Manual for the flat plank tyre tester

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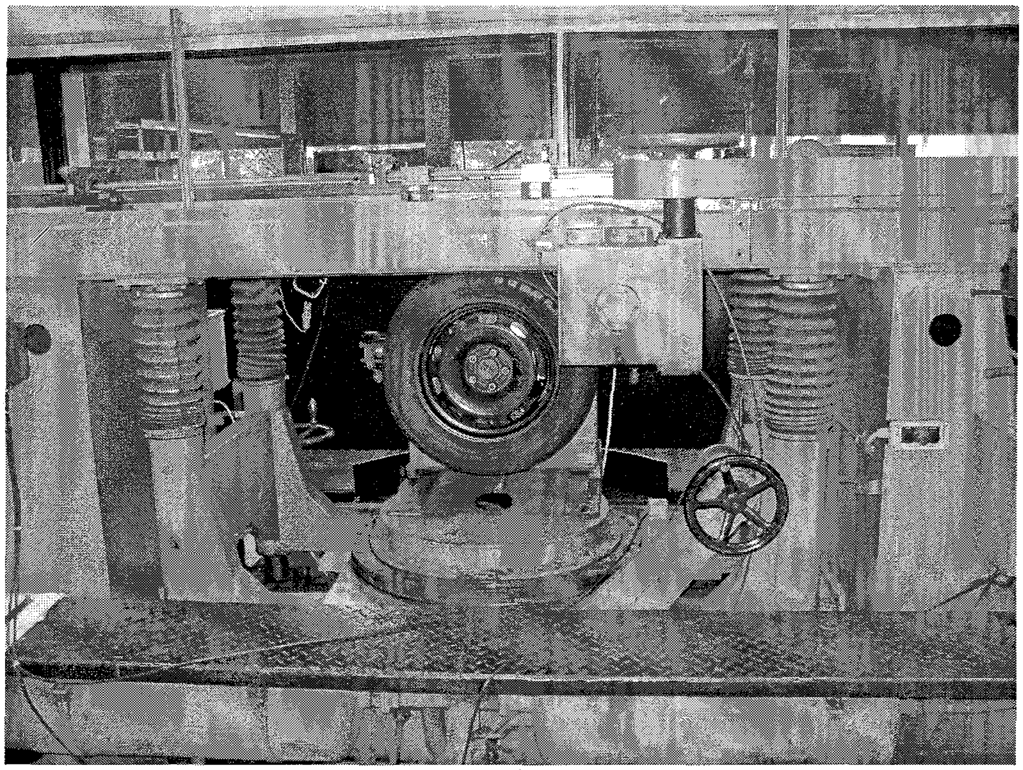

Manual for the Flat plank tyre tester

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Chapter 1 Specifications of the flat plank tyre tester

Description of the test stand:
The test tyre is mounted in the measuring hub and loaded in upwards direction against the track. This track can translate in longitudinal direction over a length of 7 meter at a fixed velocity wit a maximum of 4.75 cm/sec. It is also possible to translate the track manually.

Vertical inputs:
- The tyre is loaded at constant vertical load (by an air spring)
- The tyre is loaded at constant axle height

Lateral inputs:
- The rim (and tyre) can move laterally
- The rim (and tyre) can rotate about the vertical axis to provide side slip angles

Longitudinal inputs:
- The rim can be locked using a disc brake

Camber inputs:
- The rim can be cambered
- The road can be cambered (rotation about an axis trough the center of the contact patch)

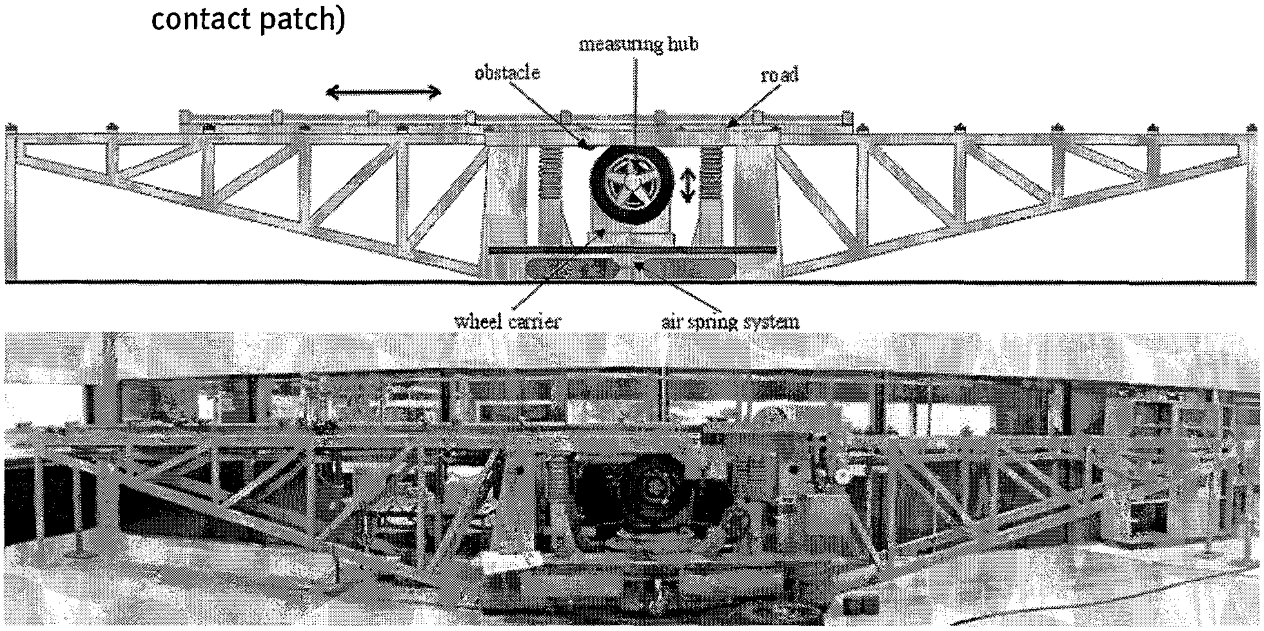

Figure 1.1: Flat plank tyre tester

Specifications:
- Radius of the tyre: 210 to 387 mm
- Vertical Load: 0 to 8 kN
- Side slip angle: -30° to 30° (scale)
- Steer angle: 90°
- Camber angle wheel: -30° to 30°
- Camber angle track: -15° to 15°
- Variable longitudinal velocity: 0.02 .. 0.0475 m/s
- Maximum traveled distance: 7 m

Chapter 2 Operating the flat plank tyre tester

To turn the machine on, the power switches 1 and 2 (nr 4 and 5 in figure 2.2) have to be switched on. The power to the optical sensor (nr 6 in figure 3.1) and the power to the signal conditioning system (nr 5 in figure 3.1) have to be turned on also.

The tyre tester has five different functions that can be controlled:

1. Track movement: This is controlled by the control panel (nr. 2 in figure 2.2).
2. Adjust side slip angle: the slip angle can be adjusted motorized or manually (nr 1 and 3 in figure 2.3). The slip angle can be read from the indicator on the front side of the machine (figure 2.4 (right) and nr 5 in figure 2.3).
3. Adjusting the inclination angle track: This is done by using the remote control, which is placed near power switch 2 (nr. 4 in figure 2.2). The inclination angle has to be determined with a digital Protractor. Measure the angle of the road and the angle of the axle; the difference is the inclination angle (The angle of the axle has to be measured on flat surface on the front of the adaptor, without the wheel).

