ACTION OF FORCE IN STEERING MECHANISMS OF VEHICLES IN AN EXPERIMENTAL LABORATORY ESTABLISHMENT

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Abstract

The safe and stable control of a vehicle undoubtedly belongs to one of the most important requirements that relate to the vehicle's design and operation. Consequently, in the near future, so called steer-by-wire systems could become the next stage in the control system development. A number of new, modern vehicles presented by car makers at important car shows definitely show how topical the issue is.

If we want to create a design for this steering system, we have to know the action of force very well.

An experimental laboratory establishment for measuring and optimizing the steering system of vehicles was developed in our centre. The testing equipment is made of aluminium sections enabling the equipment to be quickly adapted to various vehicles´ axles and tyres. An exchangeable mat located under a tyre enables the system to create behaviour simulation for various surfaces with a different coefficient of adhesion. A sliding way assisted by a hydraulic jack under a tyre allows a change in axle load for example in accordance with the vehicle's occupancy. A force sensor will be positioned between the jack and the mat to monitor the load adjustment. The testing stand design enables us to determine responses and behaviour of the system including tyres.

Keywords*: steer by wire, experimental laboratory establishment, vehicle axle*

1. Introduction

Steering allows the maintenance or changing of the vehicle´s direction of travel and must comply with the following requirements: easy, fast and safe directional dynamics (handling), no vibrations and impact in steering may occur, the wheel should spontaneously return to the forward direction, the steering mechanism must not have higher clearances etc. In addition, steering has to be in conformity with the homologation regulation of the European Economic Commissions

(EEC) OSN no.12 and EEC no.79.

The Technical University of Liberec, Department of Vehicles and Engines, has developed a design of a testing bench which would enable the testing of directional control systems. The objective of the newly designed equipment is to incorporate a real tyre as well as a flexible mounting of the axle components into the tested system. The equipment structure is made of aluminium sections enabling the equipment to be quickly adapted to the application of various vehicles´ axles and tyres. An exchangeable mat located under the tyre enables the system to create behaviour simulation for various surfaces with a different coefficient of adhesion (ranging from asphalt to ice substitution). A sliding way assisted by a hydraulic jack under the tyre allows a change in axle load, for example in accordance with the vehicle´s occupancy. A sensor will be positioned between the jack and the mat with exchangeable surfaces to monitor the load adjustment.

