HO CHI MINH UNIVERSITY OF TECHNOLOGY
FACULTY OF TRANSPORTATION ENGINEERING
DEPARTMENT OF AUTOMOTIVE AND ENGINE

GRADUATION THESIS

STUDY ON AUTOMOTIVE PUSH-ROD SUSPENSION SYSTEM

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DATE: June 15th 2022

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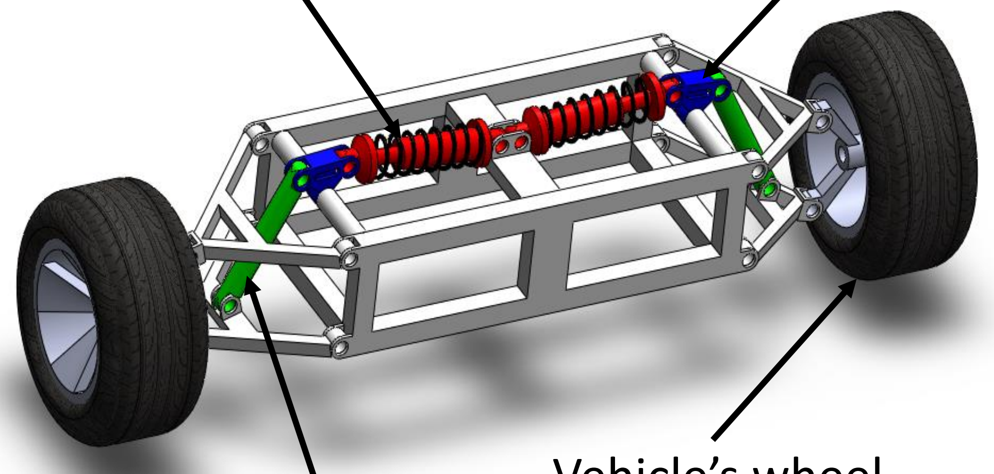


Fig 1: Push-rod suspension system

Suspension system: connects the wheels to vehicle body, allows relative motions.

Primary function of the suspension system:

- Isolating the roughness between road and the vehicle chassis
- Keep the wheel in proper position (wheel alignment)
- Stable in rapid cornering without body roll
- Keep the tires in contact with the road surface
- Support the weight of the vehicle

