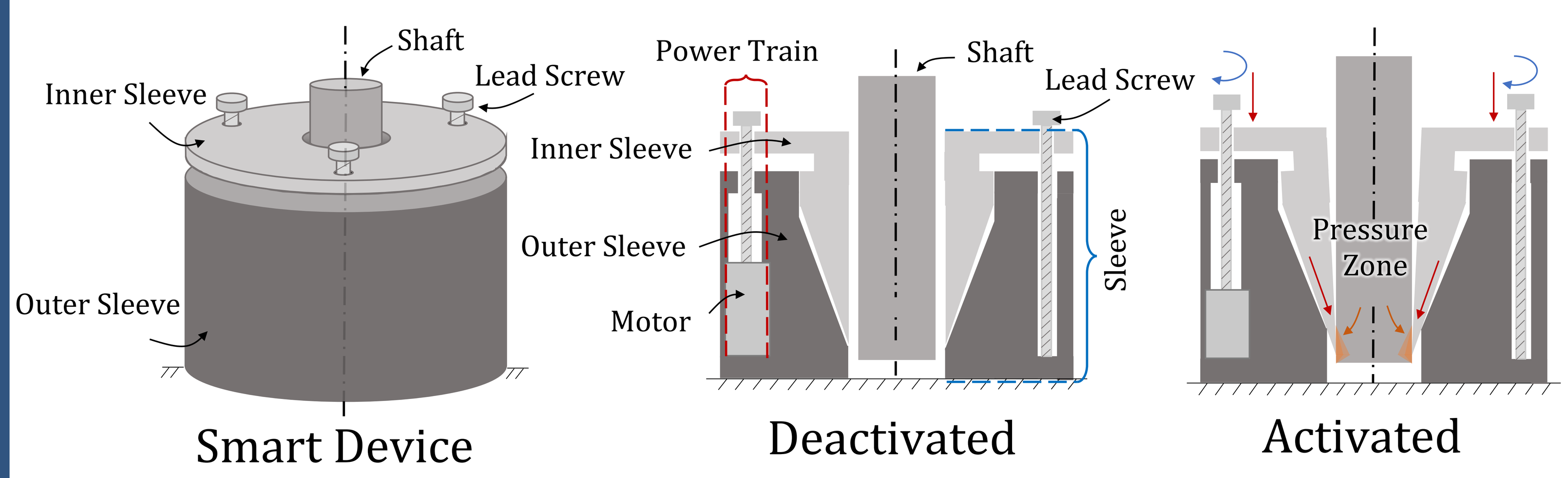
1. Vibration Control

Excessive vibrations due to **resonance** can occur in various pump systems. **Semi-active control** strategies can be utilised to avoid resonance by changing the stiffness and thus the **eigenfrequency** of the system.



2. Synthesis of Design

A Smart Device is designed as shown below: a conical sleeve is bent inwards to exploit **friction** and initiate a pressure zone to fixate the shaft.

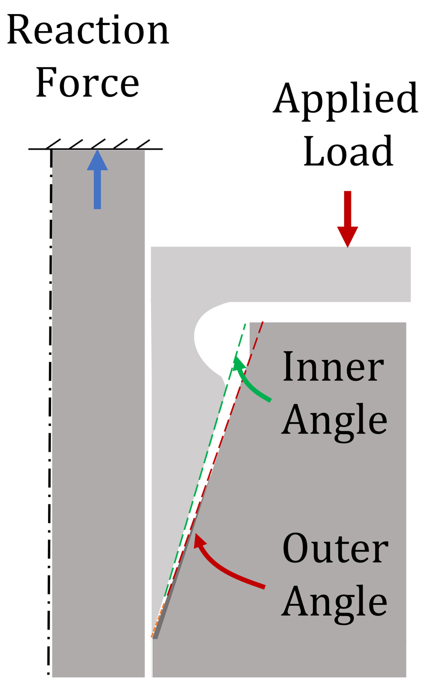


Synthesis is performed both **explicitly** with analytically derived constraints and **implicitly** by finite element parameterisation. Both optimisation schemes are set to maximise the reaction force on the shaft. The explicit optimisation is performed using **Monte Carlo** (M.C.) method and **gradient-based** optimisation (*fmincon*). The implicit optimisation uses Ansys to determine the angles of the conical sleeve.

Method	M.C.	*fmincon*	Implicit
Obj [kN]	1.38	1.65	1.12

2.1 Final Design

The final design of the Smart Device is determined based on the two independently **optimised solutions**, thus incorporating features from both designs.



Parameters	Explicit	Implicit	Final
Applied Load [N]	820	1220	850
Reaction Force [N]	707	709	717
Inner stress [MPa]	1170	1200	857
Outer stress [MPa]	25.0	289	281
Shaft stress [MPa]	23.4	58.1	36.2

Note material is Q&T ASIS 4340 yield strength 1300 MPa

3. Validation

Modal- and harmonic analyses are performed to validate the Smart Device's ability to change the eigenfrequencies of the skid systems.