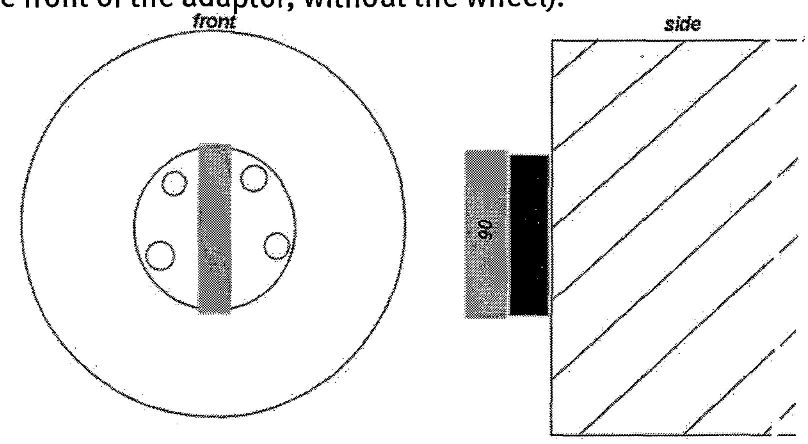

Figure 2.1: Measuring the angle of the axle.

4. Adjusting the axle height:
   - Fixed axle height: this is done manually by turning the large wheel (nr. 6 in figure 2.2) for a fixed axle height.
   - Constant load: this is done by the air spring system.
5. Adjusting the inclination angle of the wheel: Put a hydraulic claw around the axle of the hub (nr. 8 in figure 2.2) and bring pressure on the hydraulic system. Now it is possible to loosen the bolts (nr 8 in figure 2.2). After this is done on both sides, the angle of the hub with the tyre can be changed. Now fix the bolts again and remove the pressure from the hydraulic system.

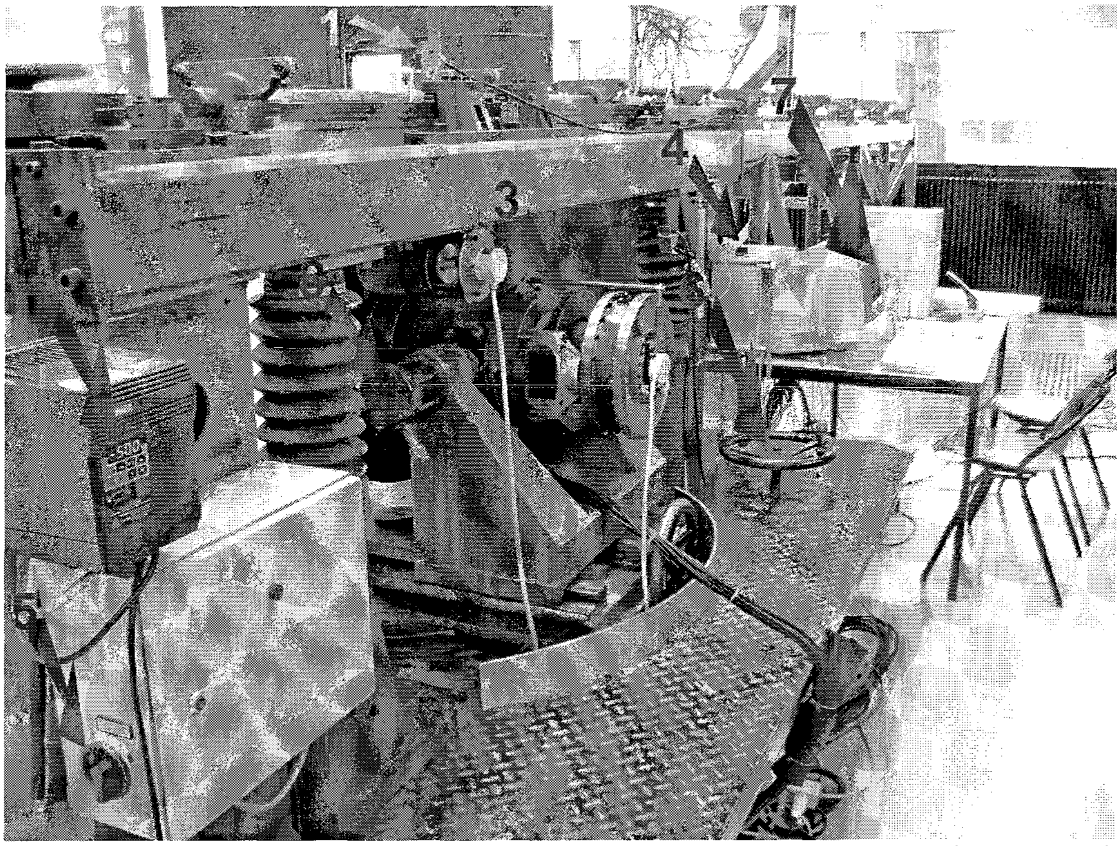

Figure 2.2: Back side: 1) Trigger mechanism 2) Control panel of the moving track 3) Brake disk / Braking mechanism 4) Power switch 1 5) Power switch 2 6) Wheel to adjust the axle height of the tyre 7) The measurement equipment (computer, signal conditional system 8) Hub axle

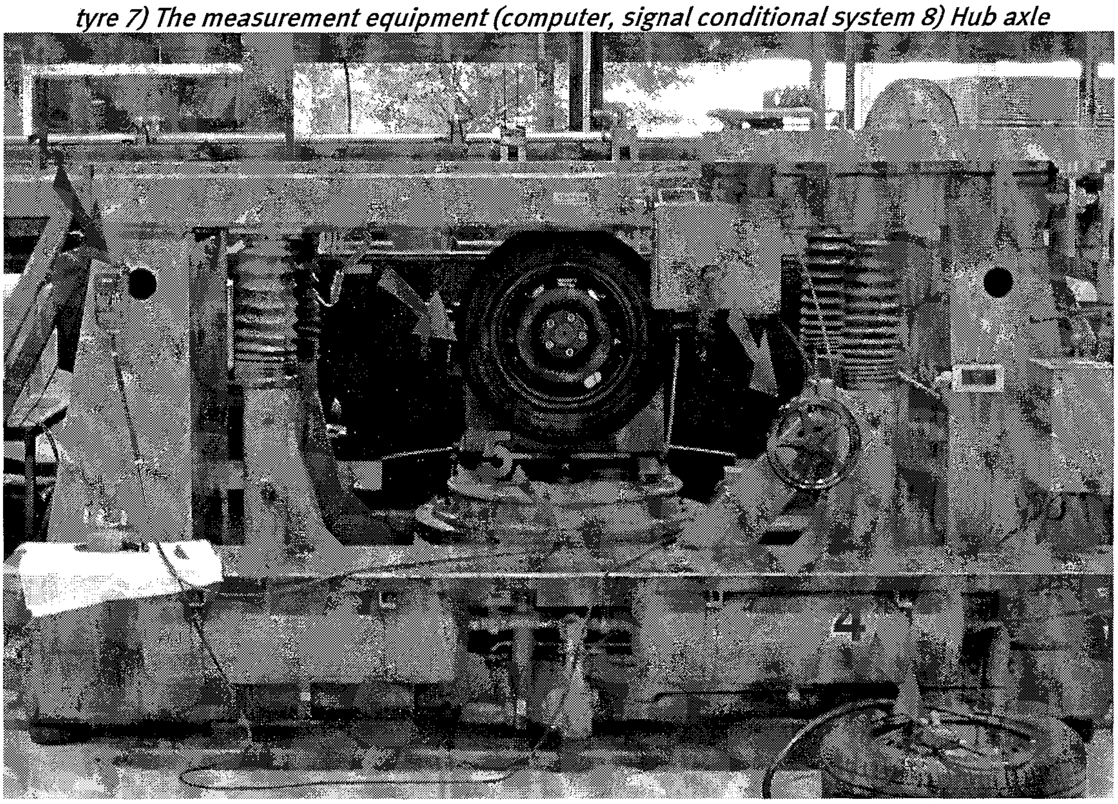

Figure 2.3: Front side: 1) Control panel to adjust steering angle 2) The tyre. 3) Wheel to adjust the steering angle manually. 4) Equipment to adjust the tyre pressure 5) Slip angle indicator