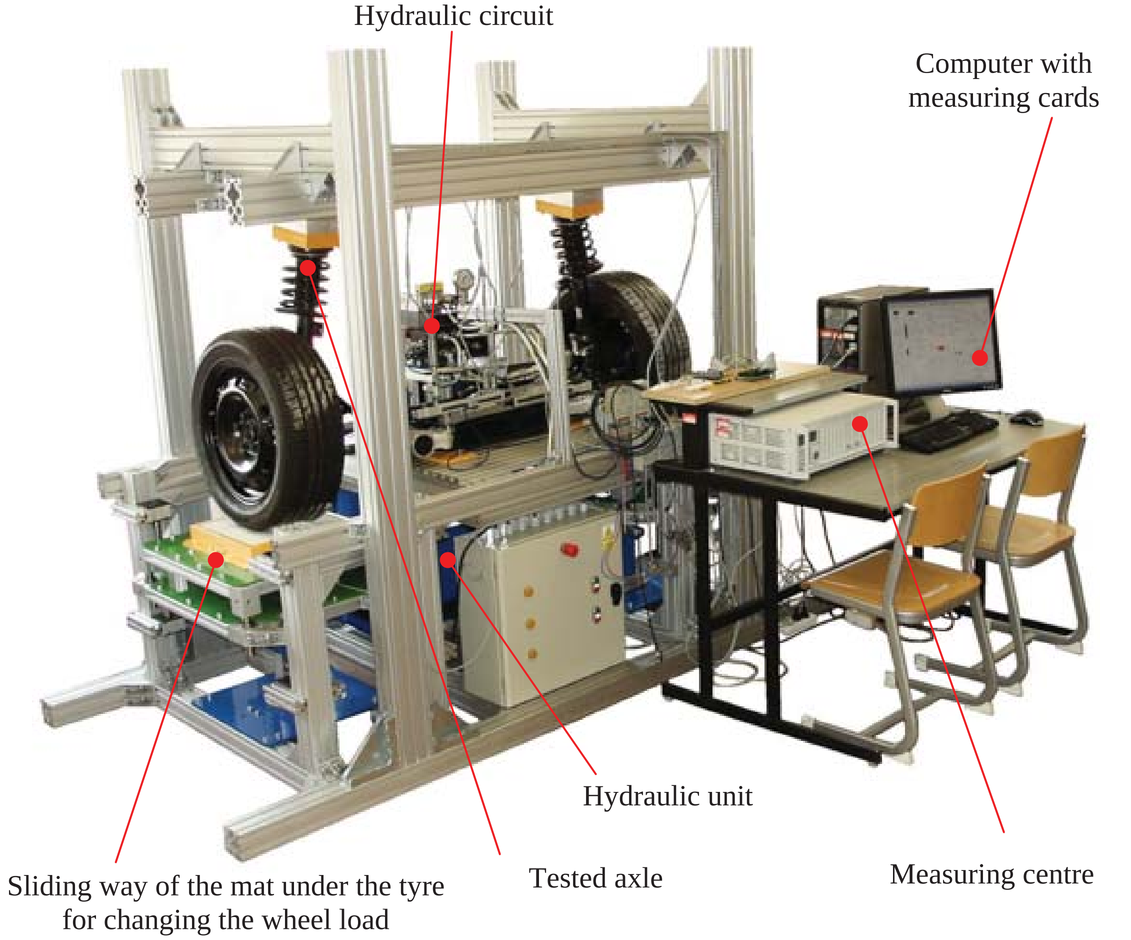

Fig. 1. View of the testing bench for the testing of steering at zero angular speed of wheels

2. Measuring circuit description

An MF624 input-output card by HUMUSOFT s.r.o. married up with the Matlab/SimulinkReal/Time Toolbox program was used to control the hydraulic circuit. In this program, an application obtaining information about the current position of the DF Plus proportional valves is created. By means of the LM10 linear incremental sensor the application receives information about the current position of the hydraulic cylinders – an indirect measurement of the wheel´s angle. The information is processed in the application of the mentioned program and then a relevant setting of the DF Plus proportional valves is calculated. A more detailed description of the hydraulic circuit the characteristics of which are being investigated at our experimental labrotary establishment can be found in the article named: „Hydraulic circuit control of steer-by-wire system“ in this Collection.

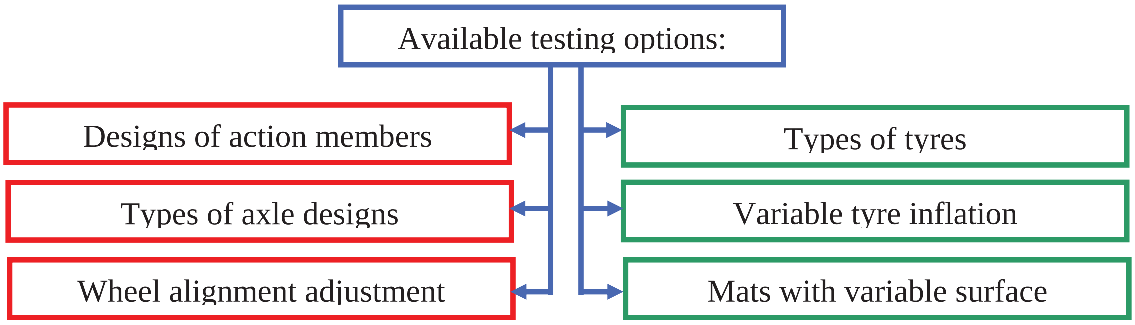

Fig. 2. Options for the setting of various parameters of the testing bench for the testing of steering at zero angular speed of wheels

The P6A sensors sense pressure at each side of the cylinders and the signals are downloaded (via the measuring amplifiers) to the measuring card. The information is processed in the Matlab/SimulinkReal/Time Toolbox program application.