1.2 Suspension components

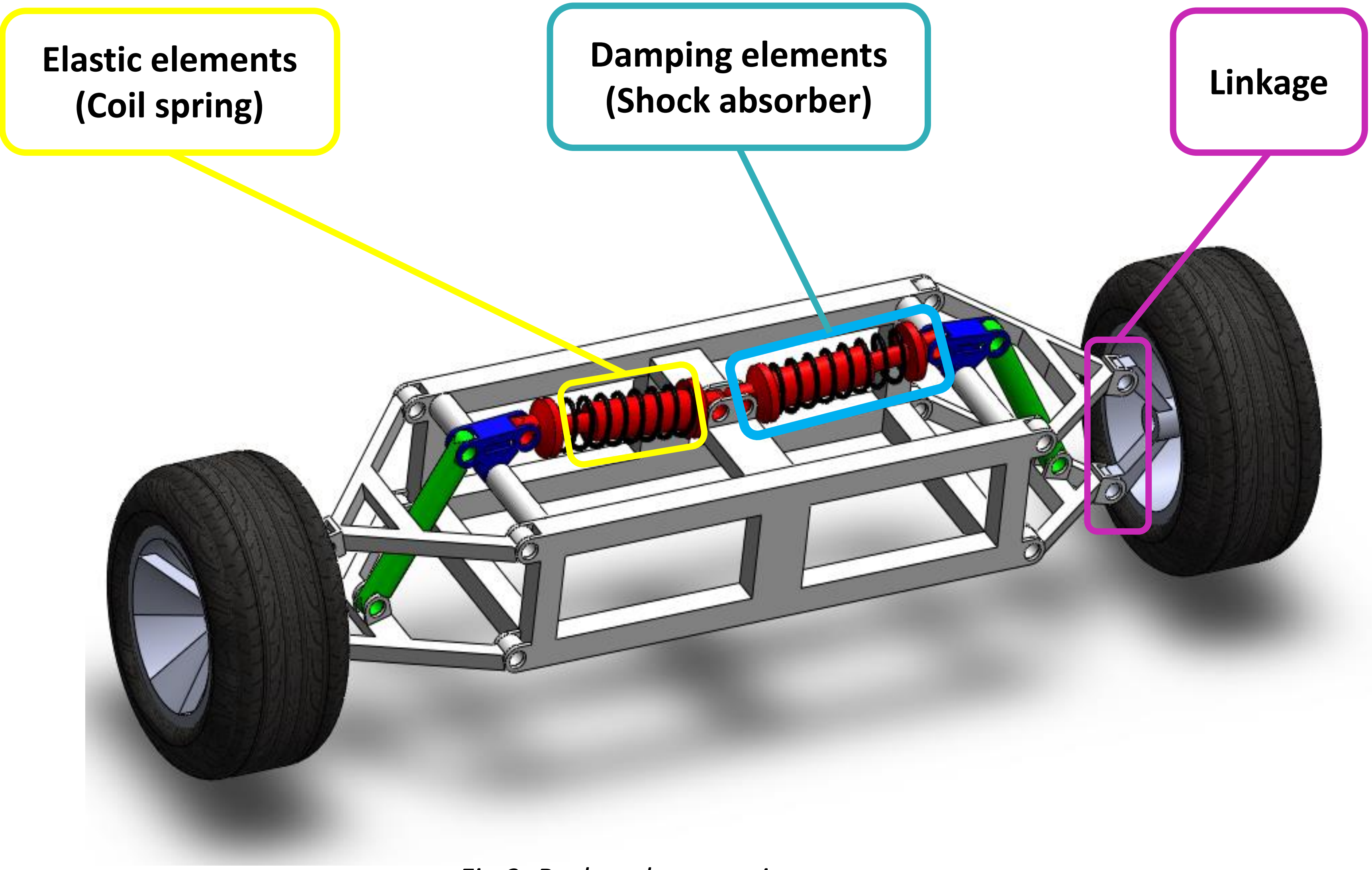


Fig 2: Push-rod suspension system components

1.2 Suspension components: Elastic elements & damping elements

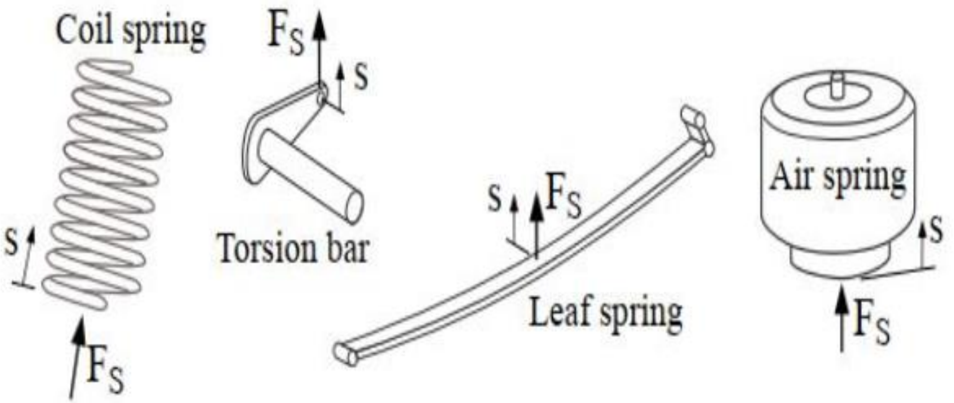


Fig 3: Type of springs

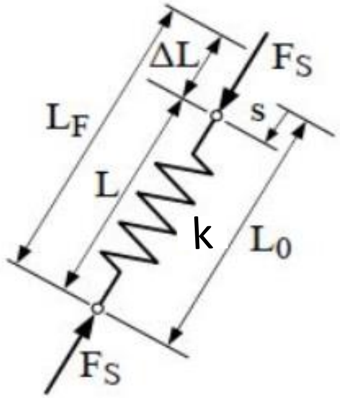


Fig 4: Coil spring parameters

Elastic element:
- Support vehicle weight
- Absorb vibration energy
- $F_k = -k(L_f - L)$

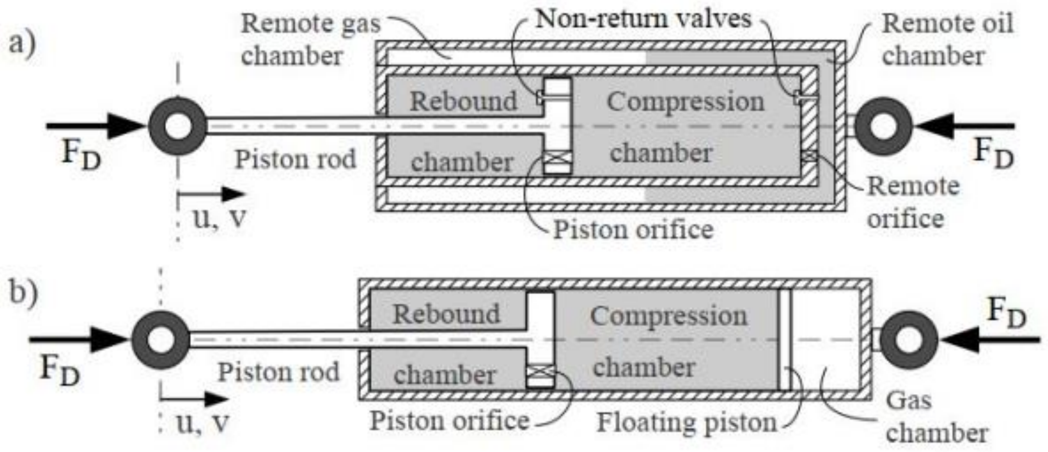


Fig 5: Twin-tube (a) and mono-tube (b) dampers

Damping element:
- Dissipate vibration energy
- $F_{\dot{c}} = -c \times v$

1.3 Technical characteristics: Natural frequency & Damping ratio

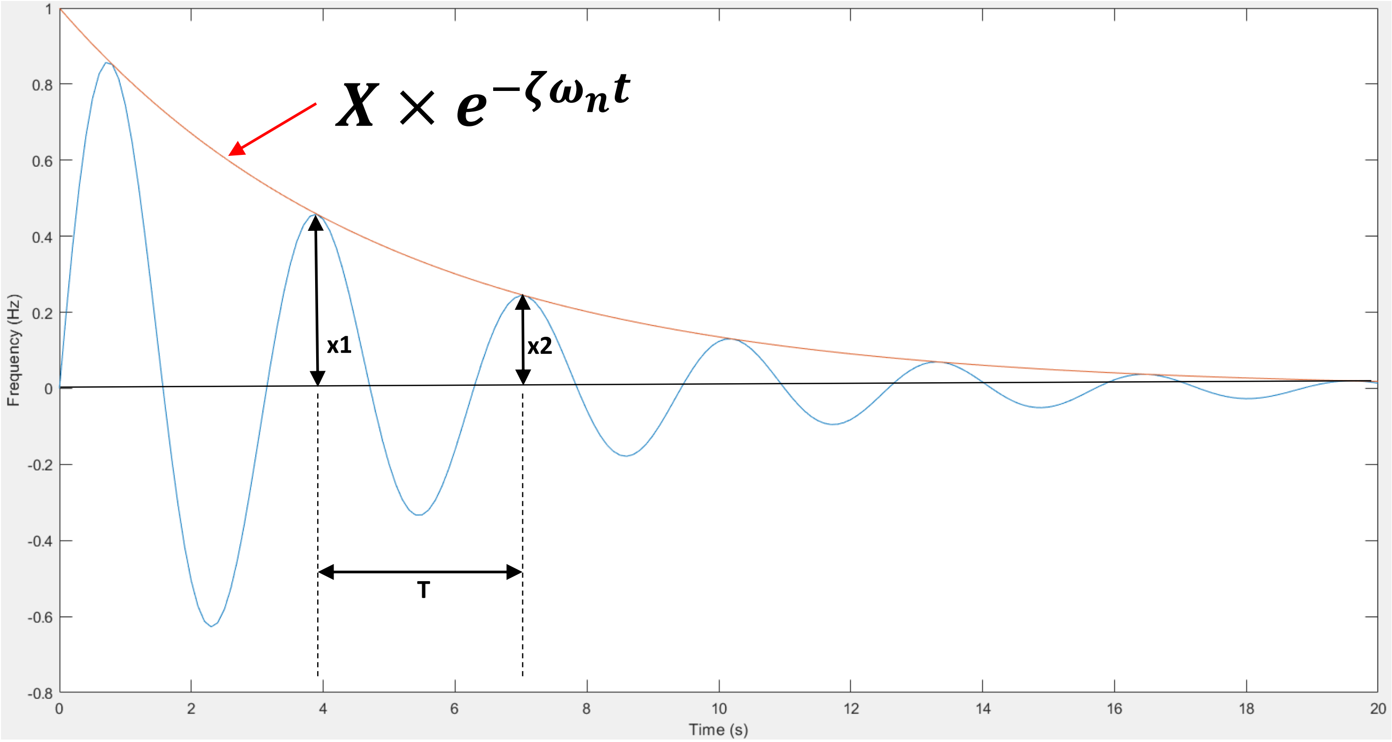


Fig 6: Underdamped characteristics curve

Natural frequency: $f_n = \frac{1}{T}$

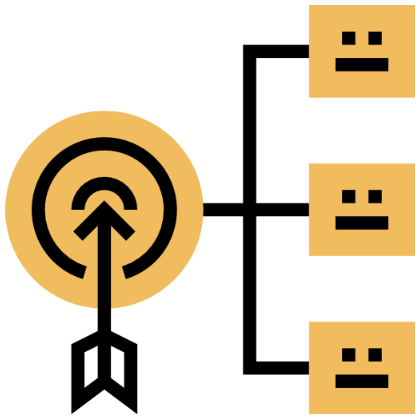
- Vehicle body supported by main suspension: **0.2 – 2 Hz**
- The un-sprung mass: **2 – 20 Hz**