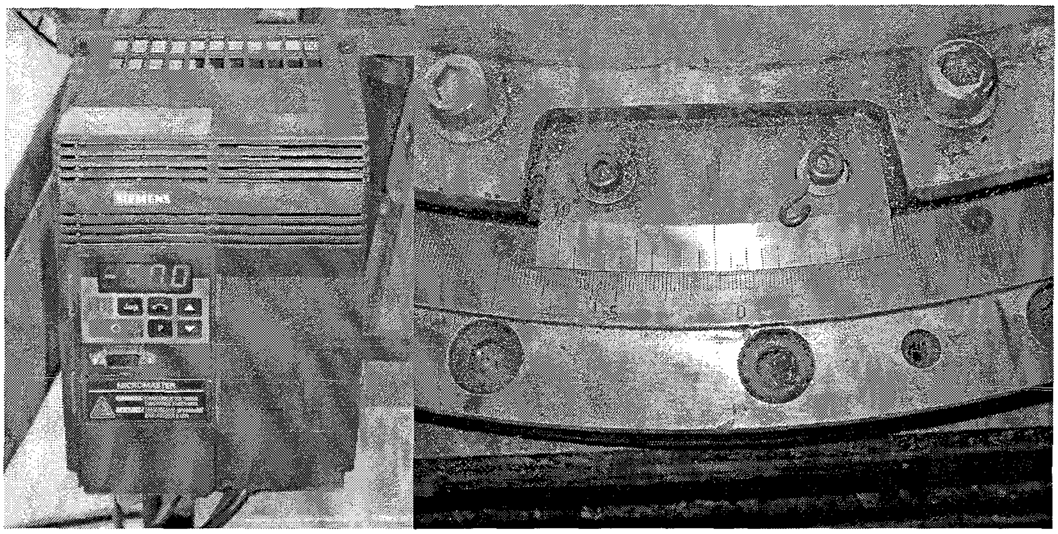

Figure 2.4: Control panel (left) and slip angle indicator (right)

Control Panel

This is one of the two control panels (figure 2.4 (left)). There is a red and a green button, which are used to start and stop a driving motor. The Jog button is to the motor turn very slow, which can be useful for positioning. The button with the arrow (top-third from left) is there to change the driving rotation of the motor. One can see the way the motor rotates in the display (–50 or +50 is shown default). Sometimes when the red button is pressed F002 is shown in the display. When this is shown, push the p button twice. Now in the display –50 or +50 will be shown. Pushing the green button can continue the experiment.

It is also possible to change the speed of the motor with this control panel.

These are the steps needed:

1) Push the p button
2) Use the 2 arrow buttons to move to p005
3) Push the p button
4) Adjust the speed to for example 25 (half of the maximum speed of the motor)
5) Push the p button
6) Use the 2 arrow buttons to move to p000
7) Push the p button

If this all went right 25 will be shown in the display.

There is a lot more that can be adjusted with the control panel (for example the ramp) but at this moment the manual of the control panel is not yet at the TU/e, so it is not clear yet what the functions of the different parameters are.

Air spring

The air spring is used if a constant load is needed during driving over cleats for example.

These are the steps to take:

1) Connect air to the air valve (figure 2.7 nr 8)
2) Find the highest and lowest value of the ruler:

- lowest load at position A (figure 2.5): read the value of the ruler (figure 2.7 nr3)
- highest load at position B (figure 2.5): read the value of the ruler (figure 2.7 nr3)

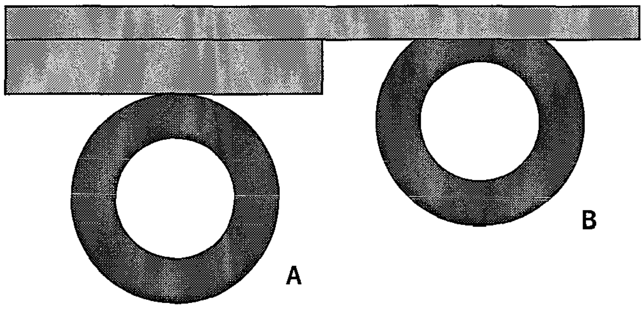

Figure 2.5: Way to find the height of the tyre and hub (yoke)

3) Find those 2 values at the left side of figure 2.6. Now look what the key value is when those 2 values are within the 2 lines.
4) Put the "key" in the hole (figure 2.7 nr 1) and adjust the height to the value found at step 3.
5) Put orange line, on the "button to create a air leakage (figure 2.7 nr 7)", to the left to "werkstand"
6) Put the on/off pressure button in the position so that air can go to the air bellows. (figure 2.7 nr 2)
7) Control the quantity of air that can flow to the bellows with the control unit (figure 2.7 nr 6). The value of the pressure can be read at the indicator (figure 2.7 nr5).
8) Finally lower the screw jack with the wheel at the back of the machine. This must be done, because the otherwise the yoke would make contact with the fixed frame during movement.

To release the tyre from the track after the experiment just switch the on/off pressure button (figure 2.7 nr 2). If in the next experiment the load must be the same, just switch the pressure button on and the correct load will be reached without adjusting the control mechanism (figure 2.7 nr 6).
The "emergency" stop (release pressure fast) (figure 2.7 nr 4) is used if the pressure rises to high so that the strain gages could brake down.