The testing bench features a second measuring circuit – independent of the control circuit – the task of which is to provide information about the loading of the mat under the tyre and about the position of the action member extension (the turning of the relevant wheel).

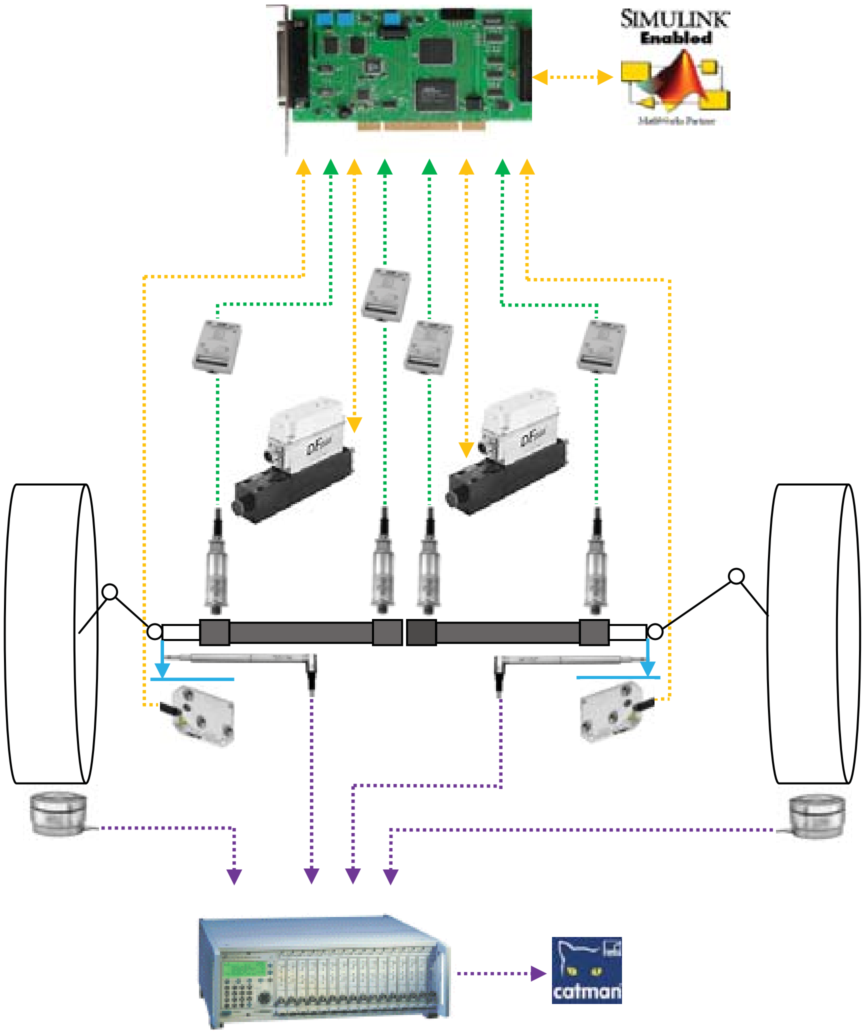

Fig. 3. Measurement of parameters of the hydraulic version of the steer-by-wire system at the experimental testing establishment

Tab. 1. Technology used for signal measurement and processsing at the testing bench

Technology used for signal measurement and processing at the testing bench	
Process Control:	
MF 624 Multifunctional input-output card MF624 (HUMUSOFT s.r.o.) Matlab/SimulinkReal/Time Toolbox software	
Data sensing:	
Pressures in liquid	P6A (Hottinger Baldwin Messtechnik GmbH) AE 101 (Hottinger Baldwin Messtechnik GmbH) measuring amplifier
MGCplus (Hottinger Baldwin Messtechnik GmbH) measuring unit catman®Easy software	
Forces under the mat	U3 (Hottinger Baldwin Messtechnik GmbH)
Positions of action members	WA 200 (Hottinger Baldwin Messtechnik GmbH) AE 501 (Hottinger Baldwin Messtechnik GmbH) measuring amplifier

3. Pattern of measured forces

To determine the consequence of forces in action members of the directional control mechanism (hydraulic cylinders) the +/- 65 mm (max. range of +/-70 mm) extension of the hydraulic cylinders was simulated. The right side of the directional control mechanism (in forward travel direction) was chosen to compare the pattern of forces. The design of the front axle arrangement is of the McPhearson type.