Damping ratio: $\zeta = \frac{1}{\sqrt{1+(\frac{2\pi}{\delta})^2}}$ where $\delta = Ln\frac{x1}{x2}$

➔ **0< ζ<1** (Underdamped)

1.4 Thesis objectives & limitations: Evaluate the technical characteristic of Push-rod suspension system

Thesis's objectives:



- Relationship between the wheel displacement and the Suspension travel
- The Spring stiffness and the Damping coefficient
- The change in Camber angle and sliding range of the tire

Idea:

Compare with the Conventional suspension system under the same conditions:
- Natural frequency
- Damping ratio

1.4 Thesis objectives & limitations: Evaluate the technical characteristic of Push-rod suspension system

Hypothesis:

- Neglect the tire’s stiffness and sliding friction between tire and road
- Use vehicle’s mass of the conventional suspension system

Limitations:

- Not evaluate the frequency-weighted acceleration to calculate how intensive vibrations affect human body

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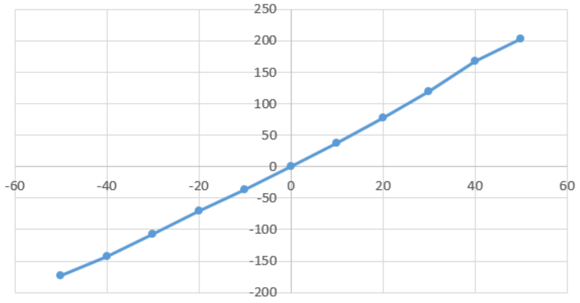
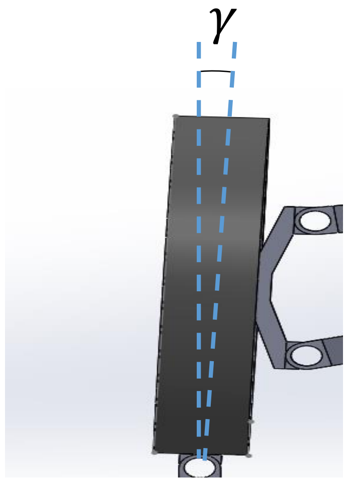
Kinematic problems

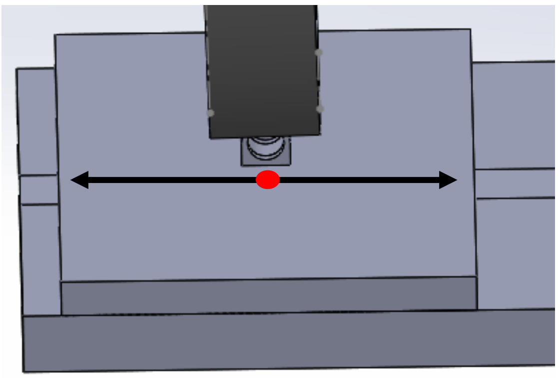
Relationship between wheel displacement and suspension travel



The change in camber angle



Sliding range between road and tire



Dynamic problems

- Spring stiffness
- Damping coefficient
- Natural frequency and damping ratio

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3. IMPLEMENTATION PROCESS

3.1 Build 3D model on SolidWorks

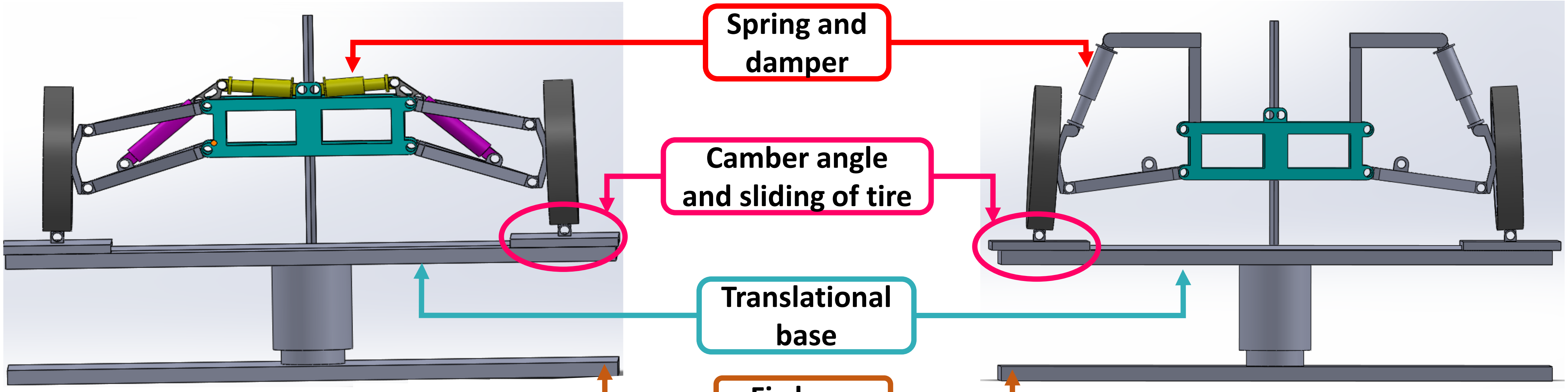


Fig 7: 3D model of Push-rod suspension system

Fig 8: 3D model of Conventional suspension system

Parameters	Unit	Meaning	Value
m_{s_1}	Kg	Sprung weight (1/3 load)	574
m_{s_2}	Kg	Sprung weight (2/3 load)	706
m_{s_3}	Kg	Sprung weight (full load)	840
m_u	Kg	Unsprung weight	80
k_s	N/m	Spring stiffness	28566
c_s	Ns/m	Damping coefficient	2090

Table 1: light truck suspension parameters (Source: Vibration analysis of a light truck by 3d dynamic vehicle vibration model by Mr. Truong Hoang Tuan, Dr. Tran Huu Nhan and Mr. Tran Quang Lam.)