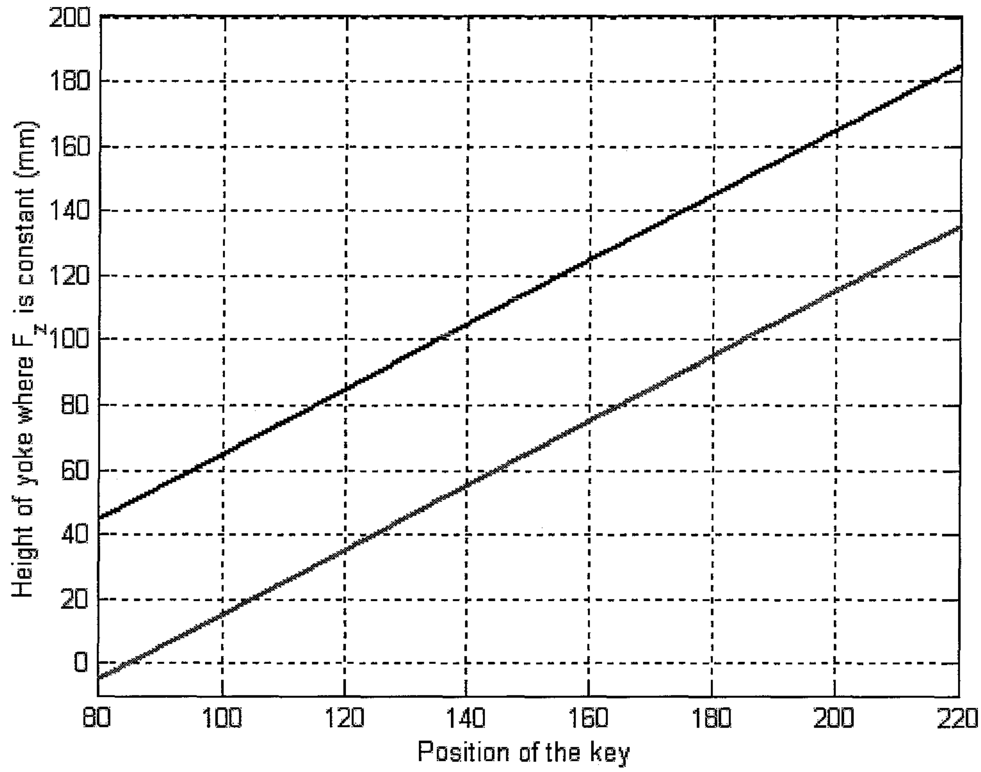

Figure 2.6: Air spring characteristic

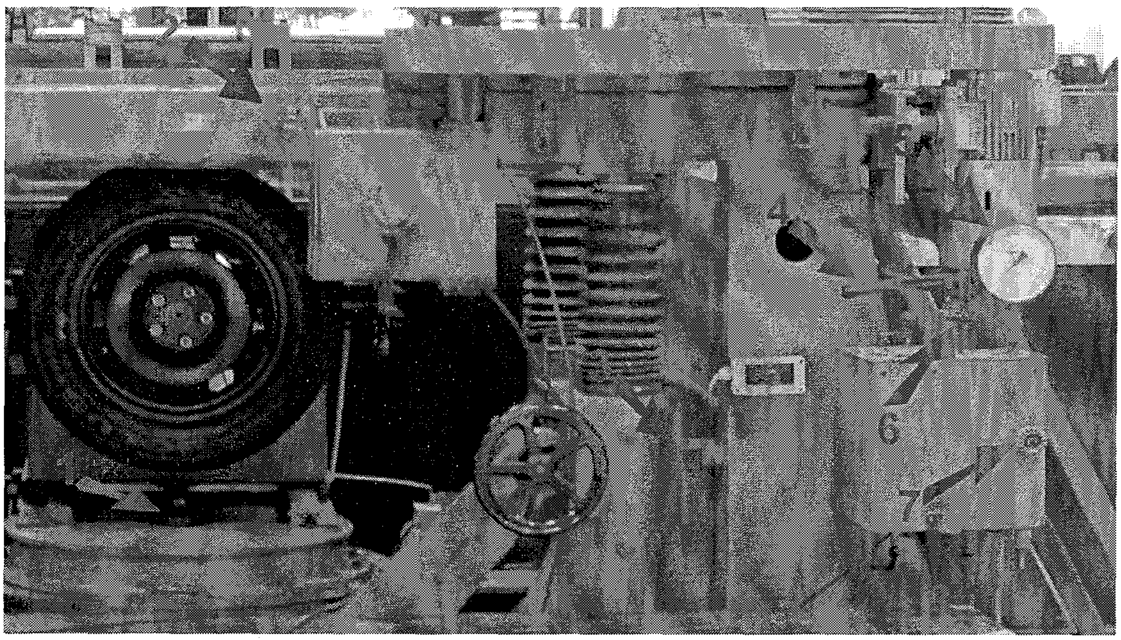

Figure 2.7: air spring system: 1) key hole 2) on/off pressure button 3 ruler 4) "emergency" stop (release pressure fast) 5) pressure indicator 6) control for pressure 7) button to create a air leakage 8) air valve

Chapter 3 The signal conditioning system

This system is used for amplifying the voltage generated by the strain gauges. There are two functions, which have to be used regularly: zeroing the channels and changing the amplification factor.

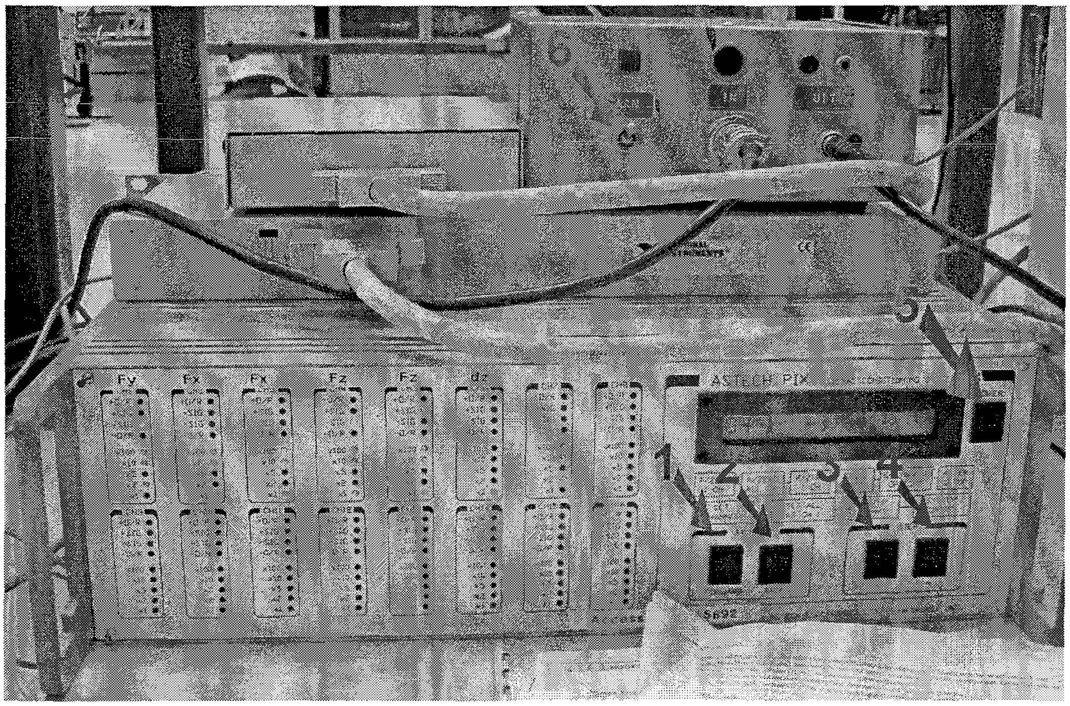

Figure 3.1: signal conditional system: 1) Forward button, 2) Back button, 3) + Step button, 4) – Step button, 5) Power switch of signal conditional system, 6) Power switch trigger.

Before each measurement all channels have to be zeroed. This is done as follows:

How to zero:

- Push the forward button 4 times
- Push the + step button once
- Push the forward button once
- Now wait until all the channels are zeroed
- Push the back button twice

If the forces are large (large slip angles, or high vertical loads), the output from the signal conditioning system may exceed 10V. The maximum input to the DAQ board is +/- 10V. In this case the amplification factor has to be lowered. Never set the factor below 500 x. This way the electric overload occurs before the mechanical overload and it is noticed immediately when the loads become dangerously high.

How to change the amplification factor:

- Push the forward button 4 times
- Push the – step button once
- Push the forward button twice

- Choose the channel with the +/- buttons
- Push the forward button once
- Adjust the gain with the +/- buttons
- Push the back button once
- Choose another channel or push the back button three times to return to the main menu.

Chapter 4 Labview & output

The virtual instrument created with Labview looks like this:

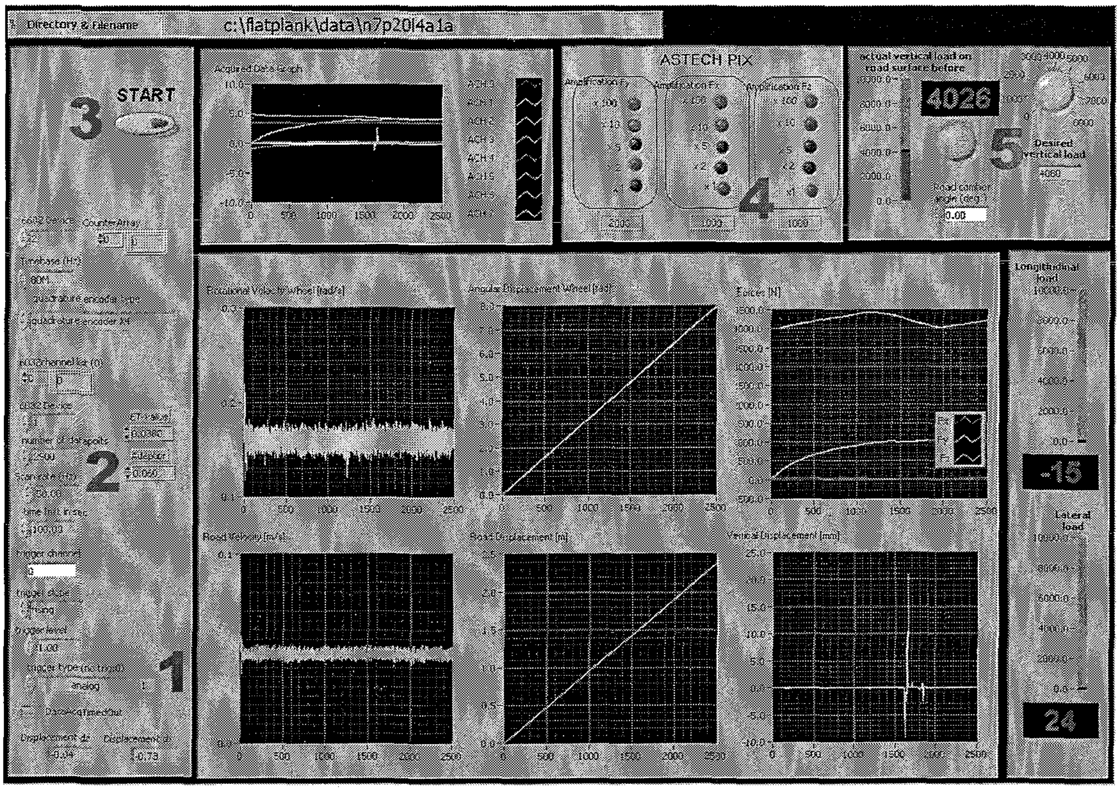

Figure 4.1 Screenshot of the virtual instrument in Labview

The trigger can be switched off by changing the number from 1 to 0 (nr 1 in figure 4.1). Close to number 2 in figure 4.1 the settings for the number of datapoints, frequency and duration (how long measurement runs maximally after you press the start button) of the measurement can be changed. Also the ET-value and adaptor value have to be adjusted here. Next to number 4 the amplification factors have to be set the same as on the signal conditioning system.
The run button (arrow), in the toolbar, must be pushed to start the loop of the displays. If this is done, the vertical load applied can be read from the display near number 5. Finally the button to start the measurement is near number 3.

The output from Labview to the specified path contains 12 columns. These contain the following elements:

Table 1

Column	Quantity	Symbol	Unit
1	Longitudinal force	F_x	[N]
2	Lateral force	F_y	[N]
3	Vertical load	F_z	[N]
4	"Overturning moment"	T_x^*	[Nm]
5	"Aligning torque"	T_z^*	[Nm]
6	Vertical displacement	dz	[m]
7	-	-	-
8	Rotation velocity wheel	ω	[rad/s]
9	Rotation angle wheel	-	[rad]
10	Track velocity	V	[m/s]
11	Track displacement	-	[m]
12	Slip angle	α	[degrees]

* See chapter 2 (Experiments on flat plank tyre tester [2003])

The forces and moments that are available from the output from Labview are the forces and moments at the axle center. If the camber angle is zero, K_x, K_y, K_z and T_z at the axle center are equal to F_x, F_y, F_z and M_z at the contact patch. T_x on the other hand is not equal to M_x. (see chapter 2 of *Experiments on flat plank tyre tester*).

The rotation angle of the wheel, the track displacement and the slip angle are measured with encoders. This means that these positions are only known relative to the starting position.

Chapter 5 Machine setup procedures

§ 5.1 Removing the flexible connection

This part connects the braking disk to the main axle of the machine. This part is designed in such way that it does not introduce a lateral force on the axle, but only a braking moment if necessary (a flexible connection). But from experiences from Delft and measurements here it became clear that this part does not work the way it should. It does introduce a lateral force so it is recommended to remove it if measurements are performed which do not need the braking disk.
This is the way to remove it:

1) Remove the bolt which prevents the encoder from rotating (1)
2) Remove the 2 bolts which fix the encoder to the hub (2)
3) Remove the encoder (White)
4) Remove the 20 bolts (3) and the ring
5) Remove the 20 bolts (4) and the ring (Watch out! See step 6)
6) Remove the 2 spring-plates. (Make sure they don't fall, because they can be damaged quite fast)
7) After this is all done, the encoder can be placed back in its position, so repeat step 2 and 1, but now in reverse order.

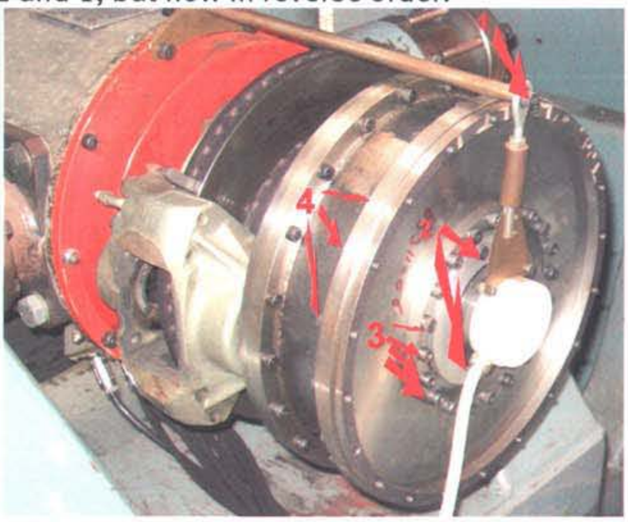

Figure 5.1: Remove flexible connection.

§ 5.2 Attaching a cleat

A cleat is an obstacle, which can be attached to the track.
This is the way to attach the cleat:

1) Attach a cleat on the ground plate. This is done with 2 screws.

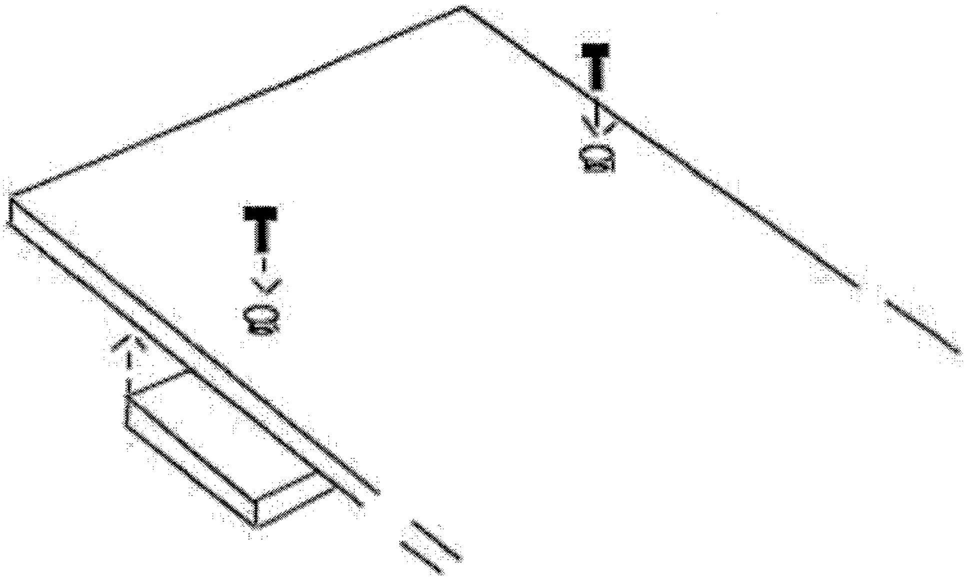

Figure 5.2: Attach cleat to ground plate

2) Next maneuver the 2 support arms (nr 2 figure 5.3 and nr 3 figure 5.4) on top of the track.
3) Attach the ground plate with the cleat to the support arms. This is done with 4 bolts (Nr 4 figure 5.3).
4) Now fix the ground plate with the cleat to the track with a spanner. Make sure that the ground plate is parallel to the track.