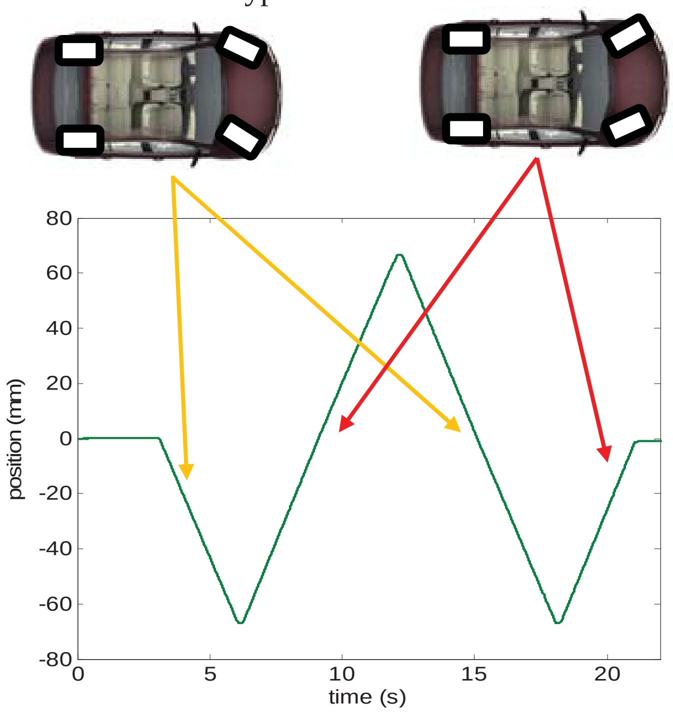

Fig. 4. The extension pattern for the action member of the passenger car front axle directional control

The wheel rim was mounted with a BRIDGESTONE EK 300 195/55 R15 tyre.The paper illustrates the pattern of forces in the cylinder in relationship with:

1a) various wheel loads – the tyre inflated to 0.25 MPa being in contact with a concrete mat

1b) various wheel loads – the tyre inflated to 0.25 MPa being in contact with a sheet-metal mat coated with an oil layer

2) various tyre inflation levels at similar loads – the tyre being in contact with a concrete mat

For clarity, the first 15 seconds of the simulation are shown, the next pattern of the forces in relation to the extension does not differ for the identical extension.