3.2 Simulate on Matlab/Multibody

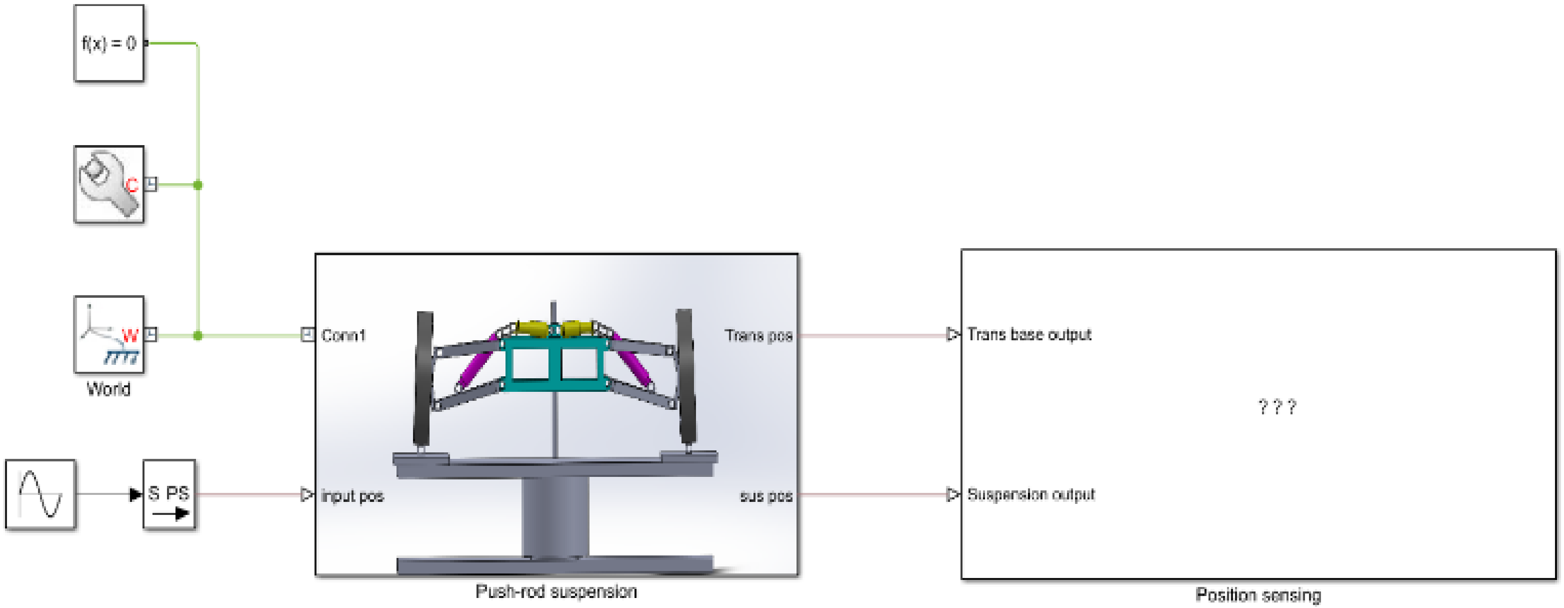


Fig 9: Simulation model in Matlab/ Multibody environment

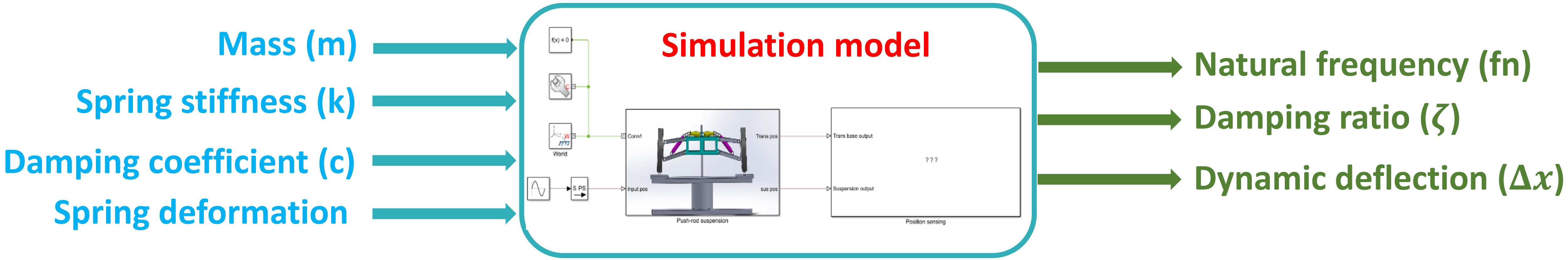
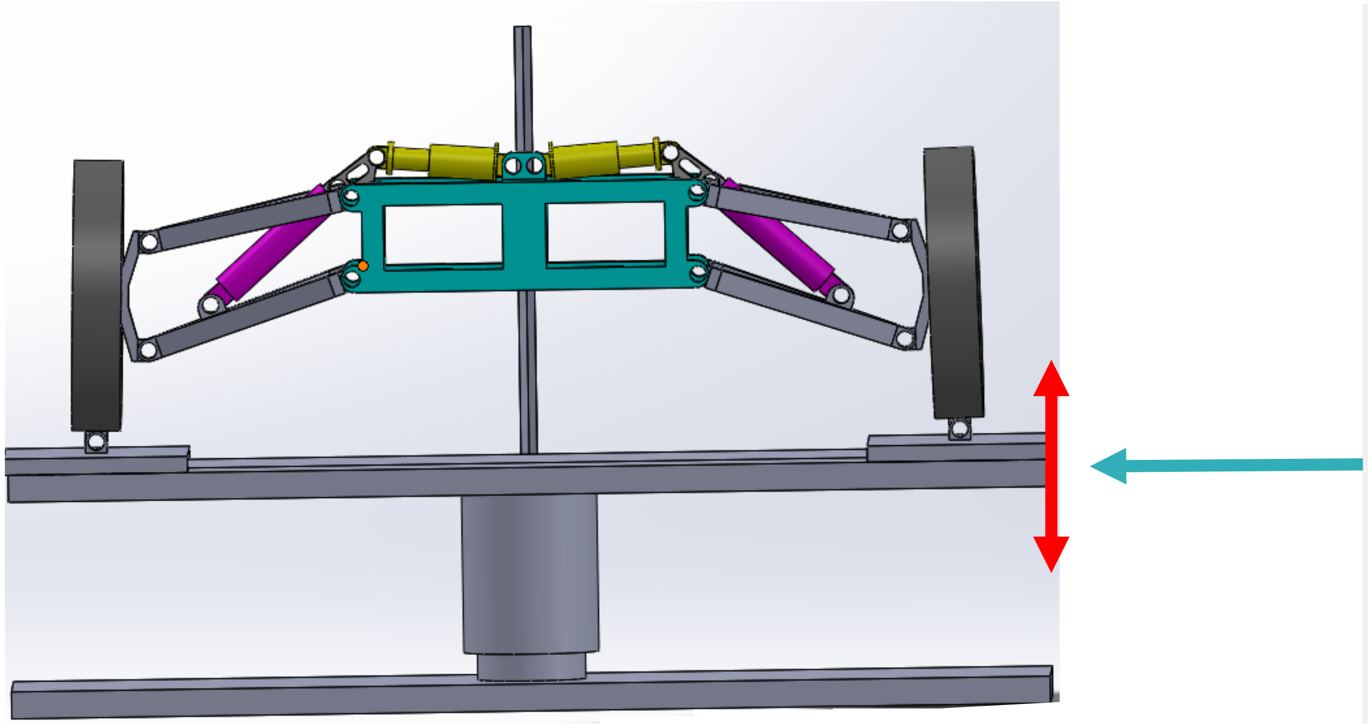