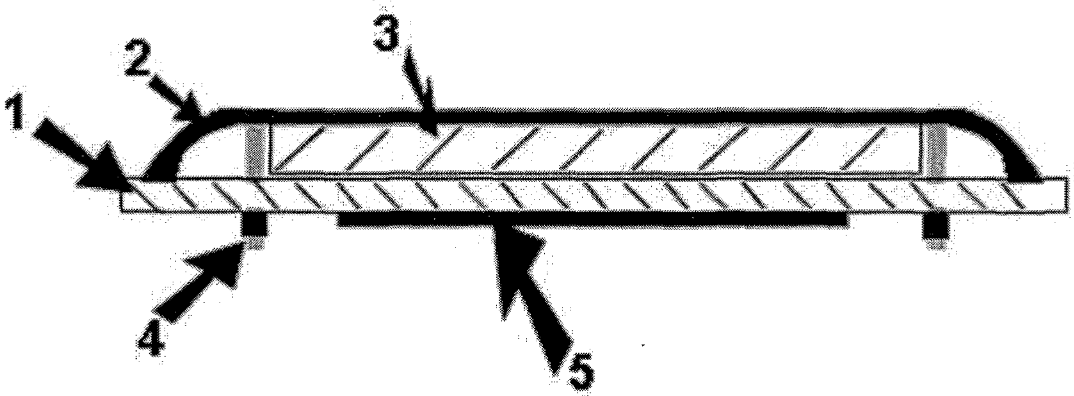

Figure 5.3: Side view 1) ground plate 2) support arm 3) track 4) bolt 5) cleat

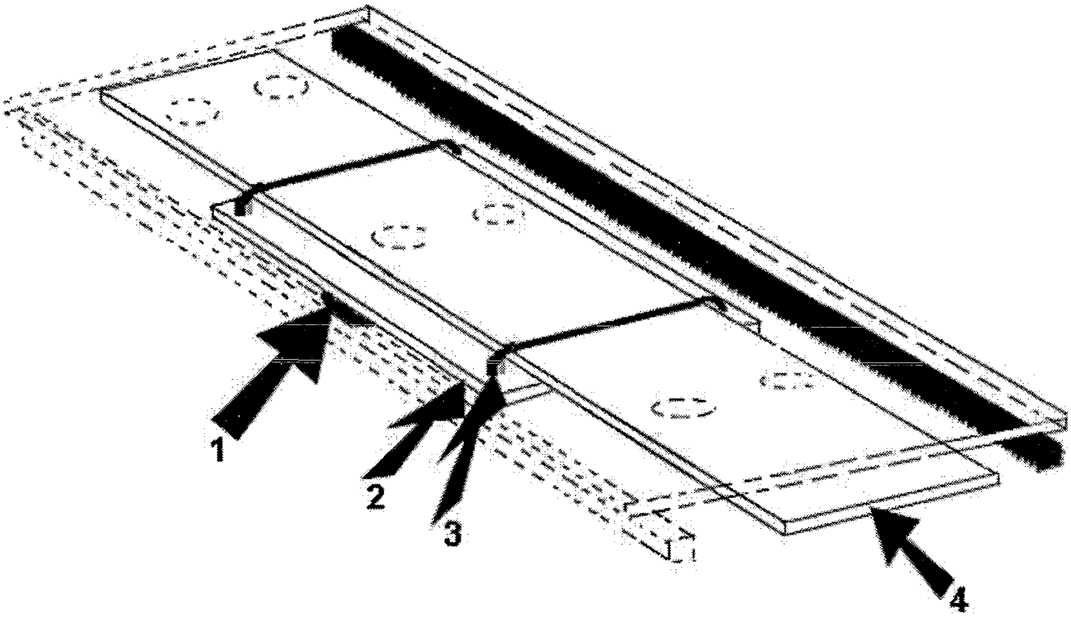

Figure 5.4: Overview 1) cleat 2) ground plate 3) support arm 4) track

§ 5.3 Removing Tyre and adaptor

The tyre is removed at the same way as a normal tyre from a road car. Just remove the 5 bolts and than remove the tyre carefully.
Most of the times it is necessary to attach a new adaptor if an experiment with a new type of tyre are going to be performed.
To remove the adaptor, 6 bolts have to be removed (figure 5.5). This must be done with a special tool (figure 5.6). After this is done the adaptor can be removed from the hub.

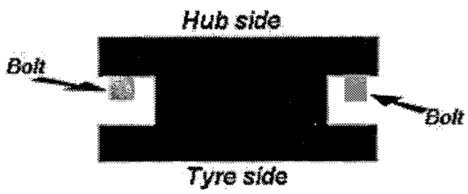

Figure 5.5: Adaptor

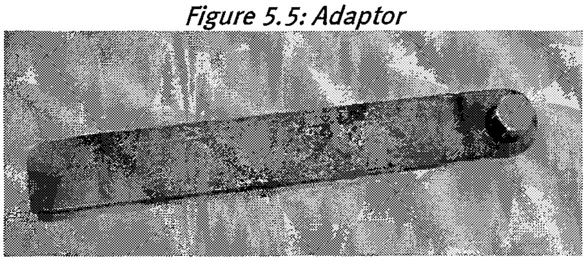

Figure 5.6: Special tool

Chapter 6 Measurement procedures

First of all it has to be said that it is very useful for data processing to give all the files a systematic name. The pressure, load and type of measurement must be named. Also the camber-angle, steering-angle and index of the measurement (if you have more than one measurement for 1 load and 1 pressure) can be named.
Here some examples are given:
Relaxation: p20l4a0a, p20l4a0b, p24l2a1a etc.
Stiffness: p20l2st1, p20l2st2, p24l6st3 etc.
Parking: p20l5park1, p24l3park2 etc.
Plysteer/Conicity: p20l2pc1f, p20l2pc1b, p24l6pc2b etc.
Cleats: p20l4cl1a, p20l4cl1b, p22l6cl2a etc.

§ 6.1 Procedure for relaxation measurement

The flexible connection has to be removed for this experiment.
There are 3 quantities that can adjusted: slip angle, tyre pressure and vertical load.
The slip angle is 0° (for the reference measurement) or 1°. The tyre pressure 2.0, 2.2, or 2.4 bar (or whatever is needed). And the vertical load 2,4 or 6 kN (or whatever is needed).
At every configuration of the three quantities three measurements will be performed. To prevent walking around the machine too much, two measurements with the same slip angle (0 or 1) will be carried out before the slip angle is changed. (See table 2)

Table 2

Slip angle (°)	Vertical load (N)	Tyre pressure (bar)	Tyre position (°)
0	2000	2	0
1	2000	2	0
1	2000	2	120
0	2000	2	120
0	2000	2	240
1	2000	2	240
1	4000	2	0
0	4000	2	0
0	4000	2	120
1	4000	2	120
1	4000	2	240
0	4000	2	240
Etc.	Etc.	Etc.	Etc.

The procedure for this measurement in steps:

1. If necessary clean the tyre and track.
2. Start Labview

3. Check if Labview (gain) configuration matches with the configuration of the signal conditioning system.
   3.1. Inflate the tyre until the right pressure is reached (no vertical load !!)
      3.1.1. Adjust the slip angle if necessary
      3.1.2. Put the track in the right position (trigger)
      3.1.3. Turn the wheel to the right position (if both the 0° and 1° measurement have been carried out the tyre is rotated 120°)
      3.1.4. Change filename, frequency 50 Hz, 2500 datapoints and run Labview.
      3.1.5. Zero all channels (after 6 measurements, so after changing the vertical load)
      3.1.6. Apply vertical load (value is displayed in Labview after the run button is pushed)
      3.1.7. Start Labview and move the track
      3.1.8. Remove vertical load start from point 3.1.1.

