Influence of system dynamics in brake blending strategies for electric vehicles

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Juan A. Cabrera & Juan J. Castillo

Department of Mechanical Engineering
University of Malaga, Malaga, Spain

Research group

Our facilities

Research Group

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Research group

Recent research themes

Regeneration

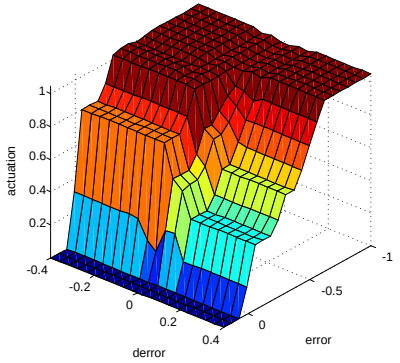
Optimization of regeneration rate on electric motorcycle

Vehicle speed estimation

Robust estimation using data fusion

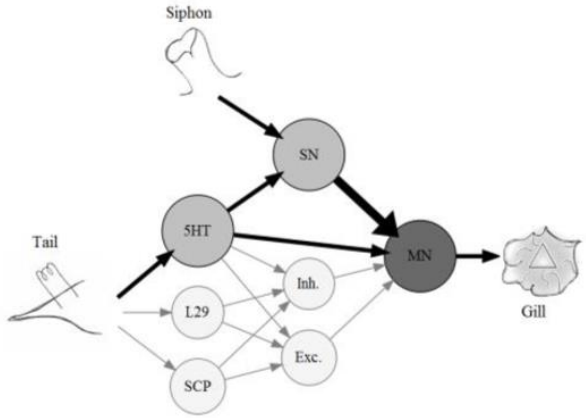
RSC AWD vehicles

Comparison between strategies



Control based on SNN

Simple SNN applied to control of systems



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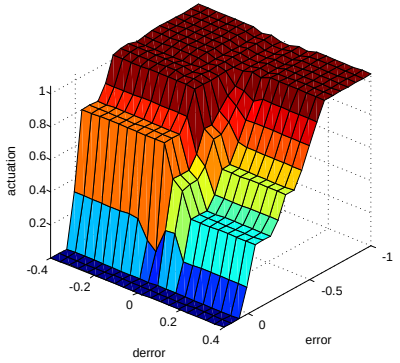

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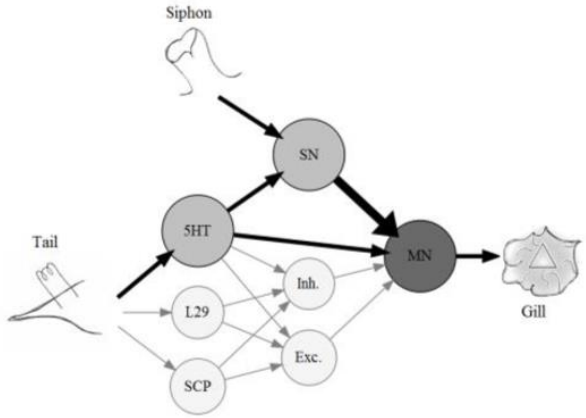

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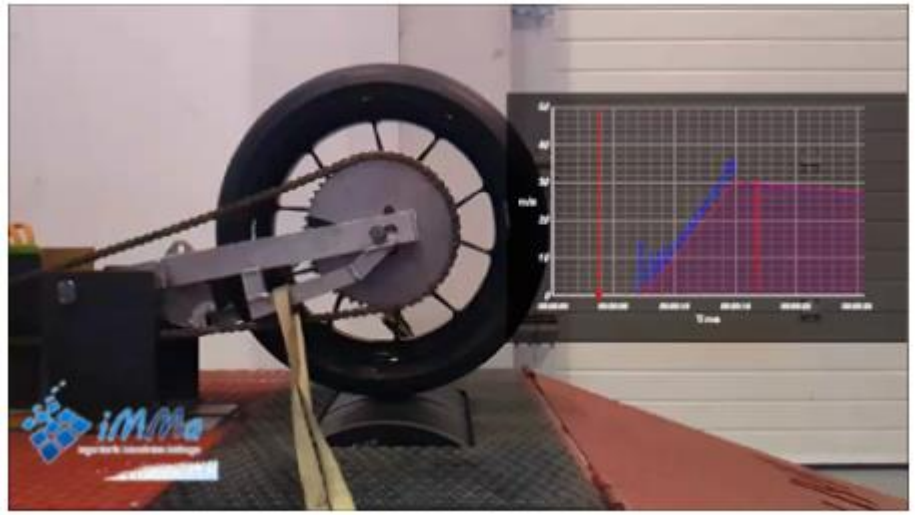

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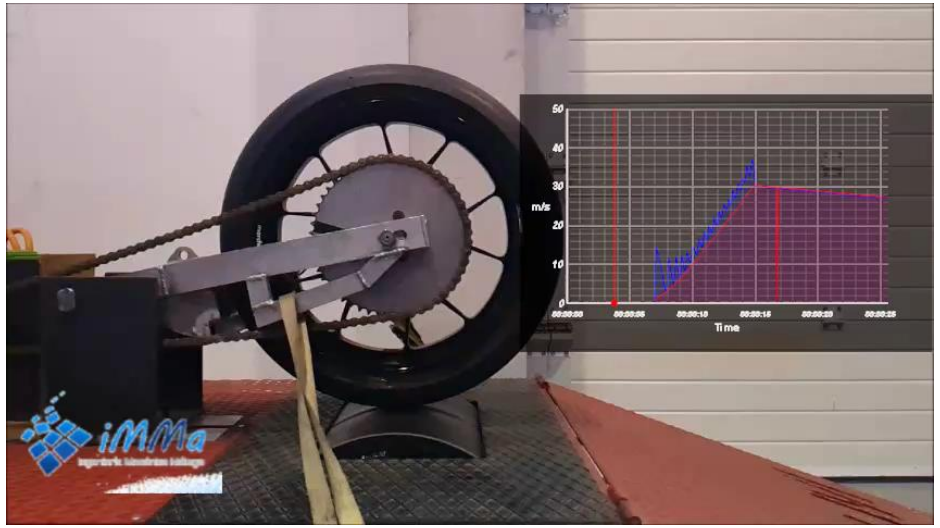

Outline

1. **Introduction**
2. Real vehicle characteristics / System components
3. Tests performed
4. Proposed regenerative system
5. Simulations
6. Real test
7. Conclusion

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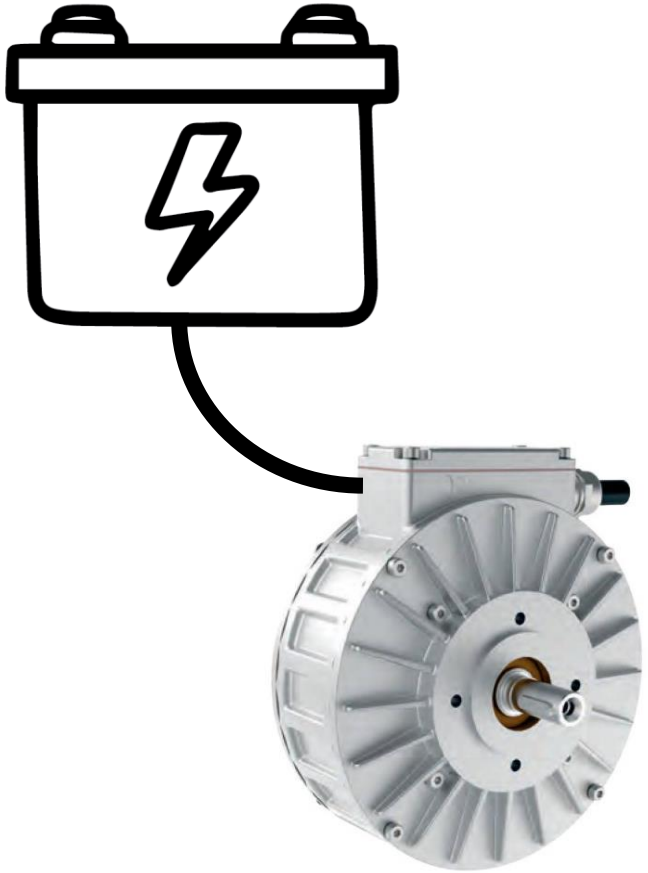


Advantages of regenerative braking

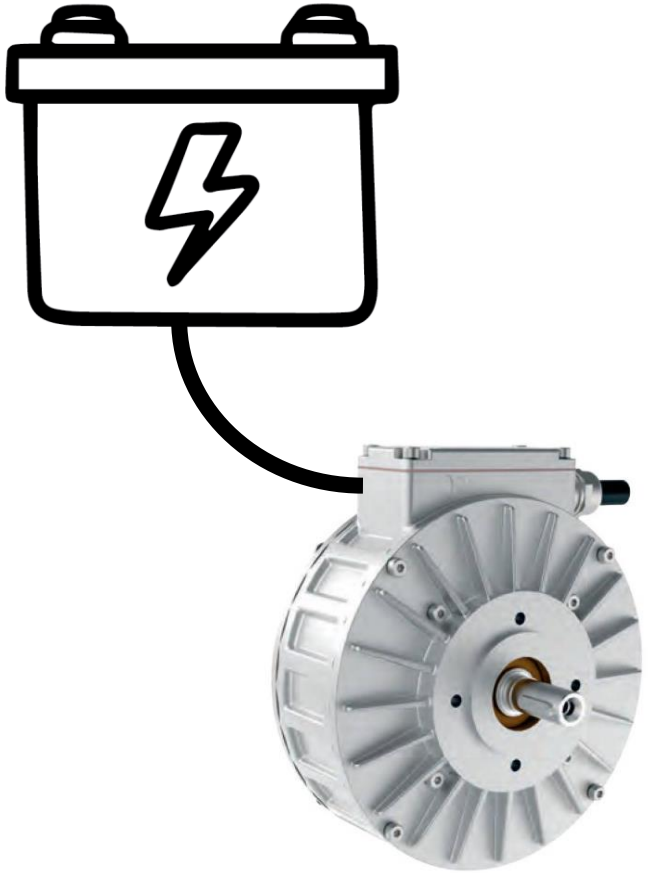
- Recovery of energy during the braking process
- Control of the wheel torque → without having to add additional components to the system

Disadvantages of regenerative braking

- The system is not normally large enough to provide the braking torque demanded by the driver
- The angular speed of the motor, the batteries state of charge (SoC) and other factors must also be taken into account

The installation of a friction braking system is still necessary

Outline



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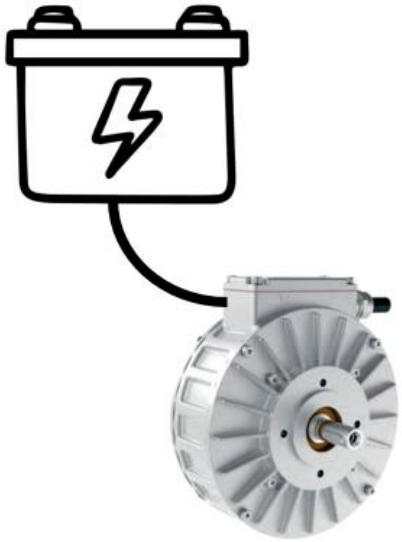
Efficiency



Safety

A study must be made of the dynamics of both systems to see how it affects the safety of the vehicle