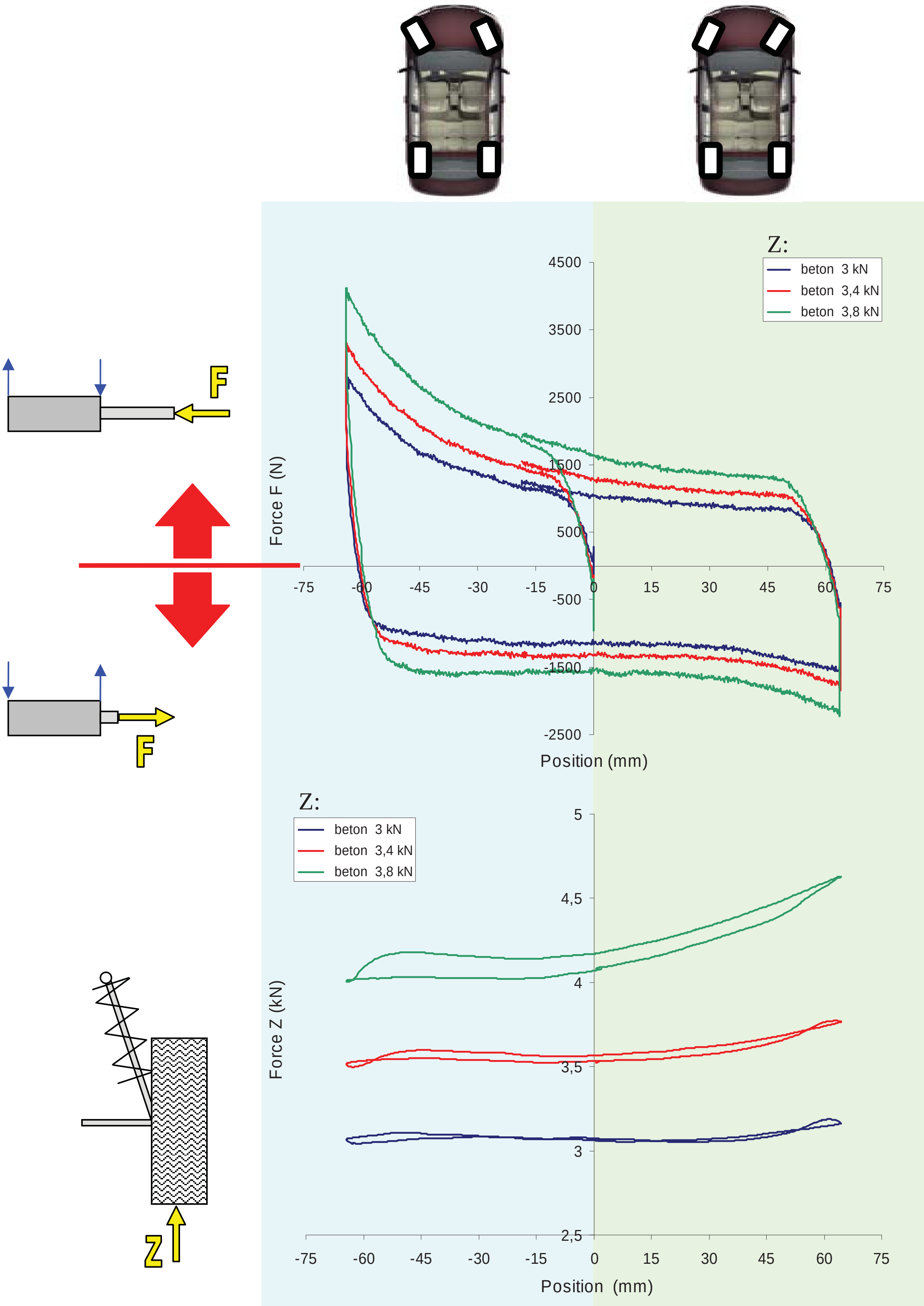

Fig. 5. Relationship of forces in the control mechanism – a concrete mat under the wheel