If the experiment is done correctly it should look something like this:

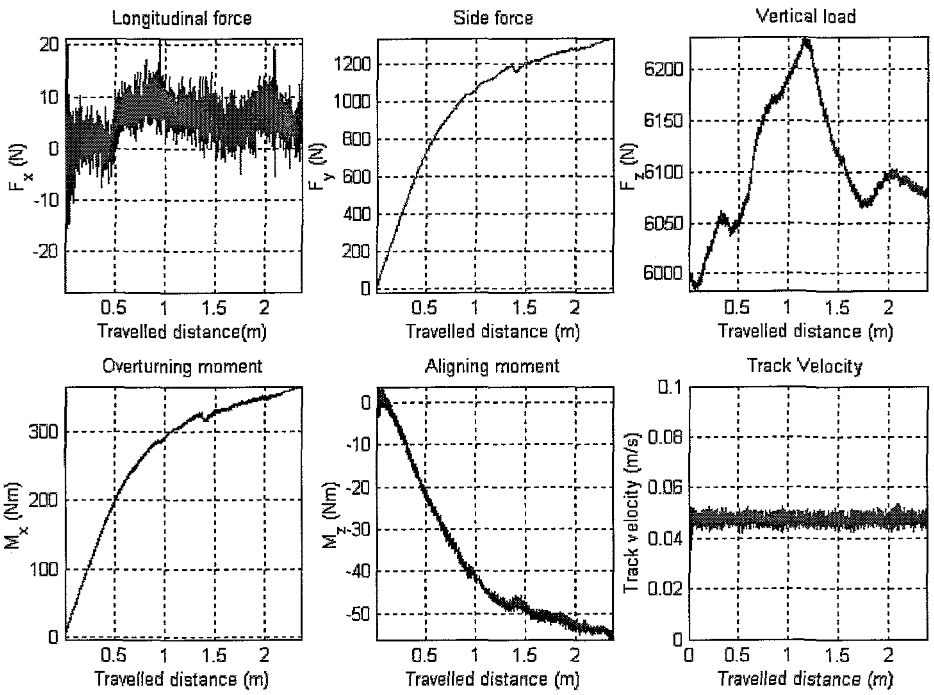

Figure 6.1 Results of relaxation measurement with a Kuhmo Solus 195 60R15. The tyre pressure was 2.0 bar and the vertical load was around 6 kN. These results have been corrected with a reference measurement.

§ 6.2 Procedure for Longitudinal stiffness measurement

First of all the flexible connection has to be installed to do this experiment.
Now there are only 2 quantities to adjust: vertical load and tyre pressure. The slip angle has to be 0° for all measurements. Also no reference measurements have to be carried out. Just like the relaxation measurements three measurements will be carried out for each configuration. This leads to the following table (different loads and pressures can be measured the same way):

Table 3

Slip angle (°)	Vertical load (N)	Tyre pressure (bar)	Tyre position (°)
0	2000	2	0
0	2000	2	120
0	2000	2	240
0	4000	2	0
0	4000	2	120
0	4000	2	240
0	6000	2	0
0	6000	2	120
0	6000	2	240
0	2000	2.2	0
0	2000	2.2	120
0	2000	2.2	240
Etc.	Etc.	Etc.	Etc.

The procedure for this measurement in steps:

1. If necessary clean the tyre and track
2. Start Labview
3. Check whether Labview (gain) configuration matches with the configuration of the signal conditioning system.
   3.1. Inflate the tyre until the right pressure is reached (no vertical load !!)
      3.1.1. Put the track in the right position (trigger)

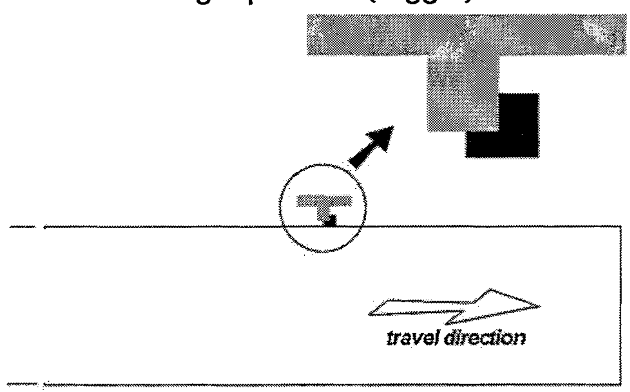

Figure 6.2: Trigger

      3.1.2. Turn the wheel to the right position (after each measurement the tyre is rotated 120°)
      3.1.3. Lock the wheel with 2 chromed pins in the brake-disc.
      3.1.4. Change filename, frequency 100 Hz, 500 datapoints and run Labview.
      3.1.5. Zero all channels
      3.1.6. Apply vertical load (value is displayed in Labview after the run button is pushed)
      3.1.7. Start Labview and move the track.
      3.1.8. Remove vertical load and start from point 3.1.1.

If the experiment is done correctly it should look something like this:

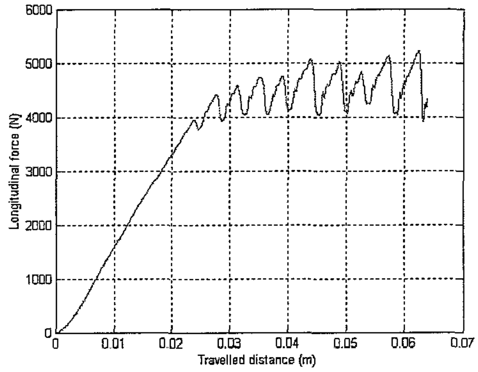

Figure 6.3 Result of a longitudinal stiffness measurement with a Kuhmo Solus 195 60R15. The tyre pressure was 2.0 bar and the vertical load was around 6 kN.

§ 6.3 Procedure for effective rolling radius/plysteer/conicity measurement

The flexible connection has to be removed for this experiment.
Effective rolling radius, plysteer and conicity can all be determined from the same measurements. To determine the plysteer and conicity the track has to be moved forward and backward. The plysteer force changes sign when the rotation direction is changed, the conicity force doesn't.
Furthermore the lateral forces generated by the tyre are very small. To cancel out the effects of disturbances on the track, the whole track is used.
For every load and pressure we do 4 measurements: 2 forward and 2 backward. We now have 3 starting positions on the track: one at the left end, one in the middle and one at the right end. The four measurements are as follows:

Measurement 1	From starting point 1 to 2
Measurement 2	From starting point 2 to 3
Measurement 3	From starting point 2 to 2
Measurement 4	From starting point 2 to 1

The procedure for this measurement in steps:

1. If necessary clean the tyre and track
2. Start Labview
3. Check whether Labview (gain) configuration matches with the configuration of the signal conditioning system.
   3.1. Inflate the tyre until the right pressure is reached (no vertical load !!)
      3.1.1. Put the track in the right position (trigger)
      3.1.2. Turn the wheel to the right position (for this measurement the wheel is turned to the same position at every measurement)
      3.1.3. Change filename, frequency 50 Hz, 2500 datapoints and run Labview.
      3.1.4. Zero all channels (only for first of four measurements)
      3.1.5. Apply vertical load (value is displayed in Labview after the run button is pushed)

3.1.6. Start Labview and move the track.

Remove vertical load and start from point 3.1.1.

As can be seen from figure 8, the forces are relatively small, which makes it difficult to perform good measurements.

If the experiment is done correctly it should look something like this:

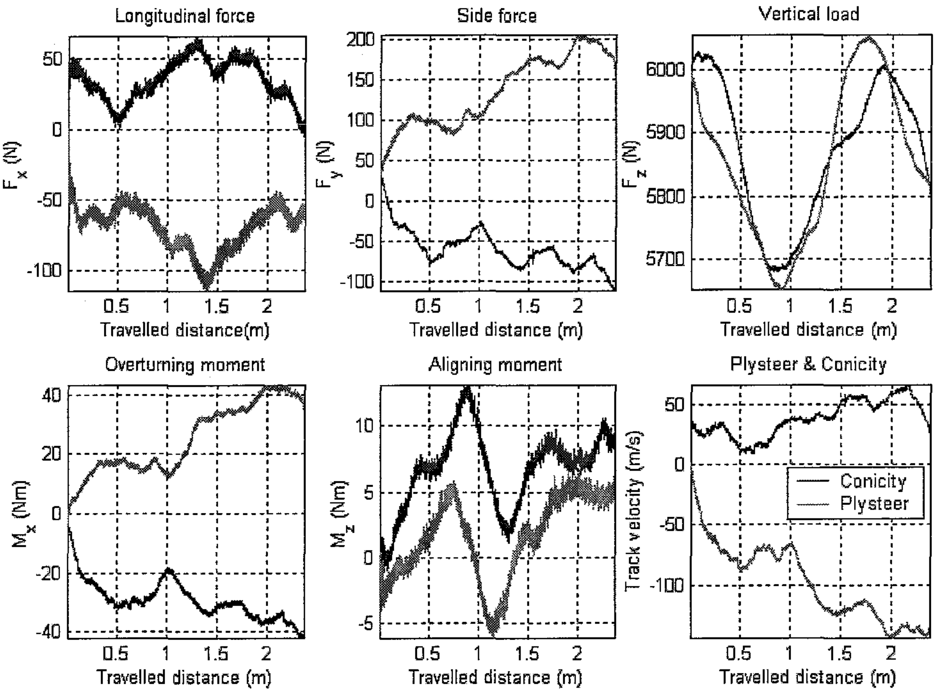

Figure 6.4 The green lines are the forces and moments for the backward movement, the blue lines are the forces and moments for the forward movement, except for the last figure. Here the plysteer and conicity are displayed. (Again for the Kuhmo tyre)

§ 6.4 Procedure for parking measurement

The flexible connection has to be removed for this experiment.