Real vehicle characteristics

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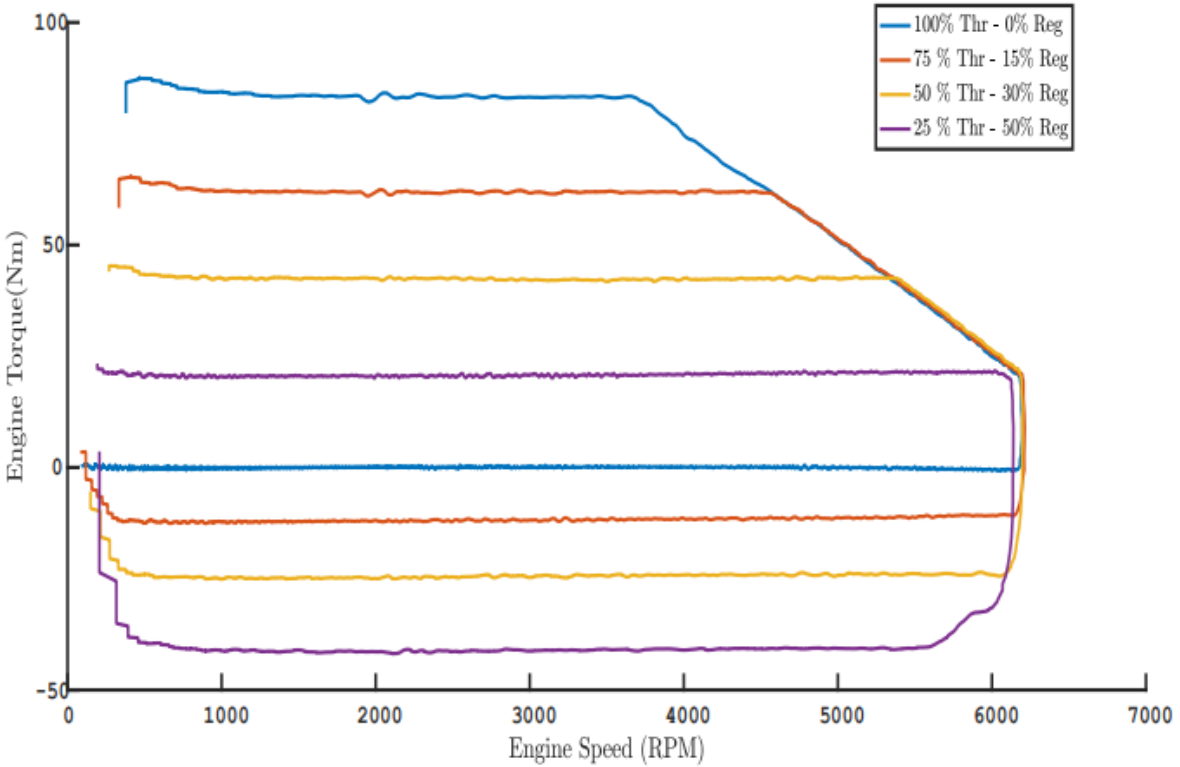
Real vehicle characteristics

Component	Parameter	Description
Vehicle	Motorcycle weight	135 Kg
	Chassis Type	Steel Tubular
	Height of gravity centre	621 mm
	Distance between axis	1370 mm
	Wheel radius	300 mm
	Distance from the COG to the front axle	670 mm
	Front tire	95/70 R 17
	Rear tire	115/70 R 17
Electric motor	Brand	Heinzmann PMS 150
	Type	Axial Flux Permanent Magnet
	Maximum speed	6000 rpm
	Maximum torque	80 Nm
	Torque constant (K_m)	0.145 Nm/A
	Maximum power	34.1 KW (46.36 CV)
Battery	Battery Type	LiPo
	Cell layout	26S5P
	Total capacity	4.8 KWh
	Rated Voltage	96 V
	Maximum discharge current	1250 A
	Maximum load current	300 A



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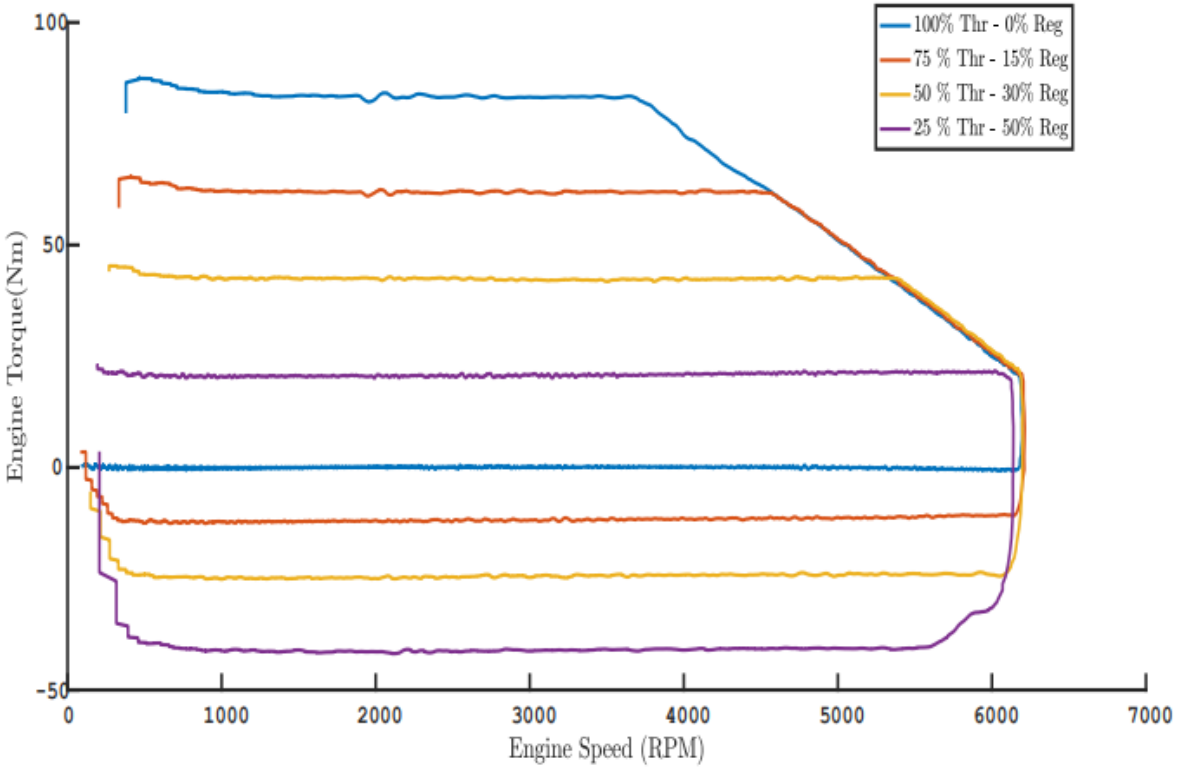
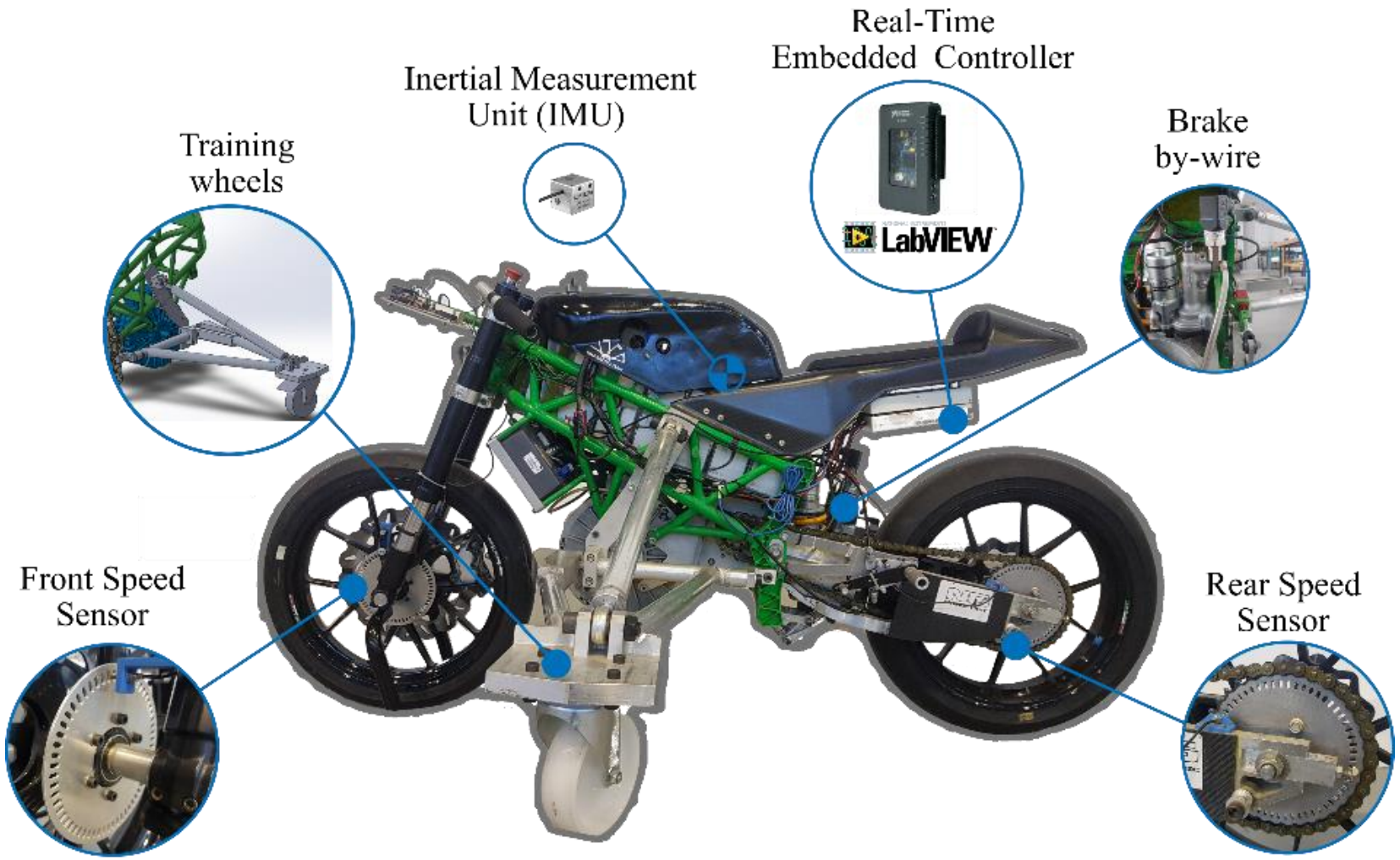


Real vehicle characteristics



Tests performed

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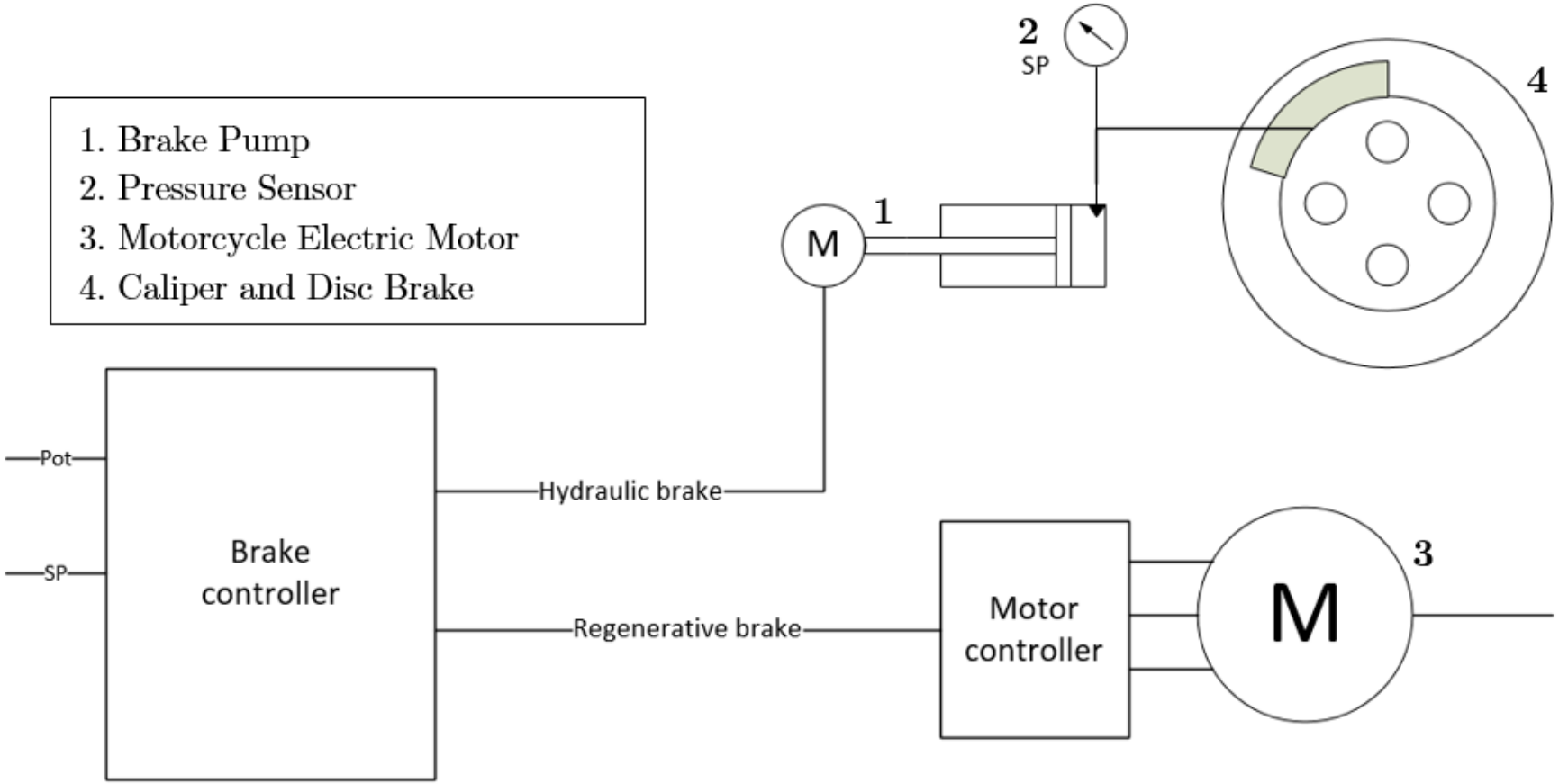
Tests and their results