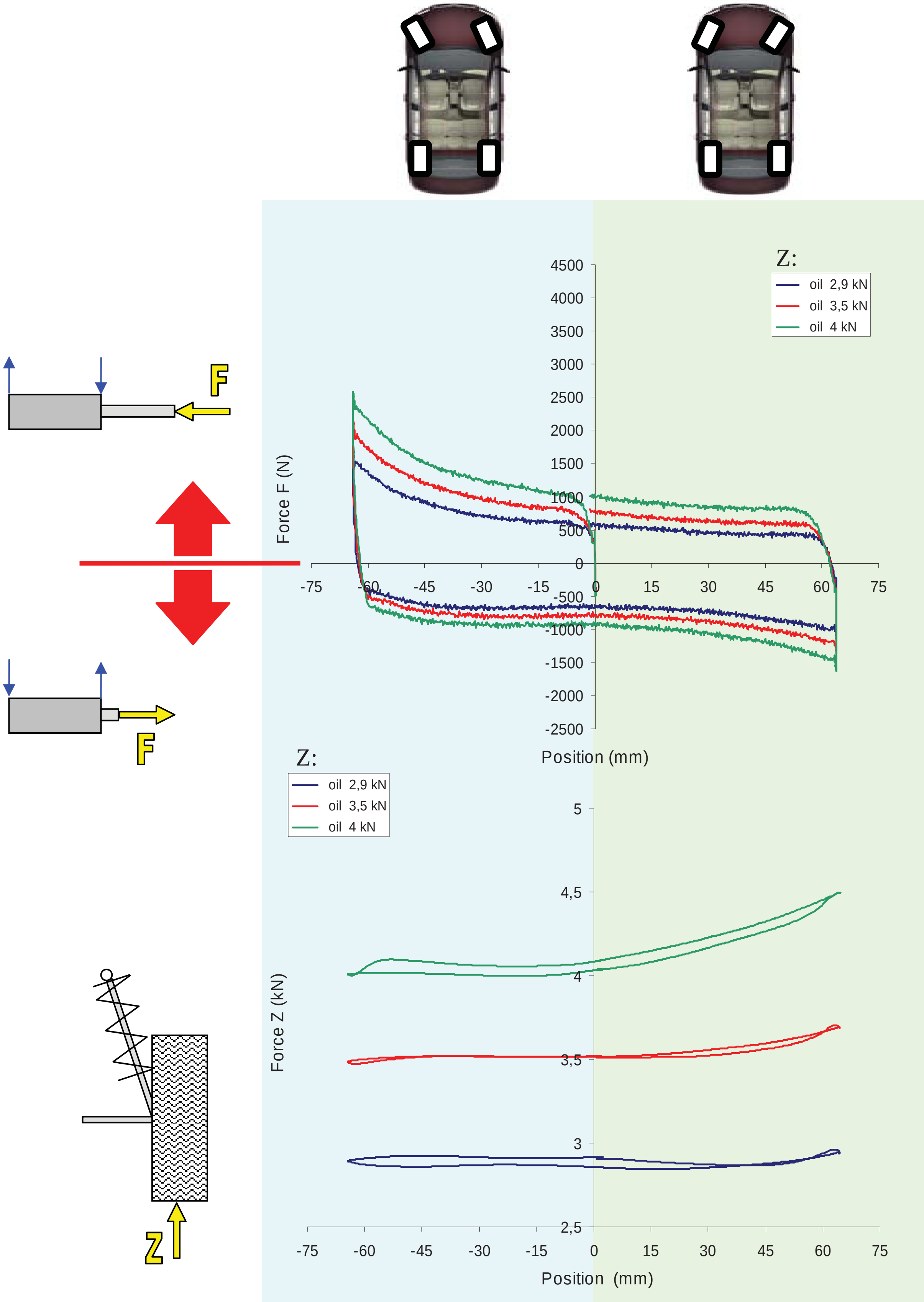

Fig. 6. Relationship of forces in the control mechanism – a slippery mat under the wheel