Fig 10: Simulation input and output parameters

3.3 Road profile simulation



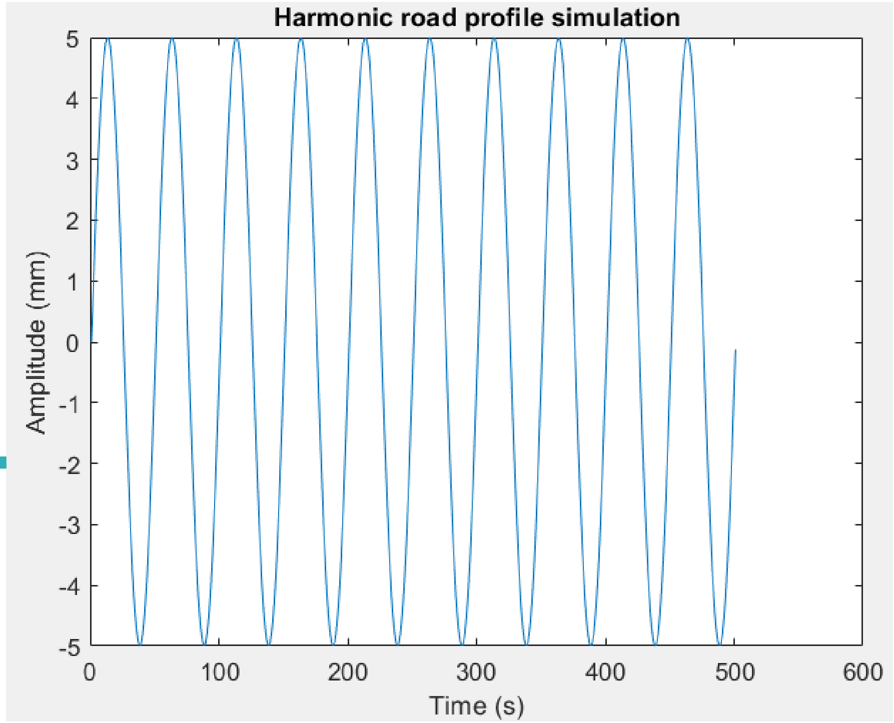


Fig 11: Harmonic road profile simulation on Matlab/ Multibody

Using harmonic road profile to find
- Natural frequency of the simulation model
- The Gain response spectrum

3.4 Calculation flow

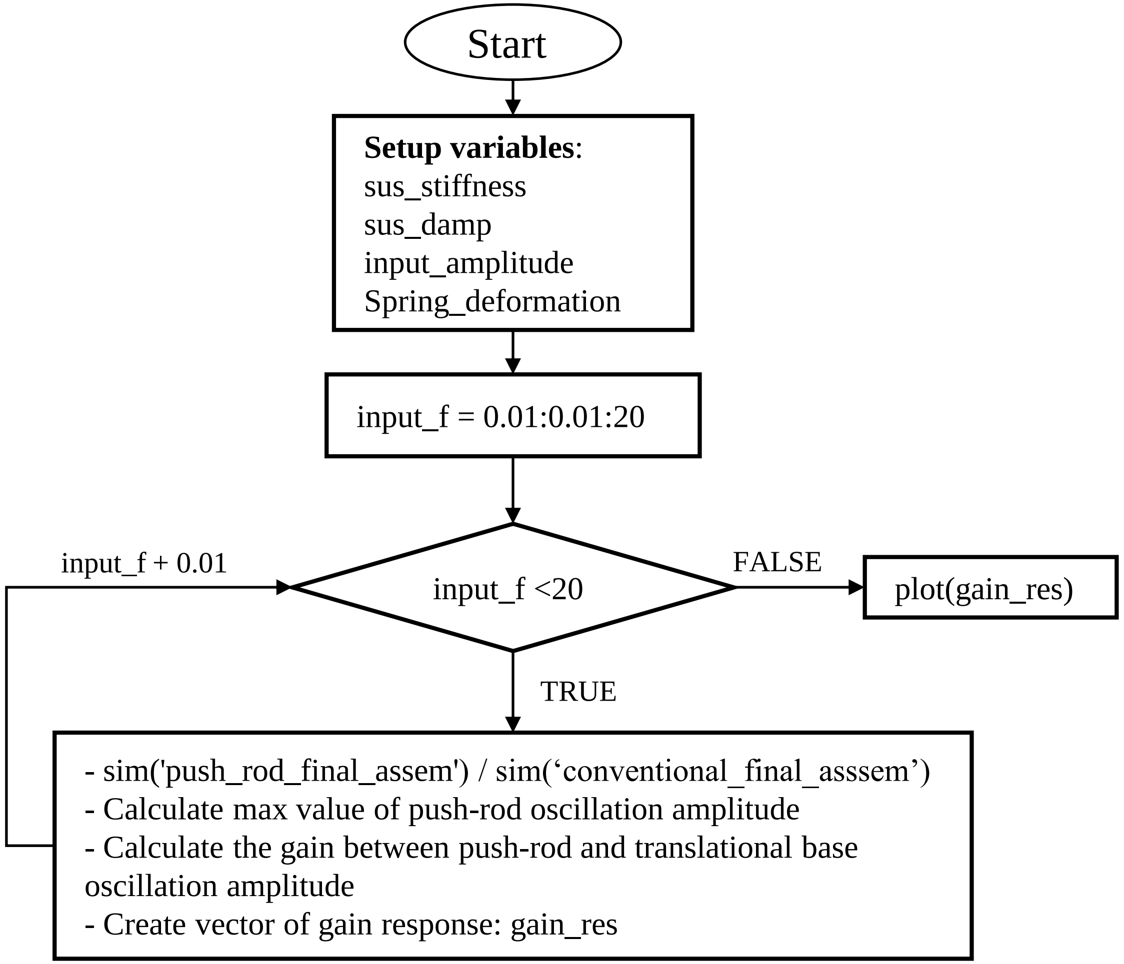
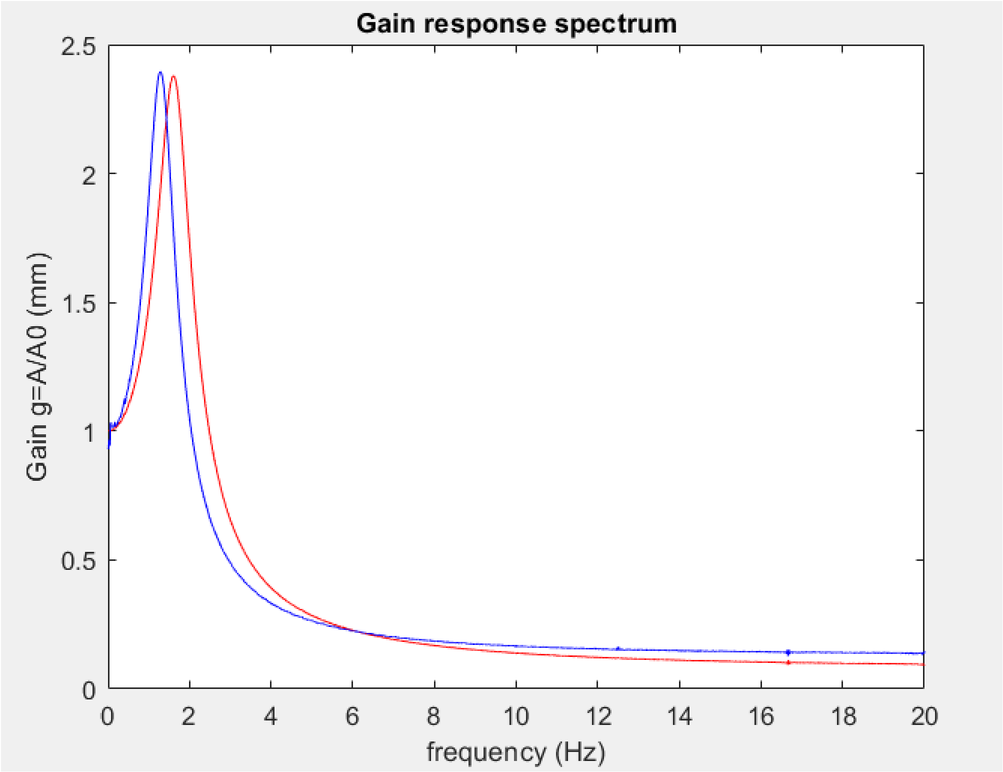