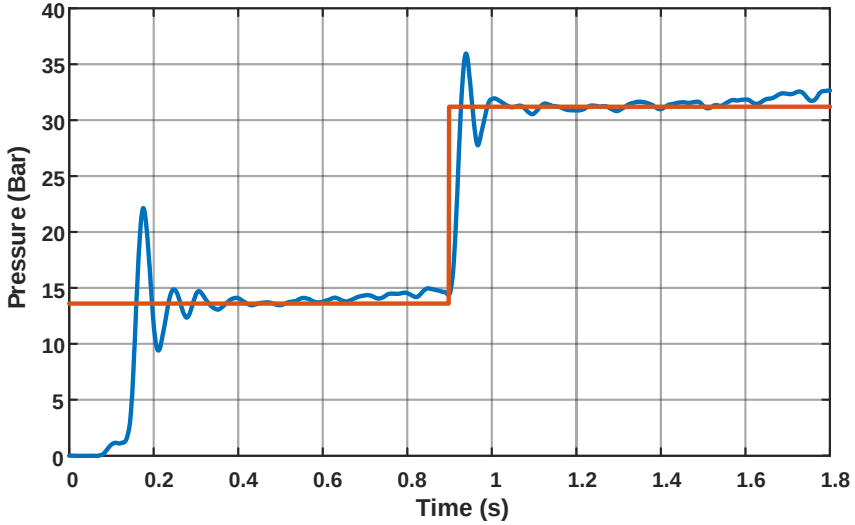
Tests performed

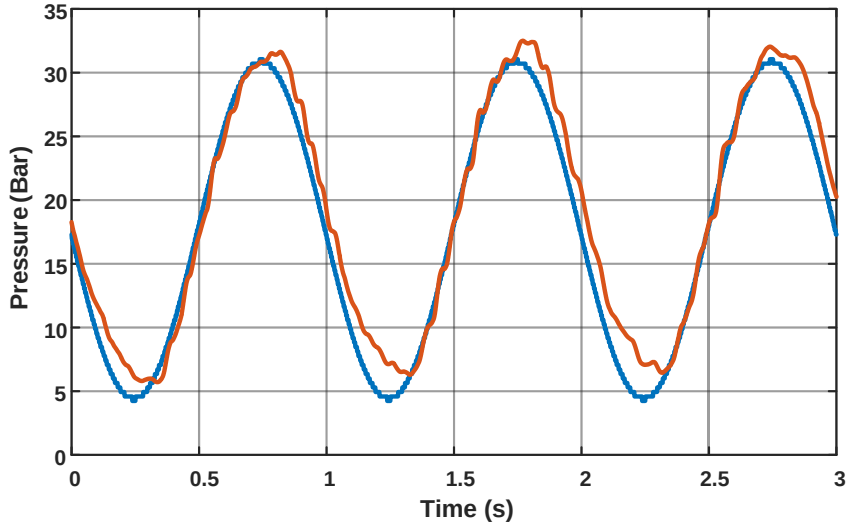
Rear braking system



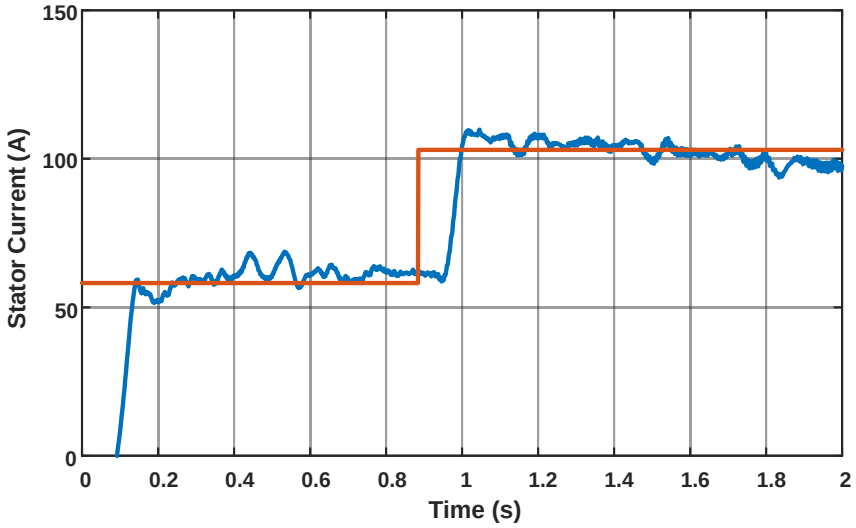
Tests performed

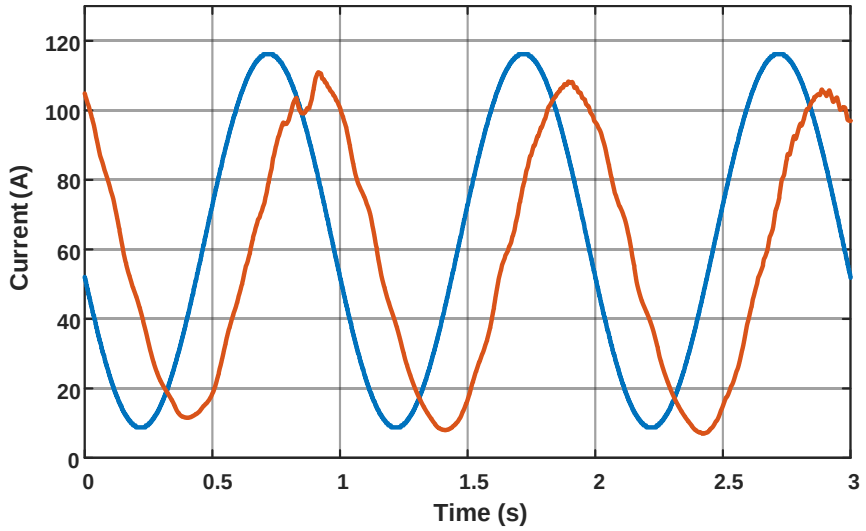
Friction





Regenerative

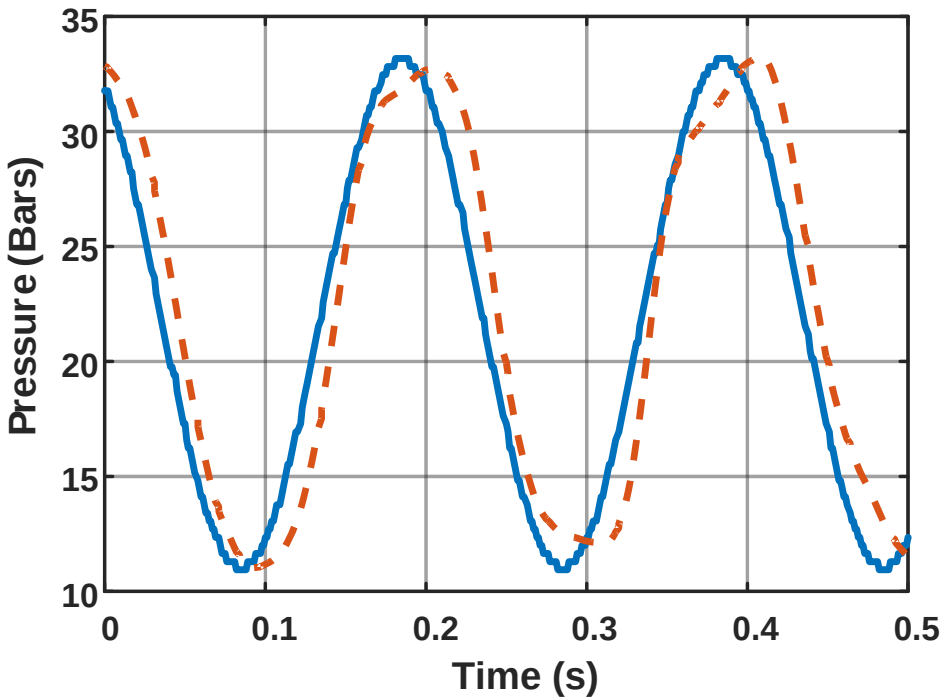




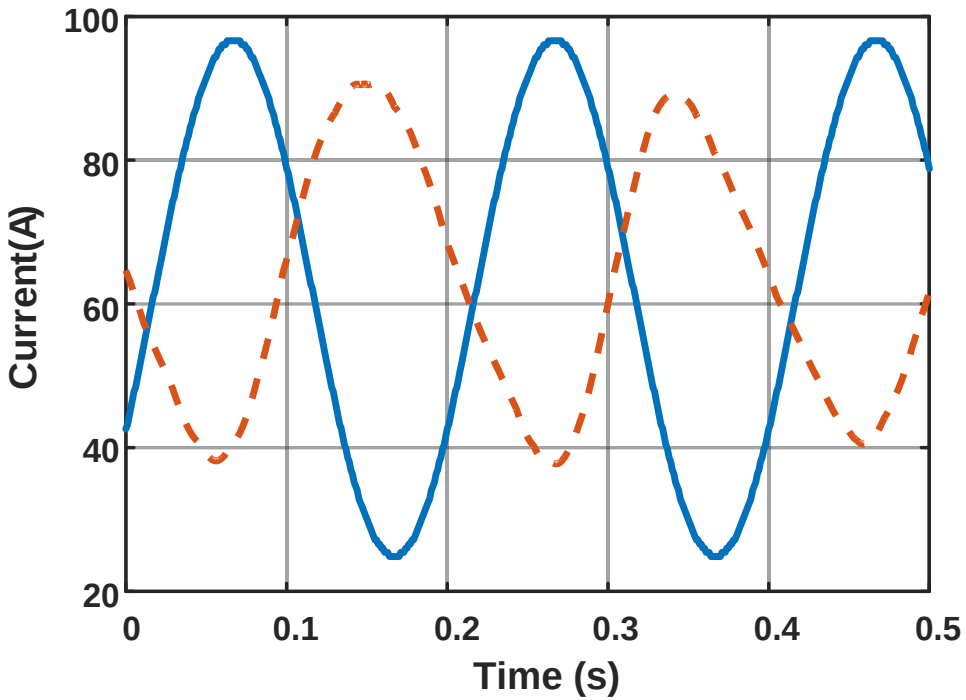
Tests performed

5Hz

Friction



Regenerative



Proposed regenerative system

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Proposed regenerative system

