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Manual

TRIBOMETER

TYPE TRM 1000

Rev. 02-2007

0. INTRODUCTION

The tribometer serves for the investigation and simulation of friction and wear processes under sliding conditions. It can be operated for solid state friction without lubrication and for boundary lubrication with liquid lubricants. Thus both material and lubricant tests can be executed.

According to the standard test principle a stationary test specimen (pin or disc) with a defined normal force is pressed against the surface of a rotary disc. Both specimens are perpendicularly arranged one on the other whereby the rotary disc is on top. Other test configurations are possible. The normal force is applied by the movable drive block and the drive spindle. The normal force is damped by means of a spring located below the linear table. The tribometer is driven by a servo motor steplessly adjustable from 0.1 rpm to 3000 rpm.

The actual test equipment essentially consists of the motor unit, the drive and the load section. The shiftable modules are one on the other fastened to two perpendicularly columns. Pin and disc are in a specimen pot heatable up to approx. 150 °C. During the test the normal force, the temperature inside the pot, the linear wear amount of both specimens and the friction torque are continuously measured.

The measurement of the normal force is done by a force sensor arranged between counter load spring and lower specimen restraint. The temperature is measured by a NiCr-Ni-thermocouple in the pot. The wear is measured over the changing displacement between lower and upper specimen restraint. The measurement is done contactlessly by a laser-optical displacement sensor. The friction torque is measured by a rotary torque sensor.

All measuring signals are transferred to the control rack to be conditioned there. Data acquisition is done by an USB measuring module with a solution of 16 bit. The measured values of rotational speed and temperature are digitally monitored with temperature values sampled at 2 Hz and rotational speed sampled at 5 Hz.

Specification

Strain collective

Type of motion	Sliding
Mode of motion	Continuous
Normal force	By means of a drive-spindle system adjustable from 5 – 1000 N
Rotational speed	From 0.1 to 3000 rpm steplessly adjustable
Testing temperature	From RT to 150 °C steplessly adjustable

Tribological values		**Measured value**
FR – friction force	M = torque r = friction track radius => friction coefficient FR / F_N F_N = Normal Force	F_R = M/r
wl – wear amount		displacement (abrasion)
=> wear rate		wl/t t = time
T - Temperature		

1. Connecting Control Rack, Test Rig and PC

1 Connect PC and control rack via USB cable cable (see Software Installation).

2 Connect the sensor interface cable and the sensors with the slide-in unit of the control rack.

3 Connect the cables of the drive and the lift-drive as well as the heater.

4 Set up the power supply for three-phase alternating current 3x400 VAC/50 Hz and 230 VAC.

Hint: All plugs match only with the corresponding socket connector on the control rack except for the RS-232/USB converter cable.

1.1 Components

1.1.1 Control Rack

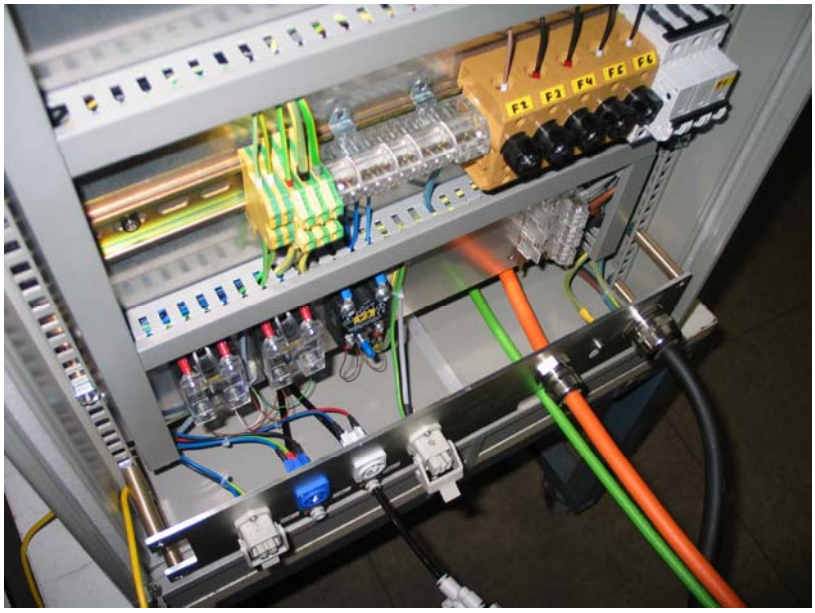
The control rack incorporates the plug-in unit with all amplifiers and power supply for all modules, the drive controller, and the drive itself. The compressed air conditioning and the main power switch are located at the bottom of the control rack.