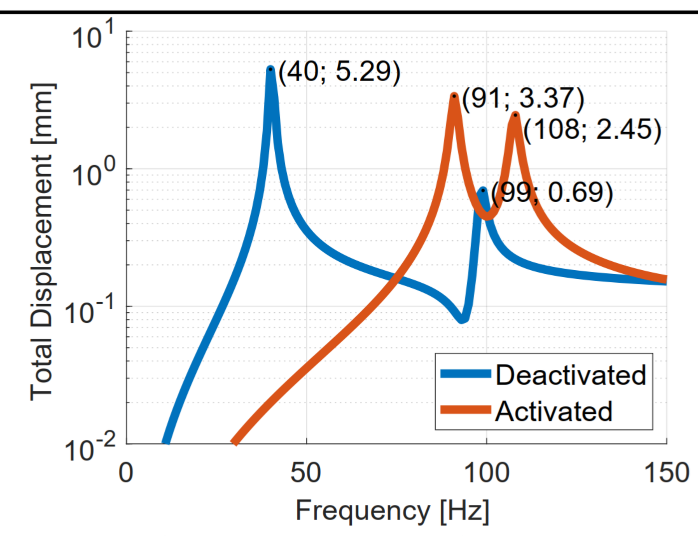
3.1 Modal Analysis

Modal analysis is performed in ANSYS for two skid systems. It is seen that skid system I exhibits a significantly greater **change in stiffness** than skid system II. This is due to the different geometries of the skids and indicates that not all systems can benefit from the Smart Device.

	Skid I System			Skid II System				
	ω_1[Hz]	ω_2[Hz]	ω_3[Hz]	ω_1[Hz]	ω_2[Hz]	ω_3[Hz]	ω_4[Hz]	ω_5[Hz]
Deactivated	40.3	40.4	122	37.3	44.2	57.8	67.0	93.8
Activated	93.1	109	199	39.0	46.3	59.9	91.7	98.5
Change	131%	170%	63%	5%	5%	4%	37%	5%

3.2 Harmonic Analysis

For skid system I a harmonic analysis is conducted, that confirms the Smart Device's ability to change eigenfrequencies when the **rotational force** from the rotor is added.

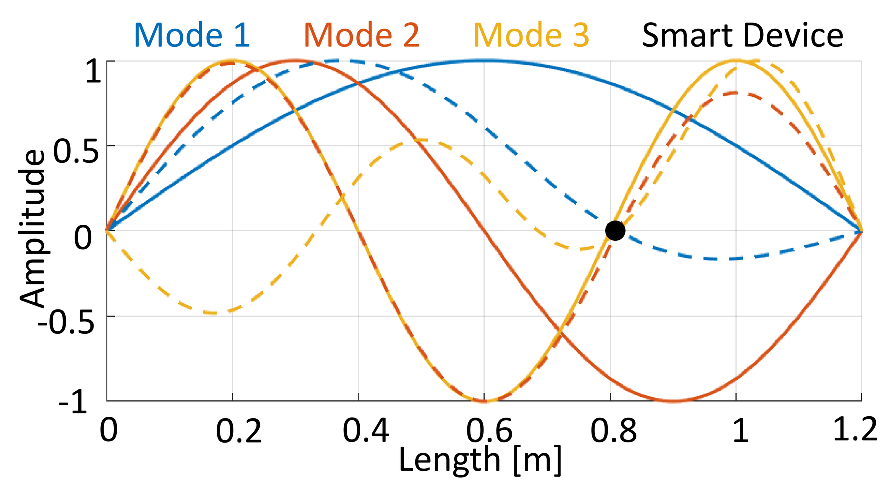


4. Location of Smart Device

The Smart Device's ability to change the eigenfrequency depends on its mounted location. Therefore an **application** has been developed to help technicians place the device for optimum effect.

The efficiency is related to the **mode shapes.** If the Smart Device is located at the maximum modal amplitudes the best efficiency is obtained.

The mode shapes before (full lines) and after (dashed lines) the Smart Device is activated are presented as output from the application. This is done along with the change in eigenfrequency obtained from the optimised location.



M.S.	$\omega_{i,off}$[Hz]	$\omega_{i,on}$[Hz]	Change
1	25.3	71.5	183%
2	101	227	125%
3	227	343	51%

5. Conclusions

A Smart Device has been conceptualised and validated using modal- and harmonic analysis in ANSYS. It has been **confirmed** that the device can change the **stiffness** of a skid pump system but is not equally efficient in all setups.

Testing on **a physical system** is necessary to demonstrate the performance in real life applications.

Acknowledgement

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