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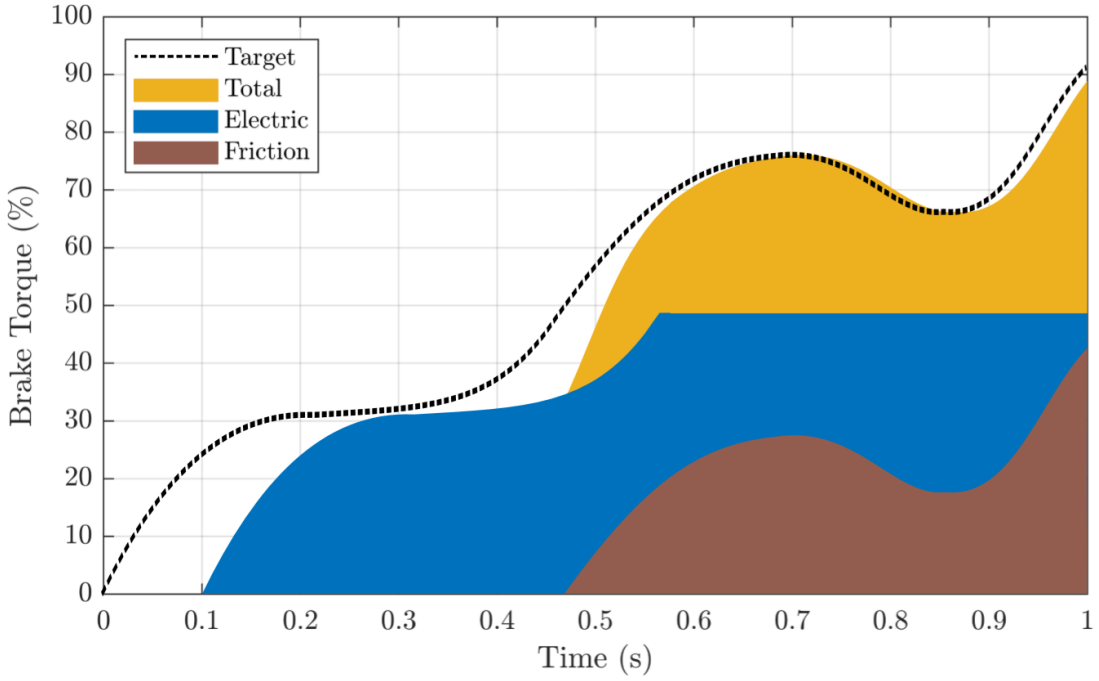
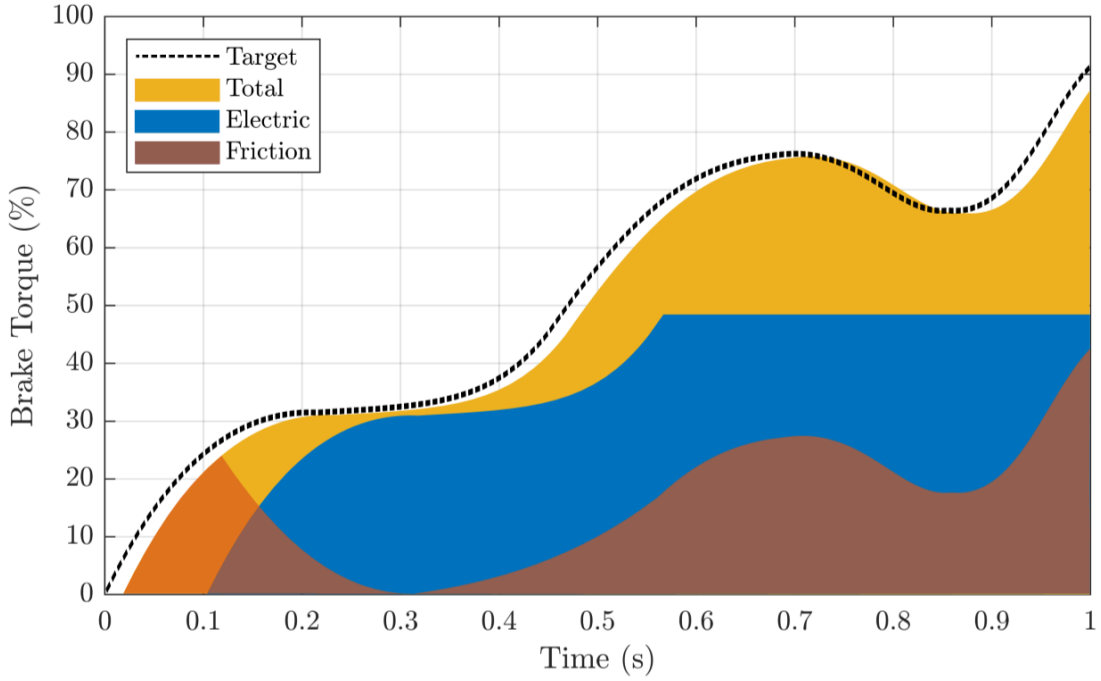
Classic brake distribution



Proposed brake distribution minimizing the delay of the electric regeneration system



When the regenerative brake starts to take effect, the friction brake adapts to maintain the torque target.

Simulations

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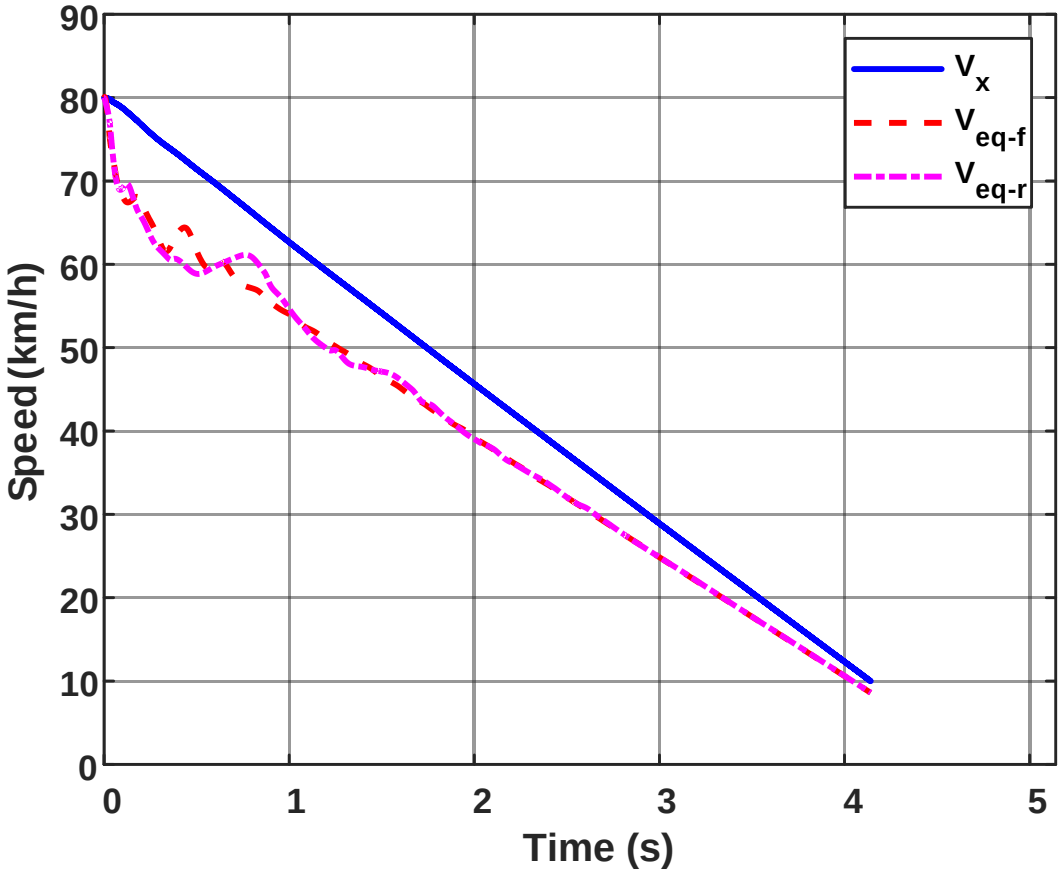
to evaluate the performance of the proposed braking strategy compared to the conventional one

Simulations

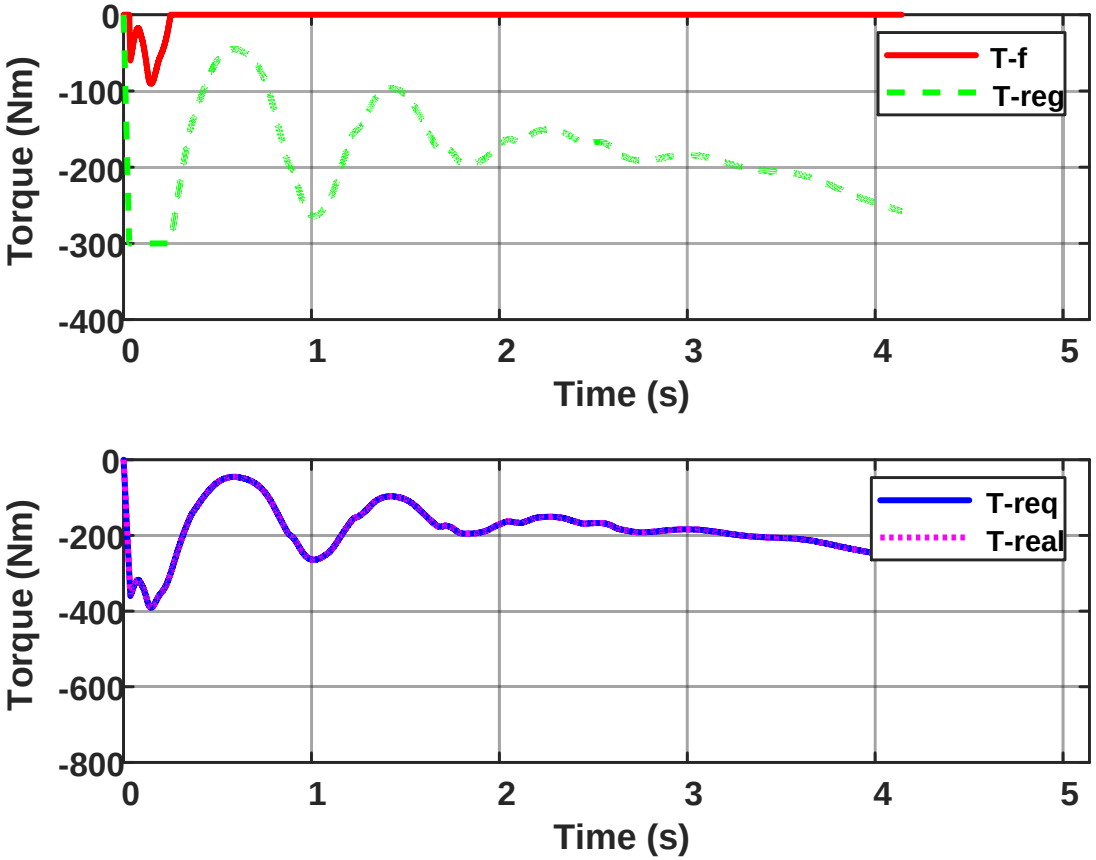
μ=0,4

$v_0 = 80\ km/h$ $\quad$ $v_1 = 10\ km/h$



Fuzzy logic ABS

Both wheels were controlled with the ABS



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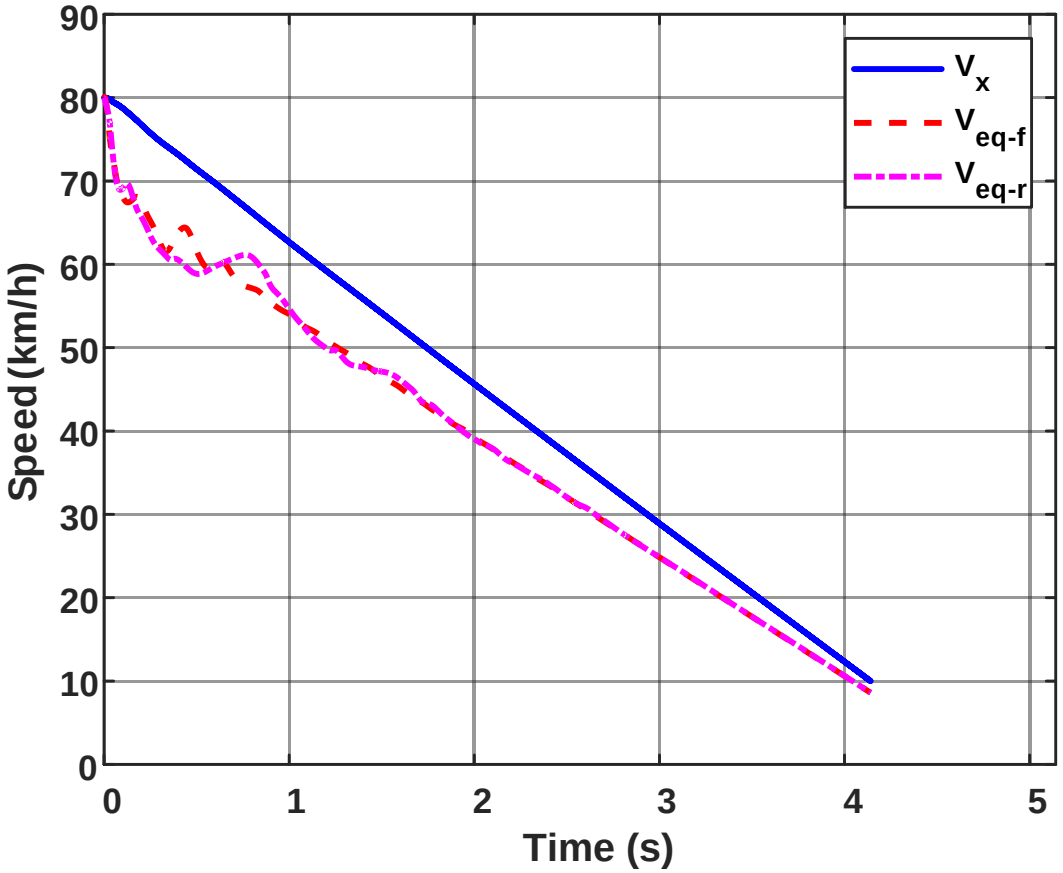