Control Rack

Slide-in unit of the control rack

Main switch and compressed air conditioning

Rear side of the control rack with connections for lead, drive, lift, heater, and compressed air (IN/OUT)



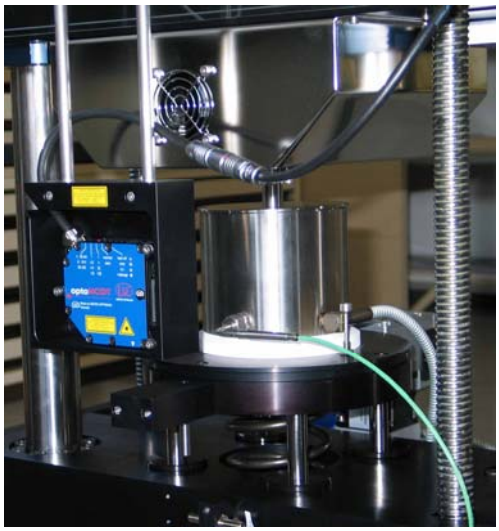
Rear side of the control rack with removed rear wall to change fuses

1.1.2 Computer

The USB measuring module and the RS 232/USB converter cable for data acquisition and controlling the test rig are connected to the computer.

1.1.3 Test Rig

The test rig represents the mechanical measuring unit other add-in modules can be added to.



Sensor Interface

TEMPERATURE Type-K	Thermocouple input for specimen pot and IR ring heater (if connected).
FORCE	Normal force sensor input.

The sensor inputs are automatically identified by its coded plugs and assigned to the corresponding measuring ranges of the software. Plug in a sensor's plug carefully to prevent the pins of the multi-pole plugs from bending which may cause a bad electrical contact or no contact at all.

Normal Force Sensor Markings

8435 – 5200 200 N	Measuring range
8435 – 5500 500 N	Measuring range
8435 – 6001 1000 N	Measuring range
8435 – 6002 2000 N	Measuring range
8435 – 6005 5000 N	Measuring range

Heating System Connection

By means of the slot the feedback control system is connected to heating system of the specimen pot.

1.1.4 Electrical Connections

Power supply: Three-phase current connection 3 x 400 V/50 Hz, plug: 5 x CEE plug, 5 x 32 A.

If a FI risidual-current circuit-breaker is used, it must be suitable for applications for frequency inverters (suitable for type U).

Fuses

The conrol rack contains fuses on the rear side for he following loads:

Drive	Fuse (F1)	3x16 A type C
Slide-in unit	Fuse (F2)	6 A E 14
Circuit board “Brake”	Fuse (F3)	2 A E 14
Power Supply Unit„Lift“	Fuse (F4)	2 A E 14
Heater	Fuse (F5)	10 A E 14
Plug-in unit	Fine fuses	2 x 2A 5 x 20 mm slow-blow fuse