Fig 12: Calculation flowchart of the simulation model



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4.1 Relationship between wheel displacement and suspension travel

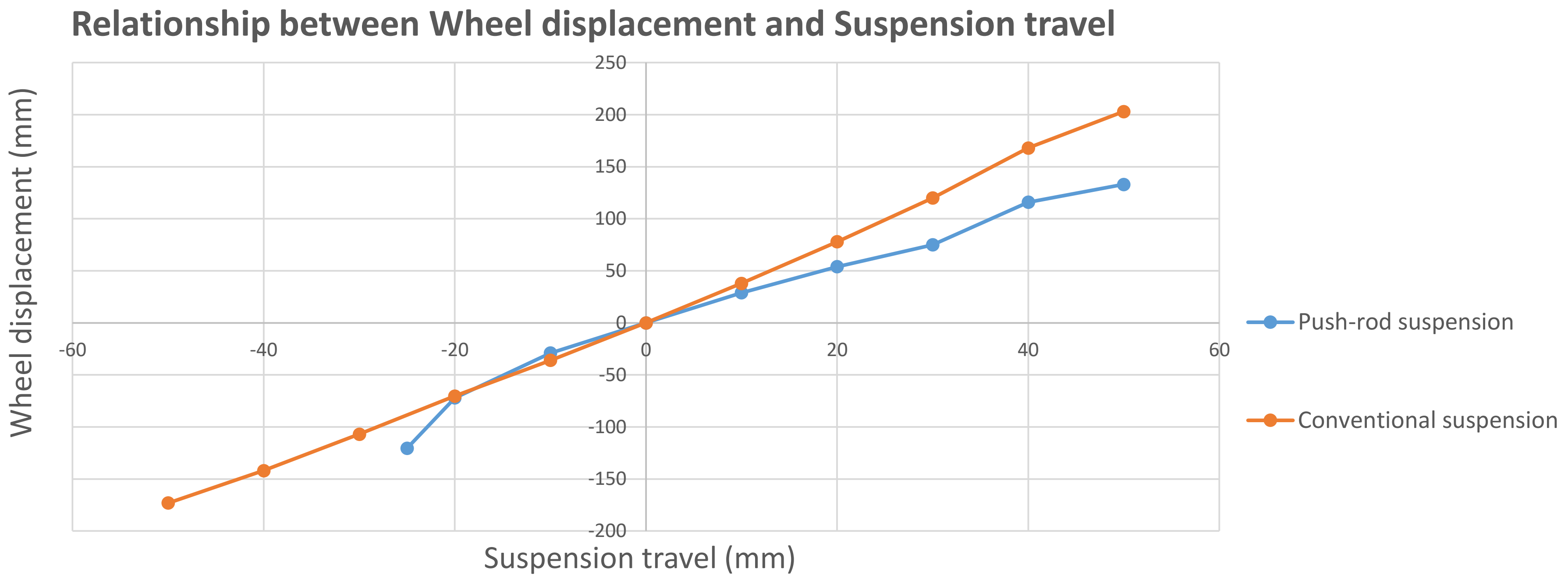

Fig 13: Relationship between wheel displacement and suspension travel curve

- Suspension travel of the Push-rod suspension system is 25 mm shorter than Conventional suspension

  → **Use shorter suspension system**

- Maximum and minimum wheel displacement of Push-rod suspension is 70mm and 50mm lower than Conventional suspension respectively