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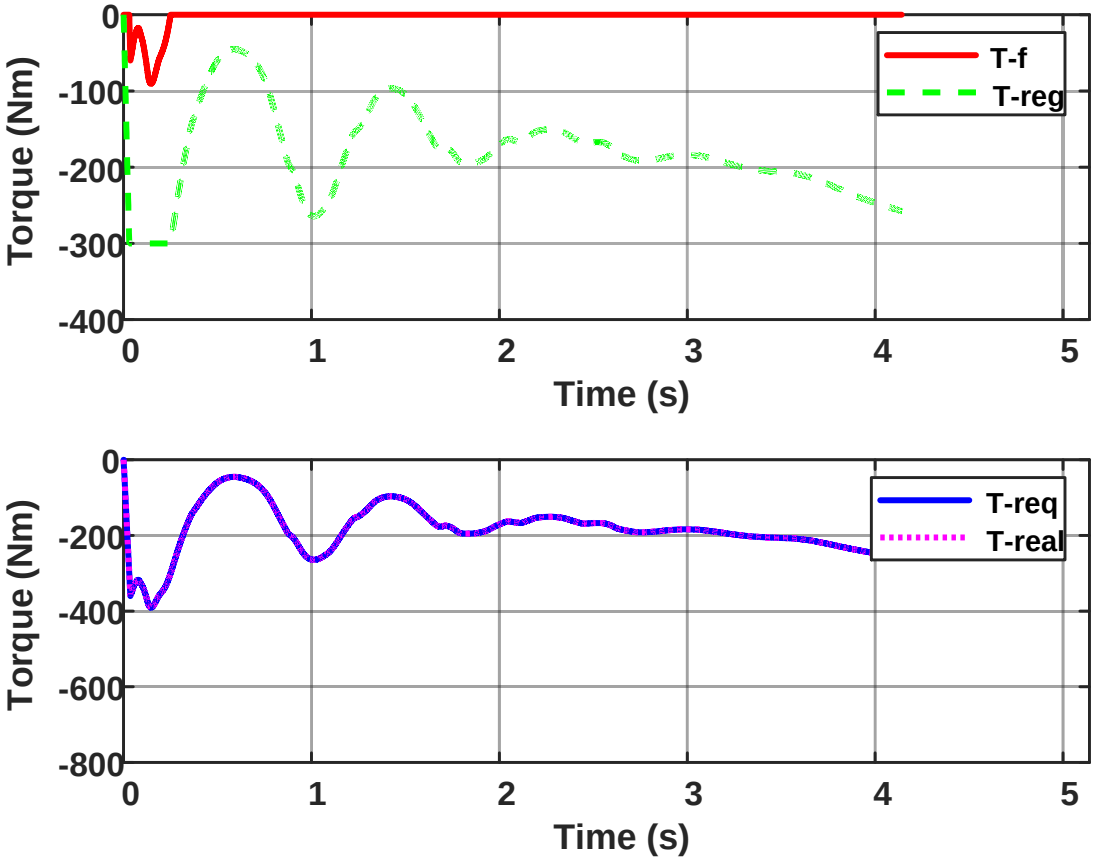
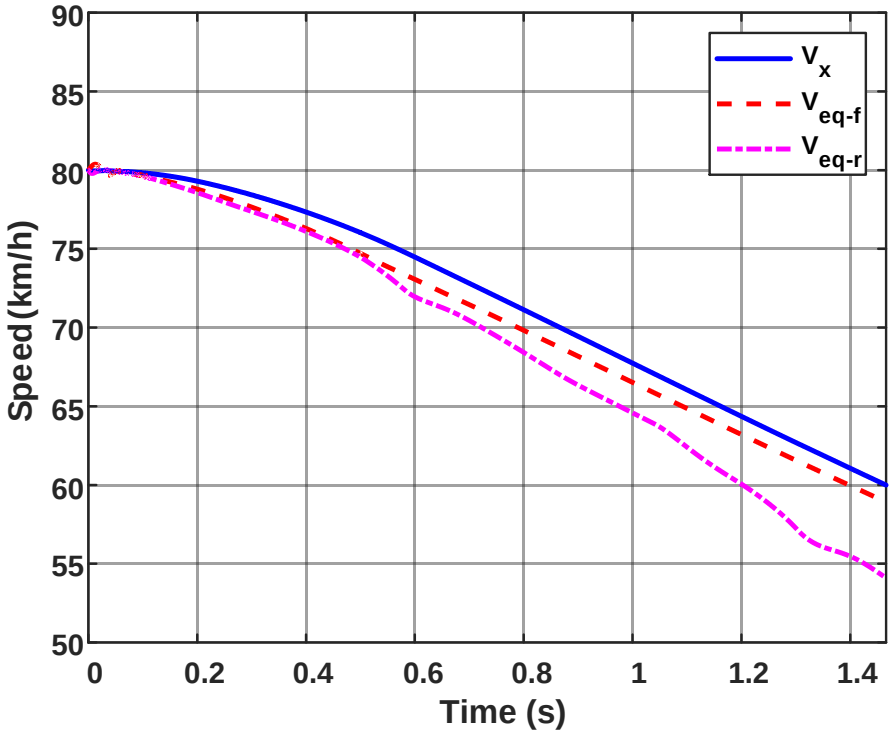


Simulations

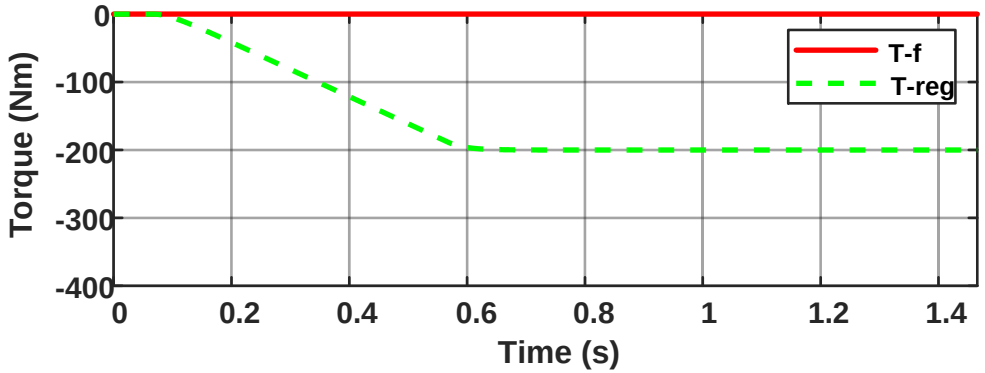
	w/o Regeneration	w/o. Compensation	w. Compensation
Brake distance (m)	72.60	77.30	75.52
Time (s)	5.98	6.33	6.24
Energy (Wh)	0	30.45	29.83

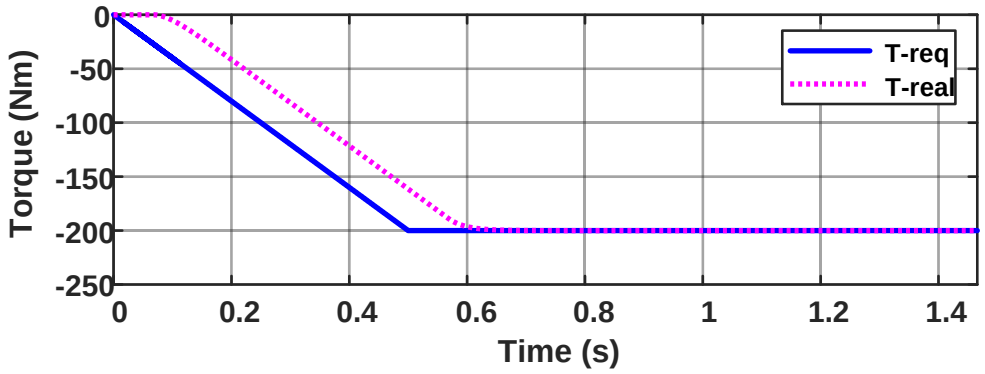
Simulations

ABS not required



No brake compensation





Simulations

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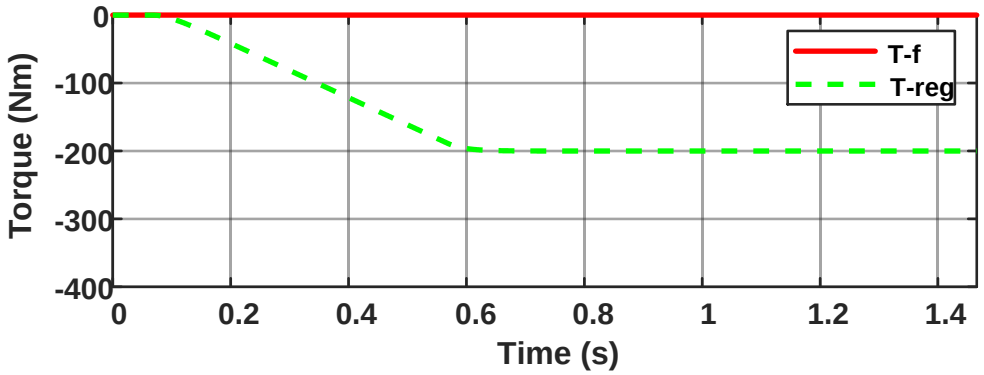
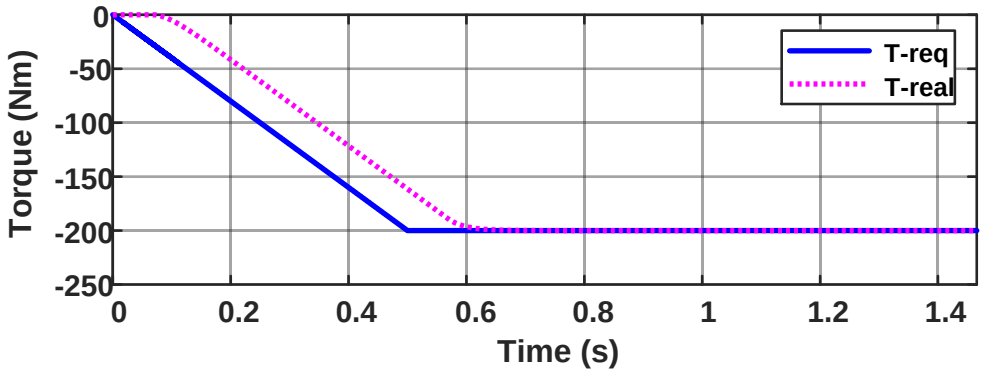
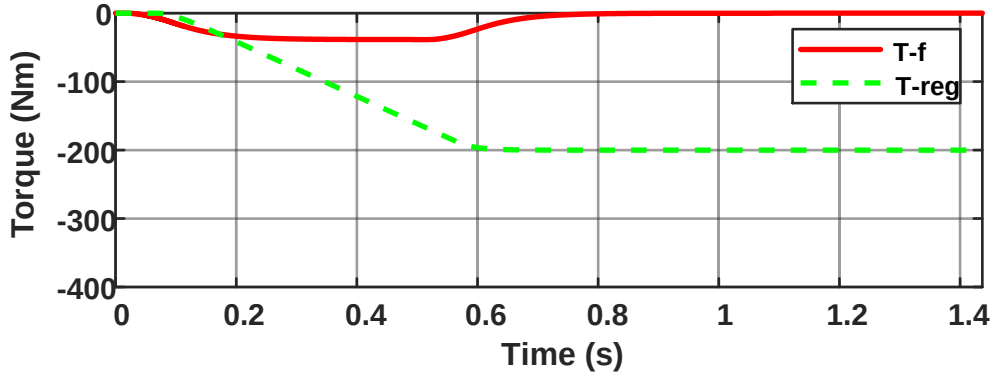
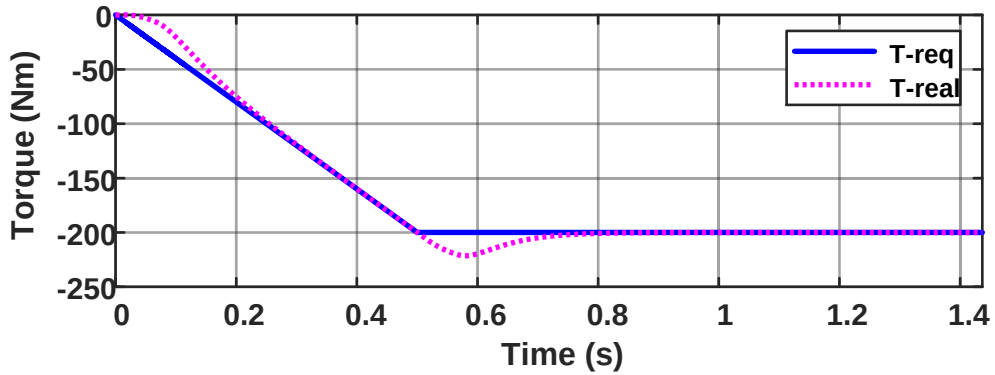