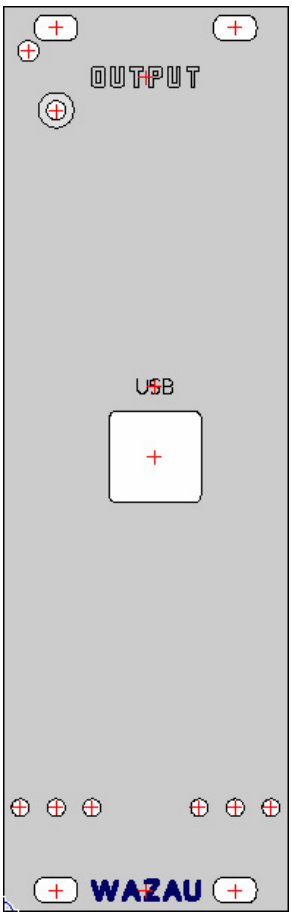
There are two fine fuses on the rear side of the control rack.

2. Control Rack

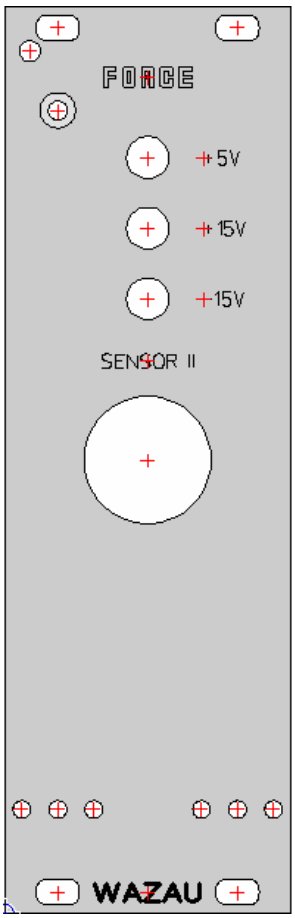
The following modules are located in the control rack:

- Module OUTPUT
- Module FORCE
- Module WEAR
- Module TORQUE
- Module TEMPERATURE CONTROLLER
- Moduel MOTORCONTROL (drive)
- Module FORCE CONTROLLER
- Module FRICTION FORCE (option)

2.1 Module OUTPUT



The module OUTOUT connects the measuring channels to the computer by means of an USB interface. The accuracy of the data acquisition is 16 bit. The USB interface should be connected to a USB 2.0 computer port in order to obtain an optimal function.



2.2 Module FORCE

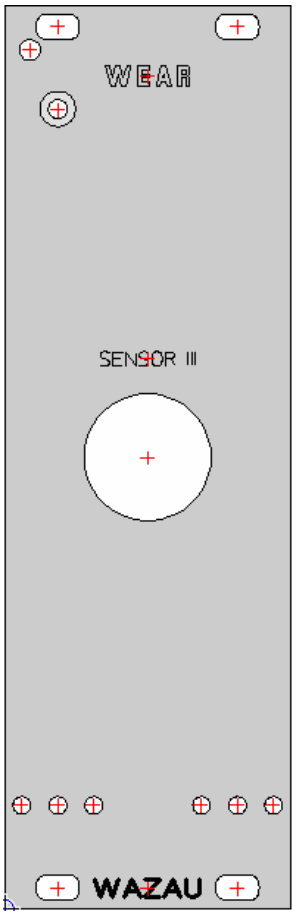
In order to achieve a precise measurement the normal force-amplifier has to be calibrated in an unloaded condition prior to the setup of the tribometer (offset adjustment). The calibration is done to eliminate influences on the sensor that may cause measuring errors such as the deadweight of the specimen pot or other parts. In addition there is always a 4 Hz low-pass enabled to eliminate interfering signals. The normal force sensor is secured against overloading by a limit switch. The alarm curcuit shuts down drive and heater if a force is reached extending the maximum measuring range by 1% (1010 N). The limit switch is always active. A re-start of drive and heater cannot be conducted until the cause of error has been eliminated and the button “Reset” on the software interface has been pressed. Before adjusting the offset let the normal force control system (containing spindle drive, spindle, normal force sensor, spring) deflect. To do this push slightly once the 4-column linear-table and release it thereafter so that the system can adjust itself. That step has also to be repeated everytime after a load has been applied on the linear-table by the normal force control system to avoid a wrong reading of the measured force value of the normal force sensor.