In this measurement a static (non-rolling) tyre is steered to very large angles.

From 0°=> 20° => -20° => 20° => -20° => 0°.

This test will be performed at different vertical loads (e.g. 1kN, 3kN, 5kN and 7kN) and different tyre pressures (e.g. 2.0 bar, 2.2 bar and 2.4 bar).

The procedure for this measurement in steps:

1. If necessary clean the tyre and track
2. Start Labview
3. Check whether Labview (gain) configuration matches with the configuration of the signal conditioning system.
   3.1. Inflate the tyre until the right pressure is reached (no vertical load !!)
      3.1.1. Put the track in the right position
      3.1.2. Turn the wheel to the right position (for this measurement the wheel is turned to the same position at every measurement)
      3.1.3. Change filename (check whether trigger is off), frequency 25 Hz, 5000 datapoints, duration time 2min and start labview

3.1.4. Zero all channels (only for first of four measurements)
3.1.5. Apply vertical load (value is displayed in Labview after the run button is pushed)
3.1.6. Start Labview, walk to the other side and turn the wheel with the motor using the control panel. When the slip angle reaches 20° or −20° reverse the direction using the <-> button.

If the experiment is done correctly it should look something like this after the data processing:

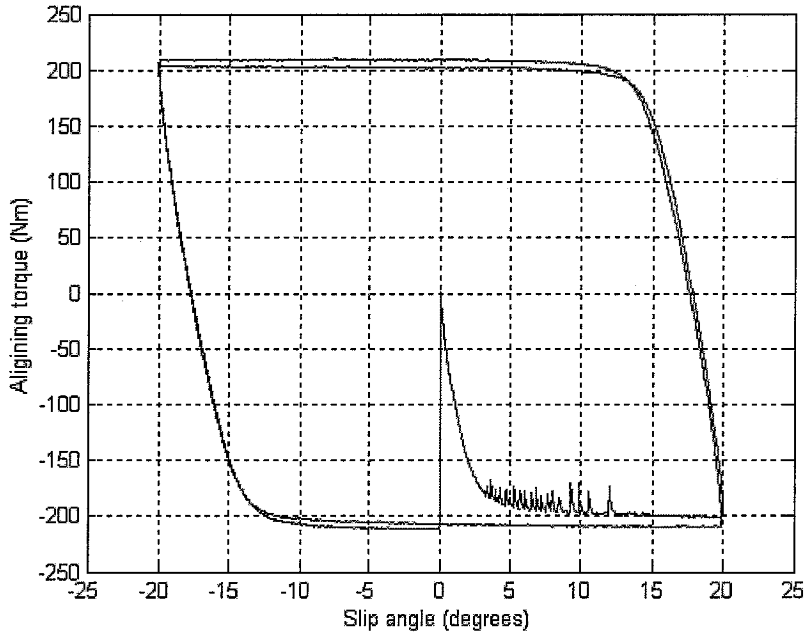

Figure 6.5 Results of parking measurement with a Kuhmo Solus 195 60R15. The tyre pressure was 2.0 bar and the vertical load was around 5 kN.

§ 6.5 Procedure for cleat measurement

The flexible connection has to be removed for this experiment and a cleat has to be placed on the track

This test will be performed at different vertical loads (e.g. 2kN, 4kN and 6kN) and different tyre pressures (e.g. 2.0 bar, 2.2 bar and 2.4 bar). For each load 3 measurements are performed at a different place on the tyre (0°, 120° and 240°).

The procedure for this measurement in steps:

1. Place a cleat onto the track a mentioned in § 5.2
2. Change the value in the control panel from 50 to 25.
3. Start Labview
4. Check whether Labview (gain) configuration matches with the configuration of the signal conditioning system.
    1. Inflate the tyre until the right pressure is reached (no vertical load !!)
        4.1.1 Put the track in the right position

4.1.2 Turn the wheel to the right position (after each measurement the tyre is rotated 120°)
4.1.3 Change filename (check whether trigger is on), frequency 500 Hz, 2500 datapoints
and run Labview.
4.1.4 Zero all channels
4.1.5 It is now important to measure the distance from the trigger to cleat. Start a long measurement (1 min name: pxxlxreference1). Run the track from the trigger to the cleat. Make sure the cleat is above the center of the wheel. This is the DX of the measurement. This measurement has to be done once every time a "new" cleat is attached to the track.
After this measurement put the track in the trigger again.
4.1.6 Apply vertical load (value is displayed in Labview after the run button is pushed)
4.1.7 Start Labview.
4.1.8 Remove vertical load and start from point 3.1.1. (Step 3.1.5 can be passed if there is not another cleat attached)

If the experiment is done correctly it should look something like this for the trapezium cleat:

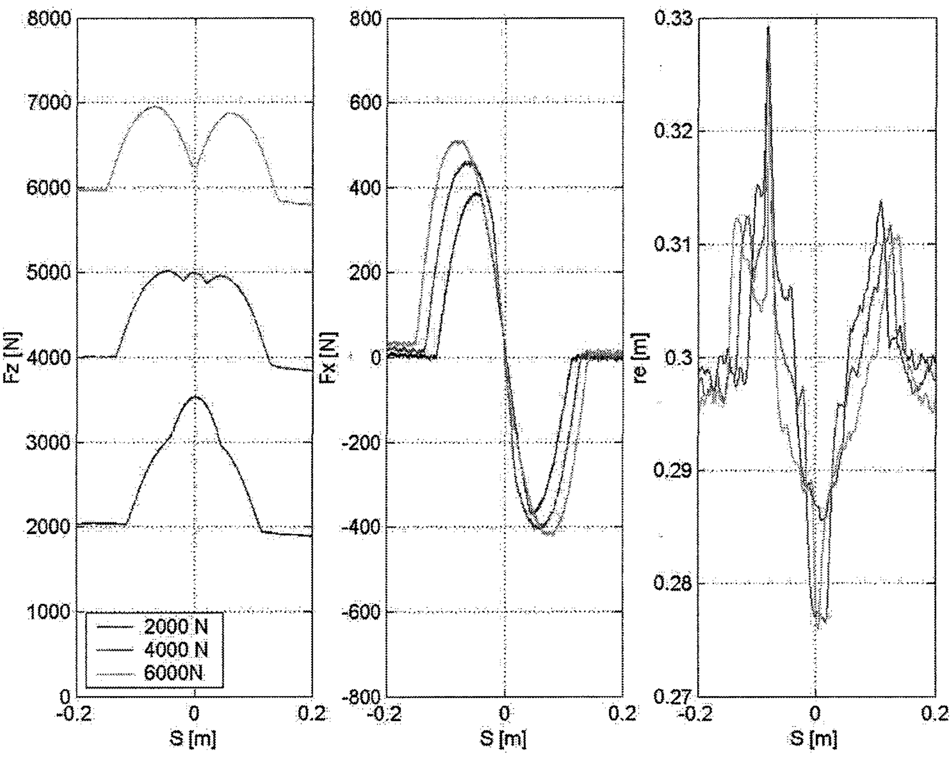

Figure 6.6 Results of cleat measurement with a Kuhmo Solus 195 60R15. The tyre pressure was 2.4 bar and the vertical load was around 2kN, 4kN and 6kN.