Brake compensation





Real test

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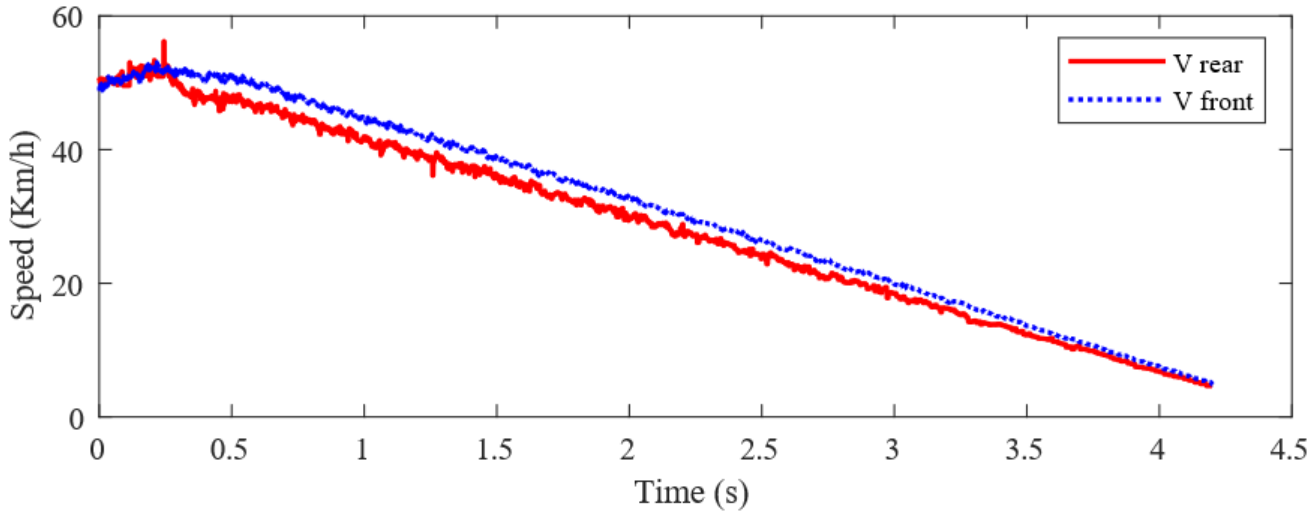
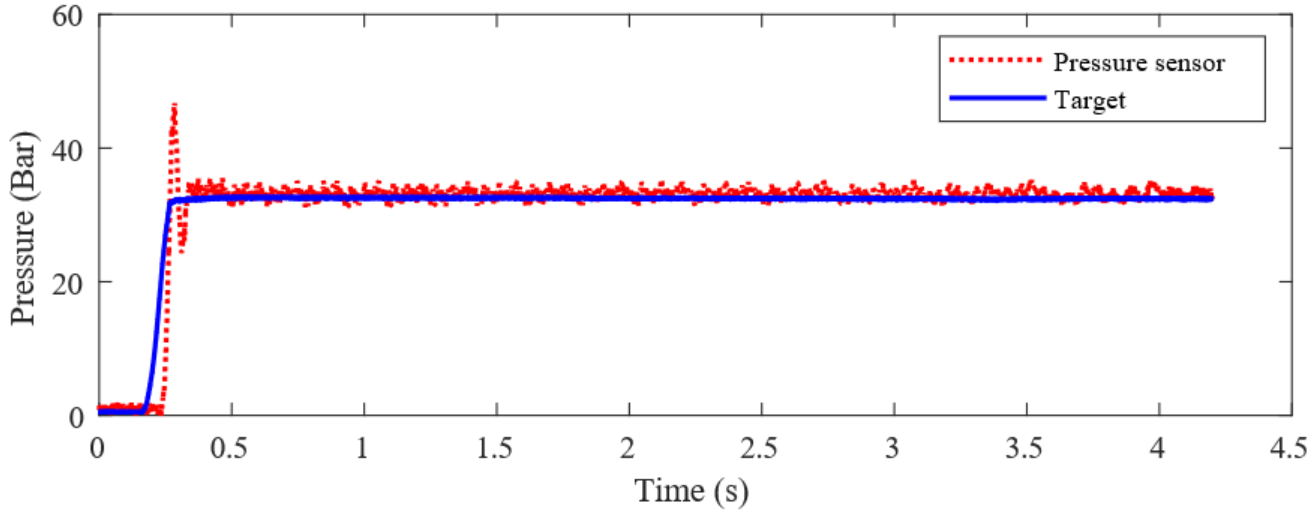
Real test