  → **Decrease the dynamic deflection, reduce the movement of vehicle's body**

4.2 Change in camber angle and sliding range

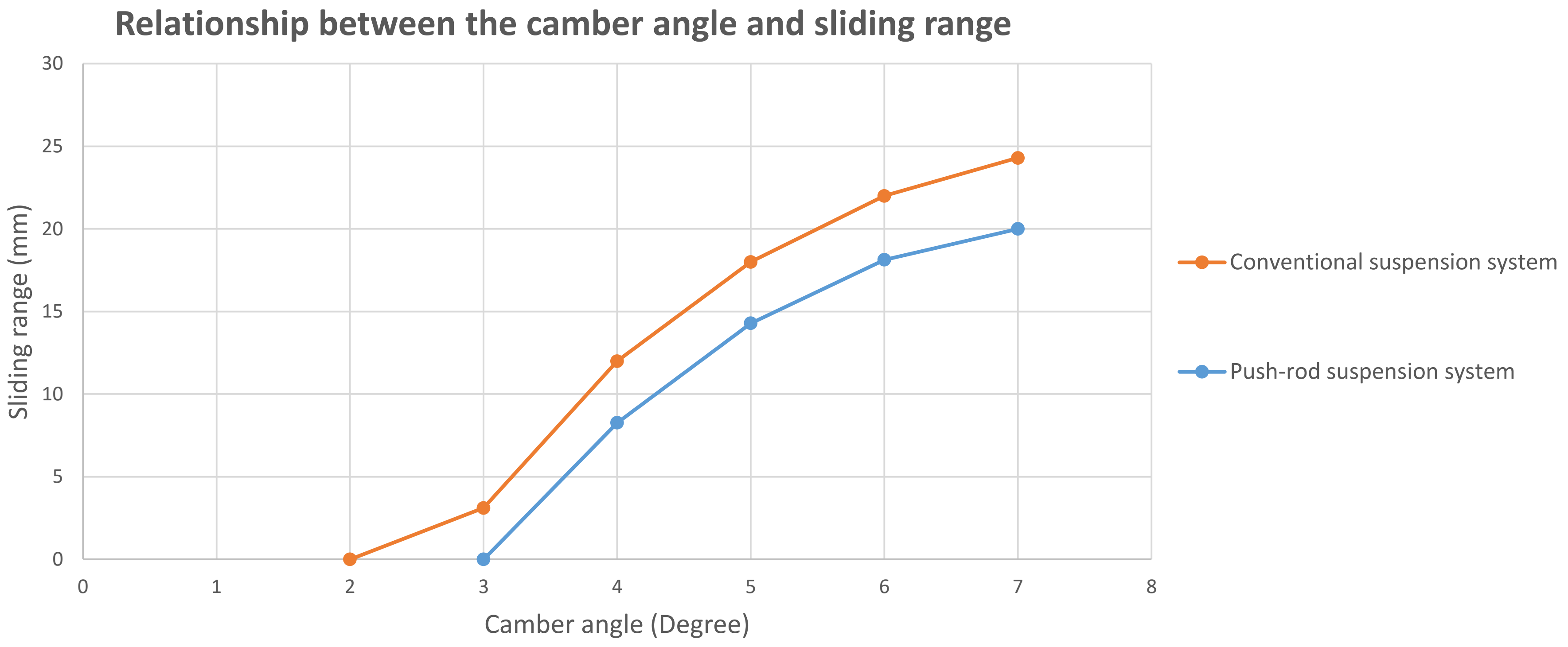

Fig 14: Relationship between change in camber angle and tire's sliding range curve

- Camber angle of both suspension system vary from 2° to 7°

- The sliding rang of the tire of the Push-rod suspension system is always lower when the camber angle change, about 4 mm lower

→ **Less tire slip compared with the conventional suspension system**

4.3 Gain response of the vehicle

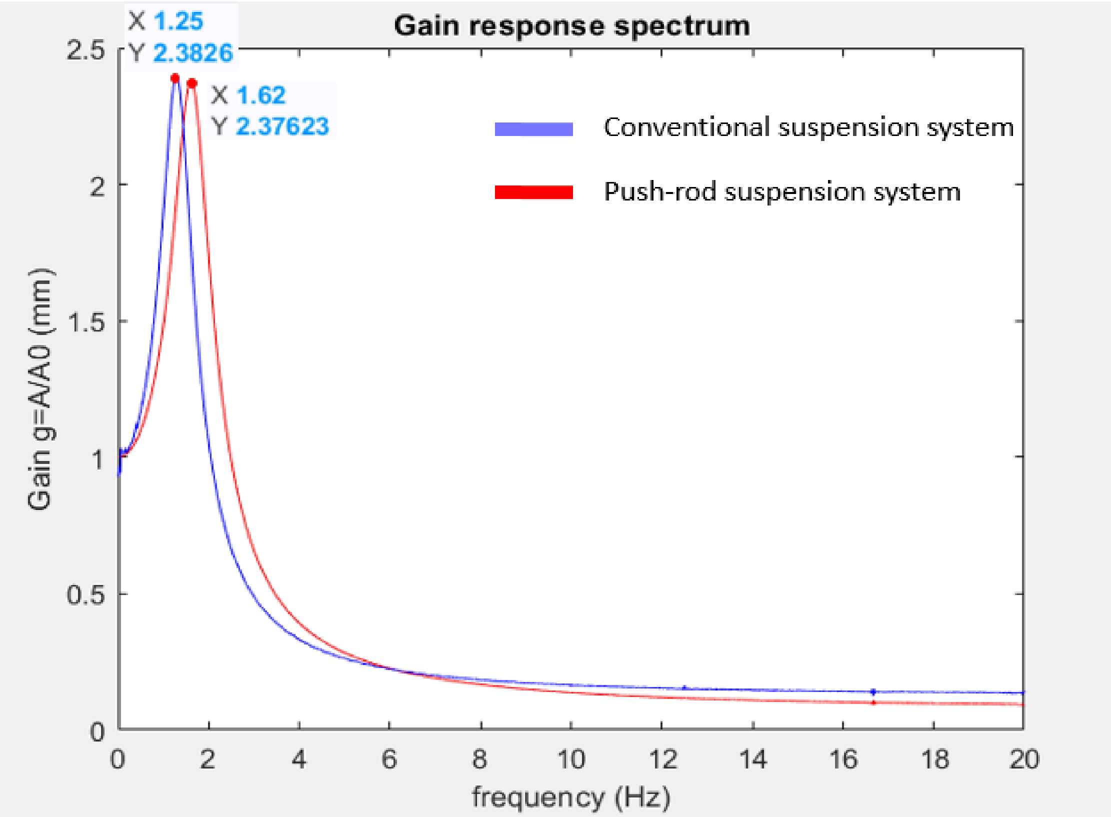

Fig 15: Gain response spectrum of 1/3 load condition

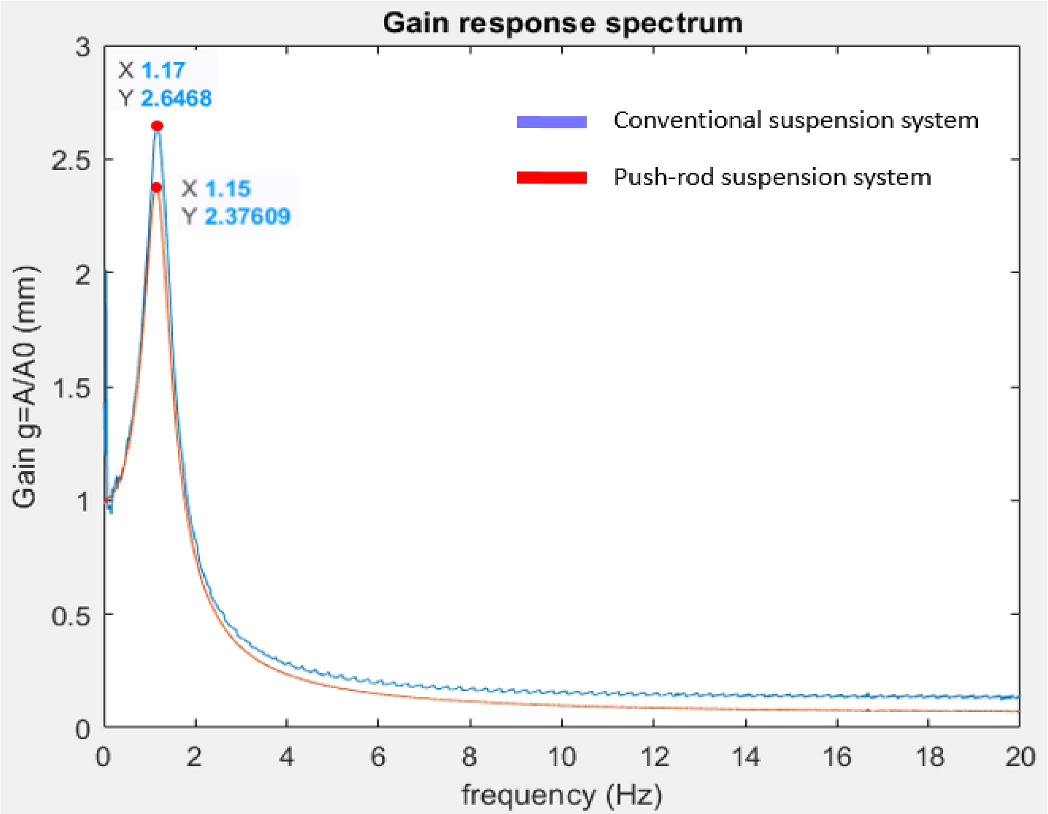

Fig 16: Gain response spectrum of 2/3 load condition

1/3 load: m = 574 kg

Natural frequency:

- Push-rod: fn = 1.62 Hz
- Conventional: fn = 1.25 Hz

Damping ratio: $\zeta = 0.259$

2/3 load: m = 706 kg

Natural frequency:

- Push-rod: fn = 1.15 Hz
- Conventional: fn = 1.17 Hz

Damping ratio: $\zeta = 0.249$

4.3 Gain response of the vehicle

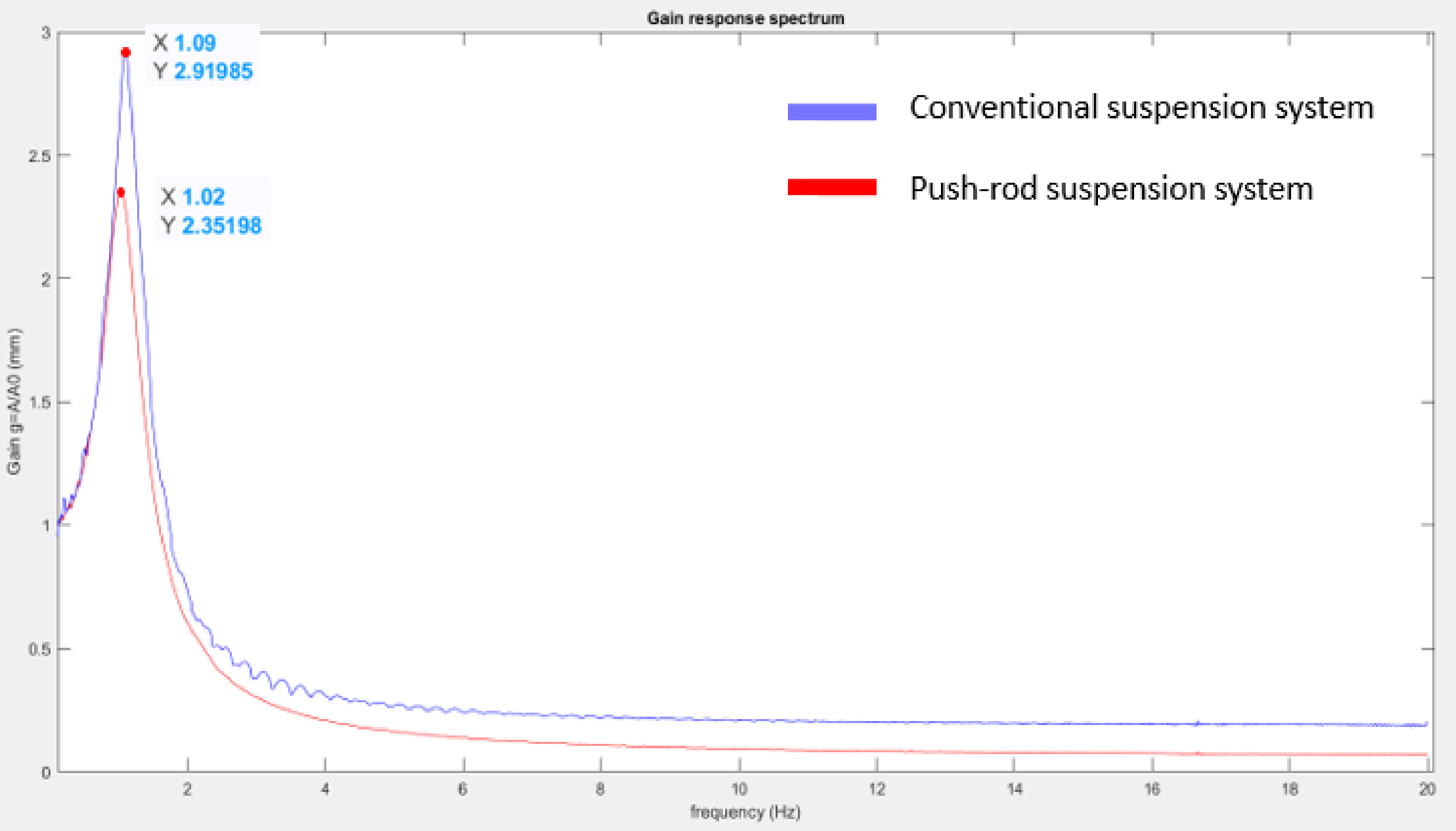

Fig 17: Gain response spectrum of full load condition

Full load: m = 840 kg

Natural frequency:

- Push-rod: fn = 1.09 Hz
- Conventional: fn = 1.02 Hz

Damping ratio: ζ = 0.274

4.3 Gain response of the vehicle

	1/3 Load		2/3 load		Full load	
Suspension	Push-rod	Conventional	Push-rod	Conventional	Push-rod	Conventional
Natural frequency	1.62	1.25	1.15	1.17	1.02	1.09
Damping ratio	0.259	0.259	0.249	0.249	0.274	0.274

Table 2: Natural frequency and damping ratio of Push-rod and Conventional suspension system with different load condition

	Push-rod	Conventional	Difference
Spring stiffness (N/m)	36500	28566	1.27 times
Damping coefficient (Ns/m)	3034	2090	1.45 times

Table 3: Spring stiffness and damping coefficient of Push-rod and Conventional suspension system

- When the load increases from 1/3 to full load → the Natural frequency decreases moderately and the damping ratio fluctuate from 0.249 to 0.274

- The Spring stiffness and Damping coefficient of the Push-rod suspension system is 1.27 times and 1.45 times greater than Coventional suspension system respectively

  → **Use a spring with higher stiffness**

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5. CONCLUSION & FUTURE WORK

CONCLUSION

- Push-rod suspension has more linkage components
- Shorter suspension travel and movement of vehicle’s body
- Spring stiffness and damping coefficient is greater than conventional suspension system
- Simulation method compared with calculus method:
  - Combination of vertical and horizontal direction
  - Use various linkage components in the simulation model
- Advantages of Push-rod suspension:
  - Better aerodynamic by optimizing the push-rod design
  - More stable when heavy cornering

FUTURE WORKS

- Optimize the design of Push rods and the rocker arms.
- Study the relationship between ride comfort and handling of vehicle. To achieve this, a 3D suspension model is utilized to consider the vehicle rotational motions.
- Evaluate the frequency-weighted acceleration to calculate how intensive vibrations affect human body

References

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[5] Figure of Push-rod suspension system at https://suspensionsguy.wordpress.com/2020/08/02/example-post-3/

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Thank You