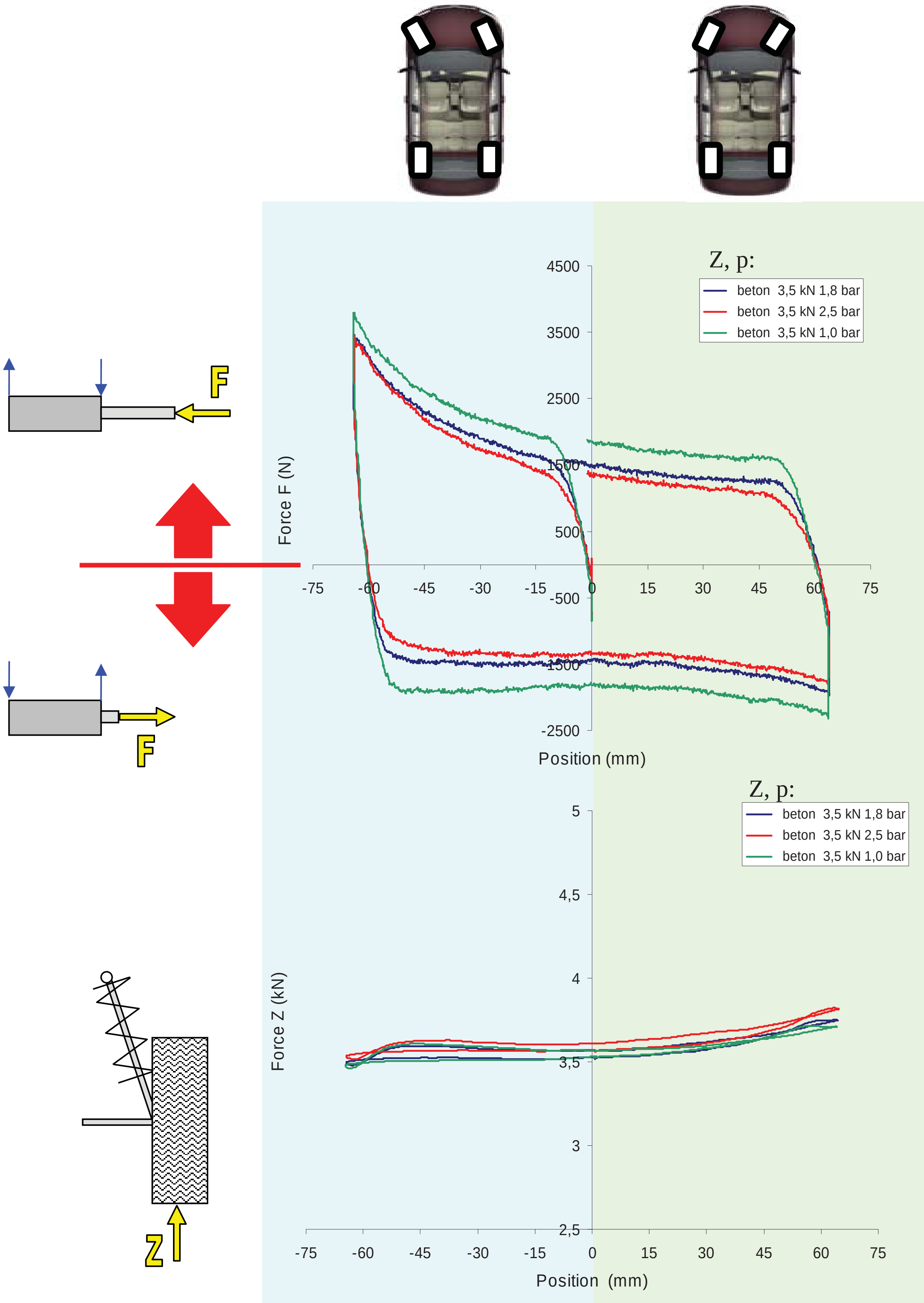

Fig. 7. Relationship of forces in the contrl mechanism – a concrete mat under the wheel, impact of tyre inflation

5. Conclusion

The project is aimed at research into the characteristics of a vehicle with an active directional control.The design of the testing bench allows the identification of responses and behaviour of the steering system including the tyres. The equipment offers another advantage: it can be used for tests of various front and rear axles. As far as the vehicle´s directional control is concerned, the so called Steer-by-wire system is gaining in interest.

For the design of a steering system it is important to know the potential forces occuring in the steering mechanism. The objective is to analyse the forces under a situation when the wheels on the axle do not roll – i.e. conditions existing during parking. Measurements for several impacts affecting the magnitude of forces in the steering mechanism were made (always for several vertical loads, i.e. dependence on the vehicle´s weight). First, dependence on the road surface was examined. Fig. 5 and 6 illustrate two extreme cases. In comparison with the concrete mat, the slippery mat under the wheel featured about a 40% lower force in the steering rod. Fig. 7 shows a relationship between forces in the steering mechanism and the tyre pressure. No significant increase in forces in the steering rod occurs here. A rapid tyre pressure change (by 60% lower) resulted in about 10% increase of the force in the steering rod. The design of the testing bench is very universal and relationships between a number of variables and the entire axle load may be monitored. The next step in the force analysis will be the identification (measurement) of forces in the steering mechanism during the vehicle´s travel.

Acknowledgments

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