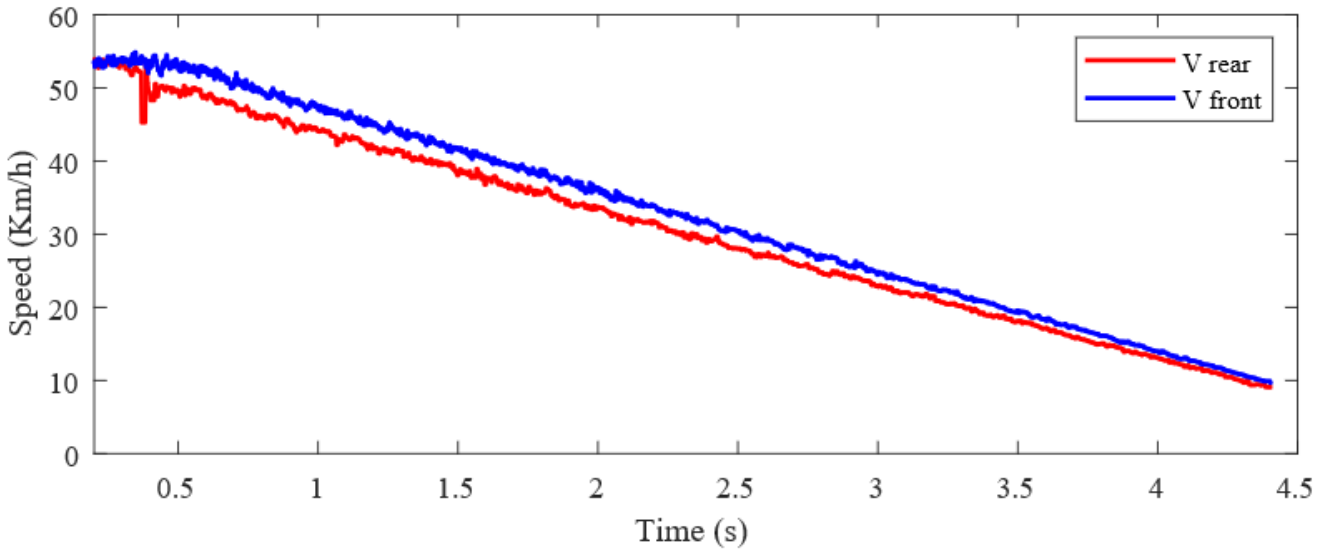
Friction

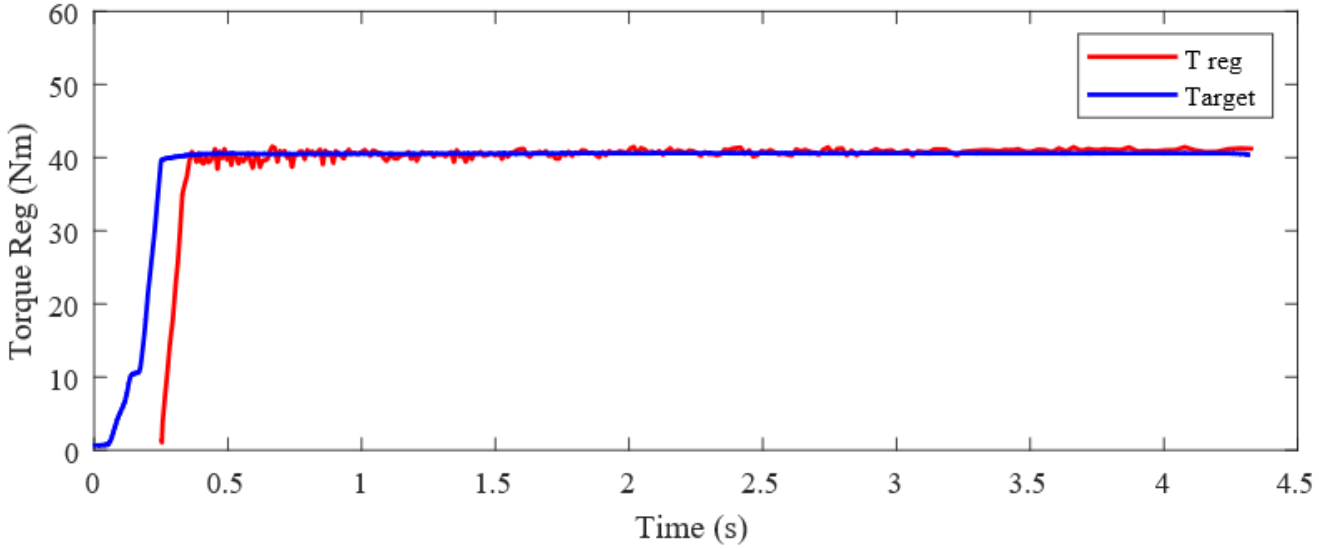




Real test

Regenerative

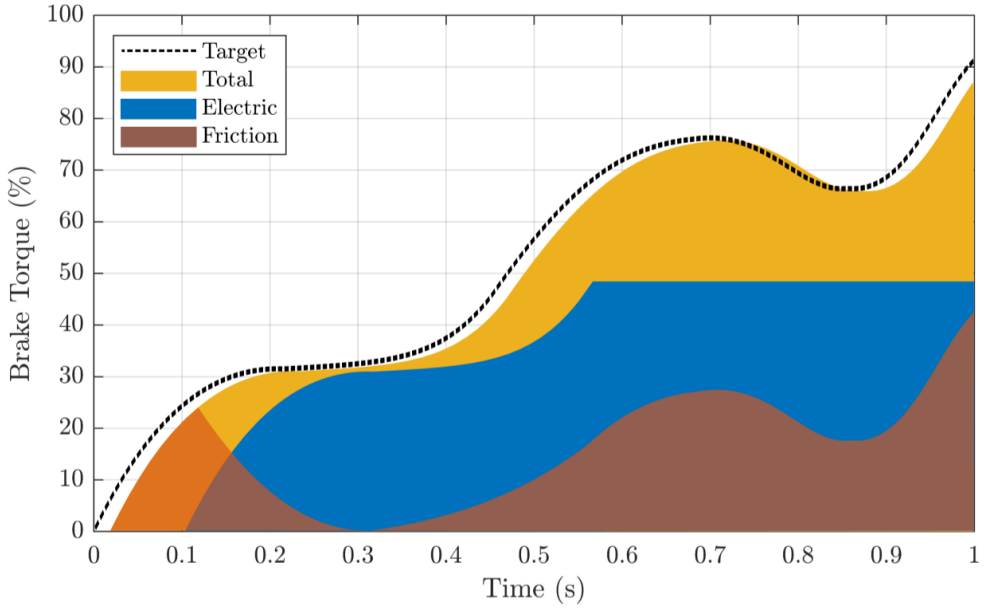


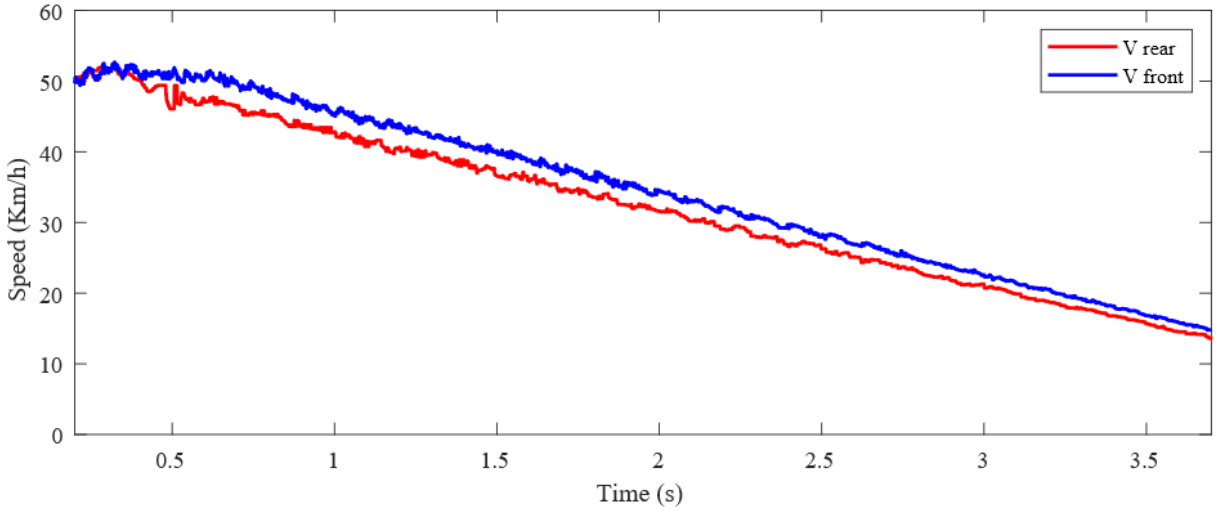


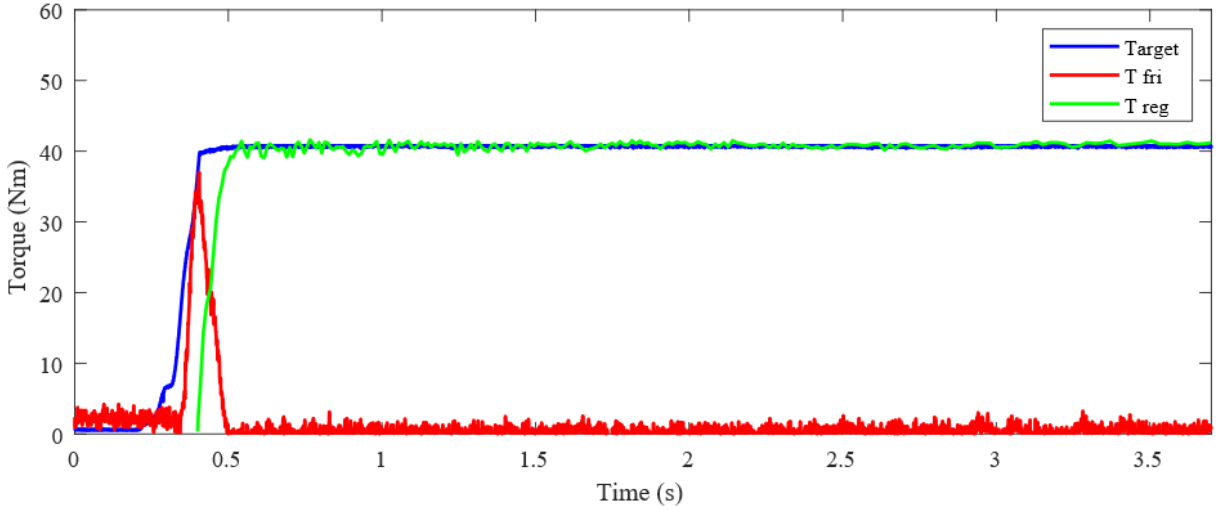
Real test

Brake compensation

Electric system	Hydraulic system
$\frac{1}{0.028 \cdot S + 1}$	$\frac{1}{0.057 \cdot S + 1}$
68	18



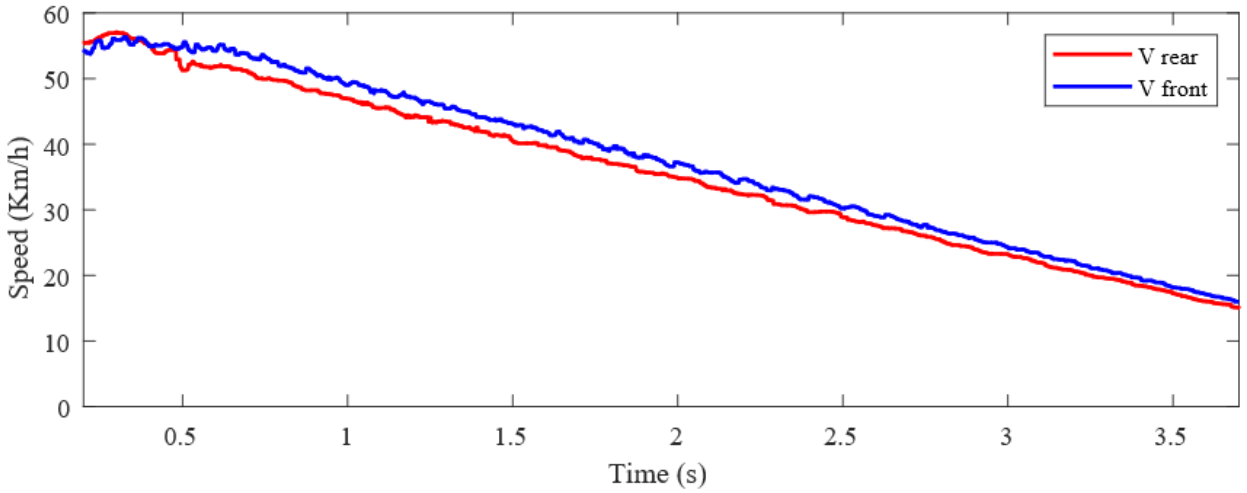


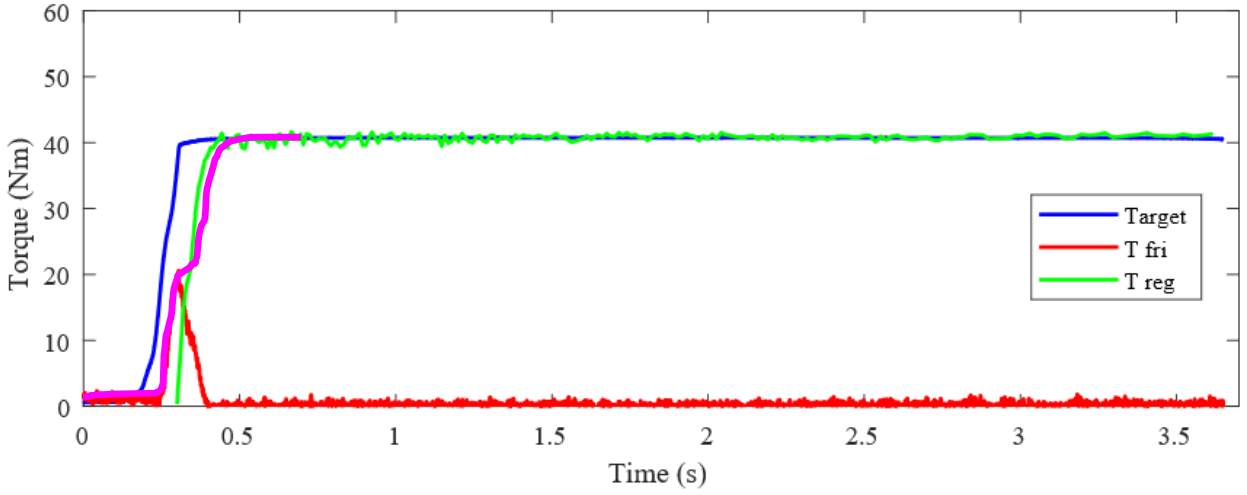


The friction brake begins to act and then gives way to the regenerative brake.