1) To calibrate the amplifier all specimen adapter and specimen pot, if required, have to be mounted to the test rig. If lubricated tests are to be conducted the lubricant has to be filled into the specimen pot and the covers have to be mounted to be regarded for calibration, too.

2) Press the button „ZERO“ on the software for simultaneous offset adjustment of TORQUE and FORCE, or press the button Lift “DOWN”. Then the offset will be automatically adjusted within a range of 0.05 % or the measuring range.

The three green LED indicate that the slide-in unit is powered with a operating voltage of ± 15 V and + 5V. The socket „Sensor II“ connects to the amplifier modules Normal Force and Temperature.

2.3 Module WEAR

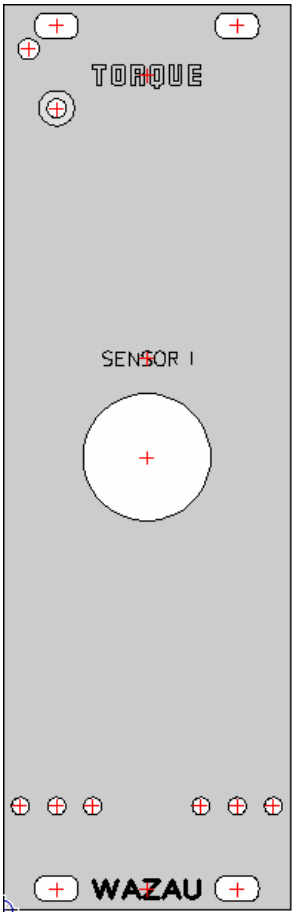


Pushing the tracer „Wear Off“ on the software enables or disables the measuring channel „Wear“. If “Wear” is disabled the offset adjustment will not be conducted.
The displacement sensor is secured against overloading by a limit switch. The alarm shuts down drive and heater if the displacement (wear) exceeds the maximum measuring range of the laser-optical displacement sensor or if the measuring system has an error. The measuring range of the laser-optical displacement sensor is ± 5000 µm. Due to the positioning of the displacement measuring system and the offset adjustment before the test the maximum measuring range decreases down to ± 4500 µm. The limit switch is only enabled during a test. That means if the drive is enabled. A re-start of the drive and the heater is only possible after the cause of error was eliminated and the button “Reset” on the software was pressed.
Socket III connects to the laser-optical displacement measurement. The setup of the displacement (wear) measuring system is described in chapter 6.

IMPORTANT! Never put your hand inside the beam of the laser-optical sensor after a test was started. This would be taken as an error of the system. The test will then be stopped by an overload signal.

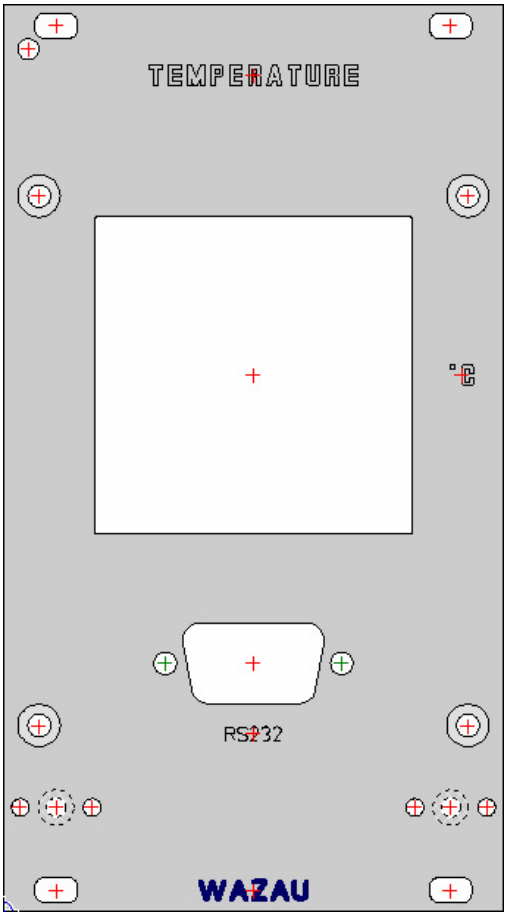
IMPORTANT! F LASER RADIATION !
LASER CLASS 2.
Do not look into the beam!