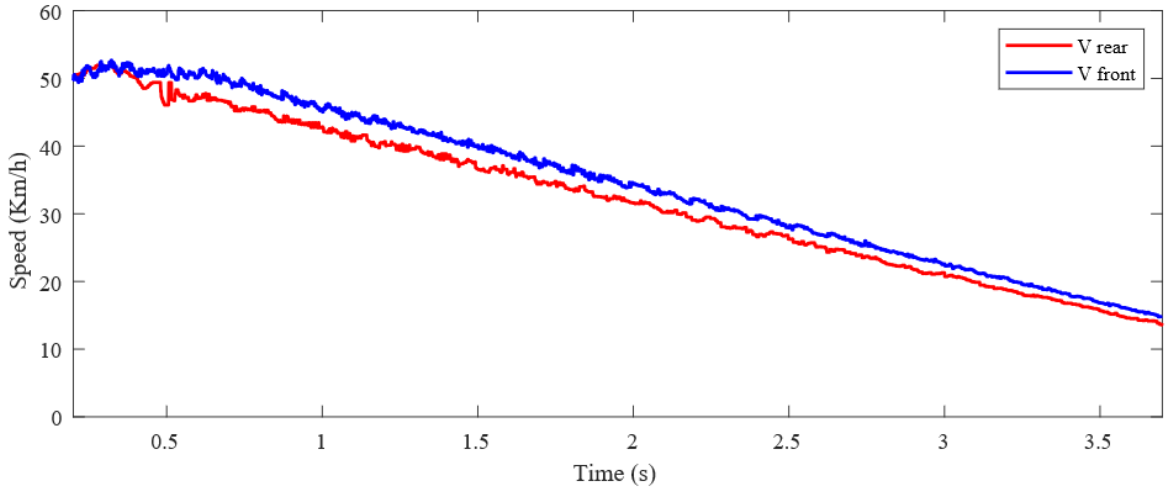
Real test

No brake compensation

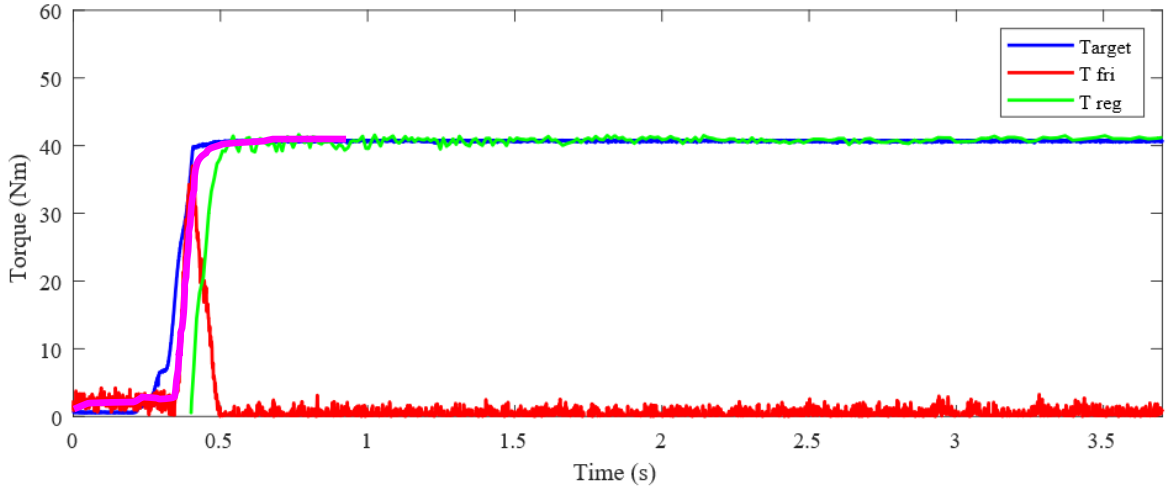




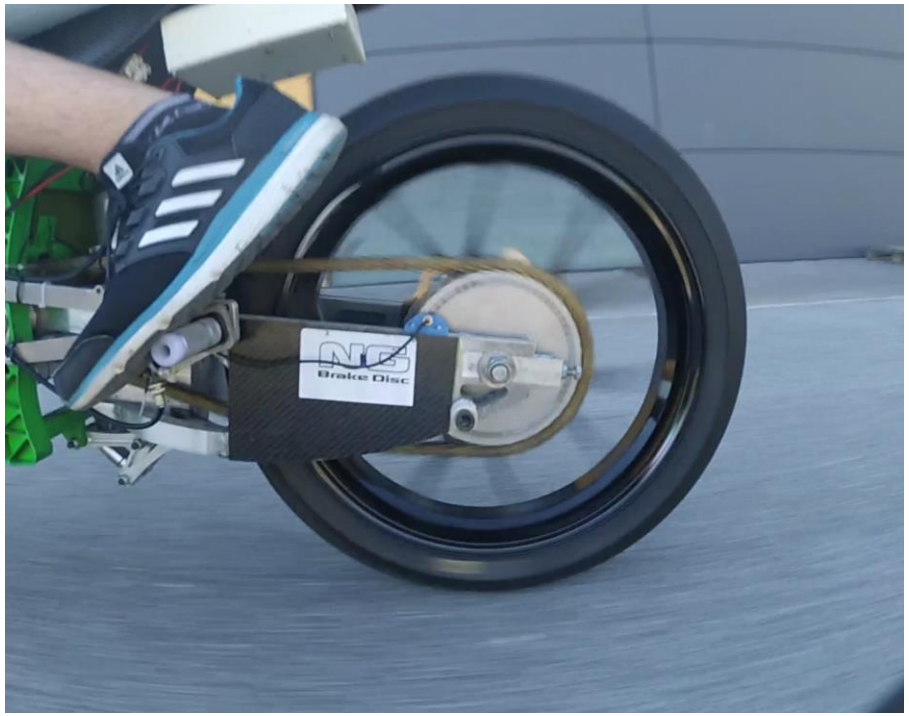
Brake compensation



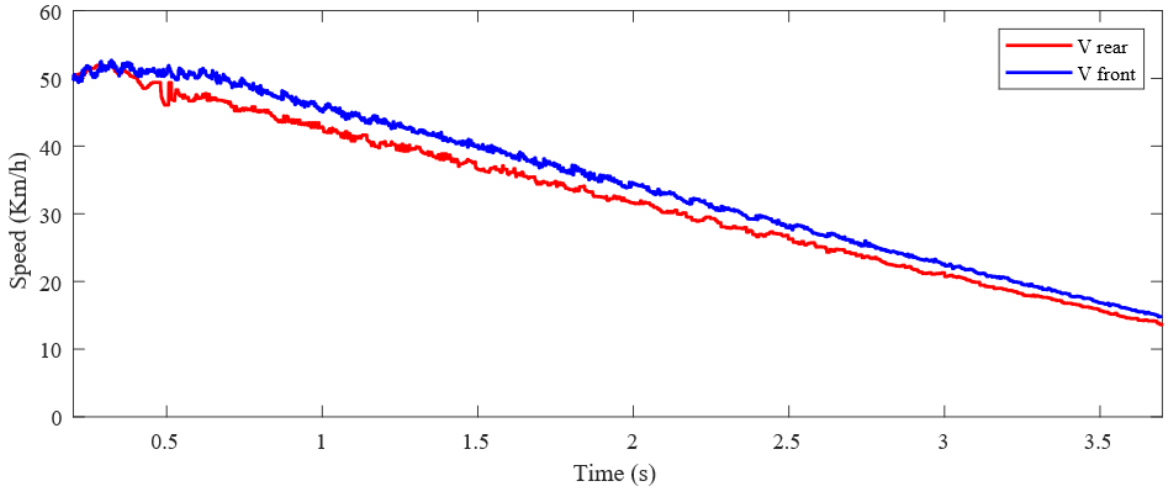
The performance of the compensated braking system is much faster

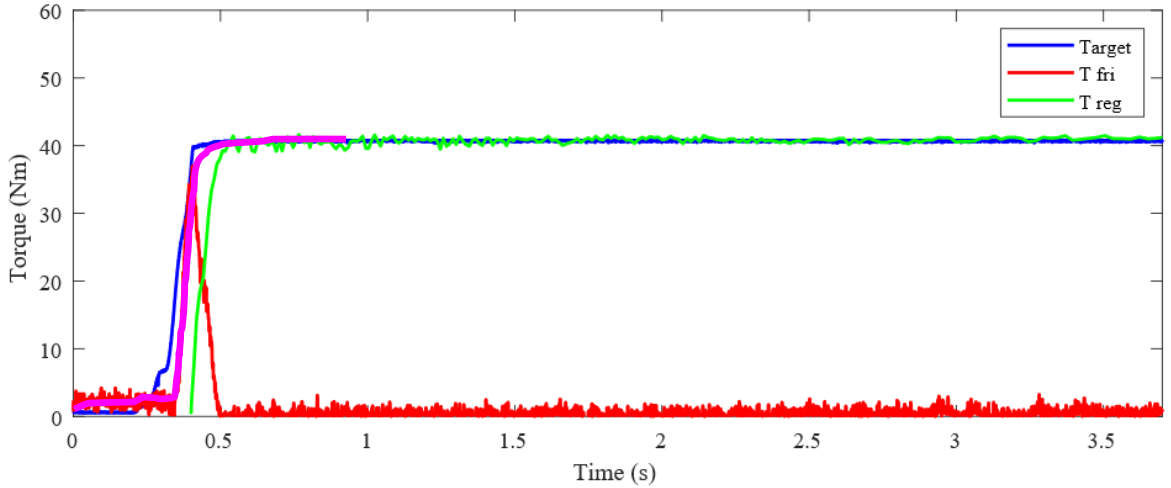


Real test



Brake compensation

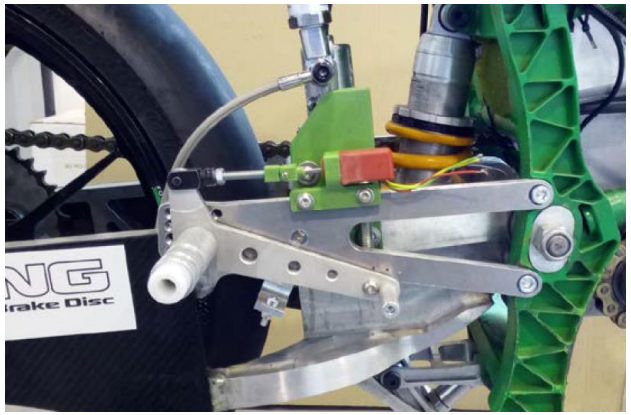




Conclusion

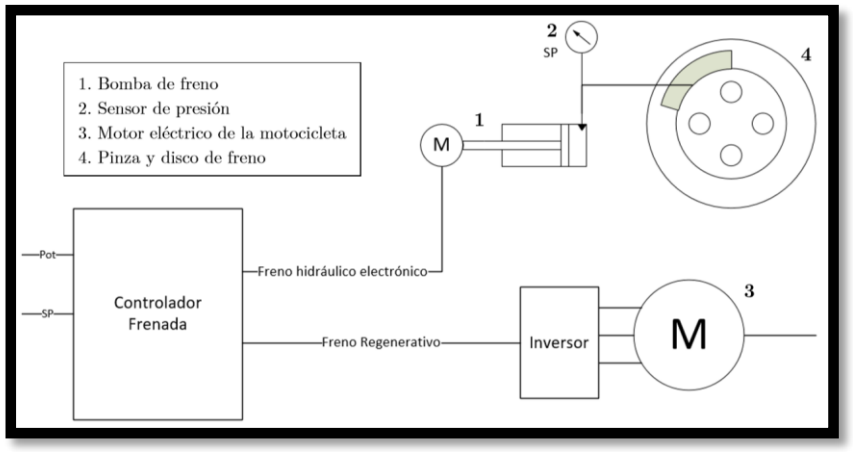
1. Introduction
2. Real vehicle characteristics / System components
3. Tests performed
4. Proposed regenerative system
5. Simulations
6. Real test
7. **Conclusion**

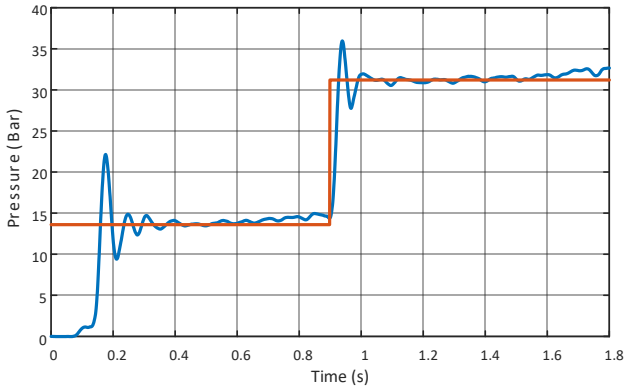
Conclusion

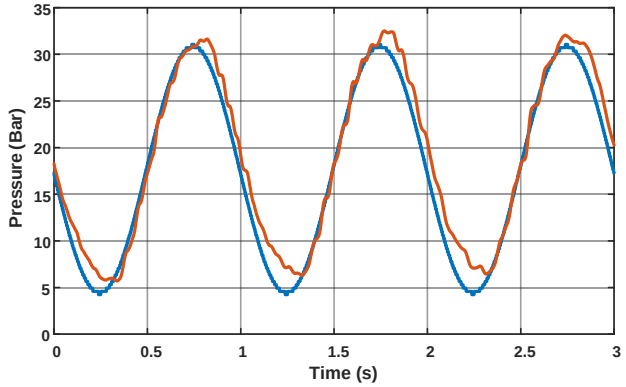


We have studied the dynamics of a by-wire friction braking system and a regenerative braking system

Three different types of braking systems installed on the motorcycle used to carry out the tests







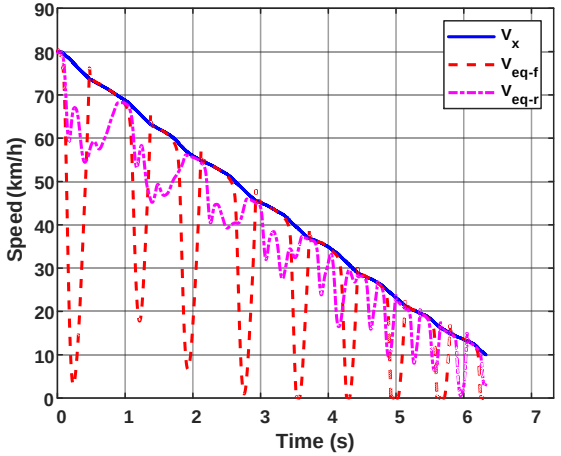
Step and sinusoidal control signals were introduced and the response of both systems has been compared

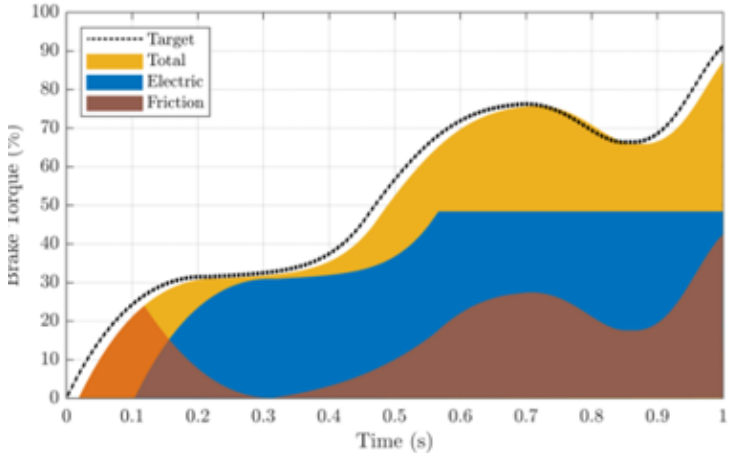
Our hydraulic system is much faster than our regeneration system

Conclusion

The main objective is to regenerate the maximum energy possible without affecting safety

A combination algorithm of both systems has been proposed





We have proved that it is essential to take these dynamics into account when designing braking control systems, such as the ABS braking system.

Influence of system dynamics in brake blending strategies for electric vehicles

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