2.4 Module TORQUE



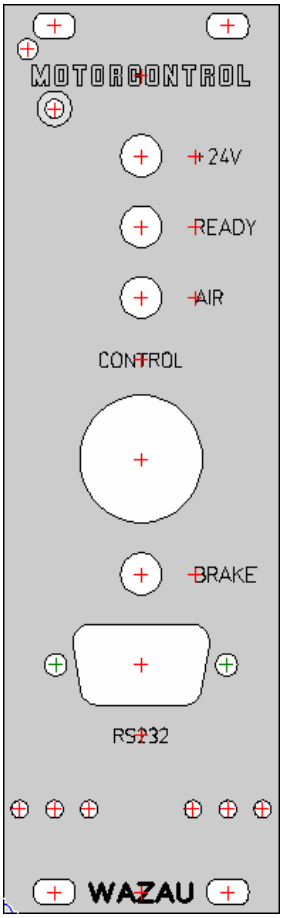
Pressing the tracer „Torque RMS“ on the software interface enables the root mean square (RMS) rectifier. In addition there is a 25 Hz low-pass enabled to disable interfering signals. The torque shaft is secured against overloading by a limit switch. The alarm shuts down drive and heater if the measured torque exceeds the maximum measuring range by 1 % (± 10.1 Nm). The limit switch is always enabled. A re-start of the drive and the heater is only possible after the cause of error was eliminated and the button “Reset” on the software was pressed. The socket Sensor I connects to the torque shaft.

2.5 Module TEMPERATURE



Control parameters and requested values are set on the software. The temperature controll cannot be changed manually as it is locked. The heater is secured against overloading by a limit switch.
The alarm shuts down drive and heater if the temperature exceeds the maximum temperature range by 15°C or if the thermocouple is broken. The limit switch is always enabled. A re-start of the drive and the heater is only possible after the cause of error has been eliminated and the button “Reset” on the software has been pressed. The RS 232 socket connects to the computer via an USB hub, thus controlling the temperature.

2.6 Module MOTORCONTROL



Pushing the tracer „BLOCKING" on the software blocks the drive shaft. That way the operator can loosen or tighten the screws of the specimen adapter easier. The torque shaft is secured against overloading by a limit switch. The alarm enables the blocking function if the measured torque exceeds the maximum measuring range by 1% (± 10.1 Nm).
The green LED +24V indicates that the operating voltage supplies the slide-in unit. The green LED AIR indicates that the operating air pressure of 5 bar supplies the air-bearing spindle. The red LED BRAKE indicates that the drive's brake is enabled. In this state the drive cannot be enabled. The brake is active if the tribometer is off or if there is a loss of pressure. The socket "Control" connects to the control interface at the rear side of the drive block. The RS 232 socket connects to the computer by means of a USB hub, thus controlling the drive.
The compressed air supply on the air-bearing spindle is released automatically. Once operating voltage and compressed air supplies the control rack the air will be conditioned for the membran dryer. It takes the membrane dryer up to 15 minutes until the air is optimal dried. After that process the compressed air is automatically applied on the air-bearing spindle. Hereafter the tribometer is ready for operation. Possible mountings on the sprecimen holder can then be carried out.

AIR LED states:

red shining	- Compressed air of 7 - 8 bar does not supply the control rack.
red blinking	- Air conditioning of 15 min. Has been started.
green shining	- Compressed air of 5 bar supplies the air-bearing spindle (tribometer is ready for operation).

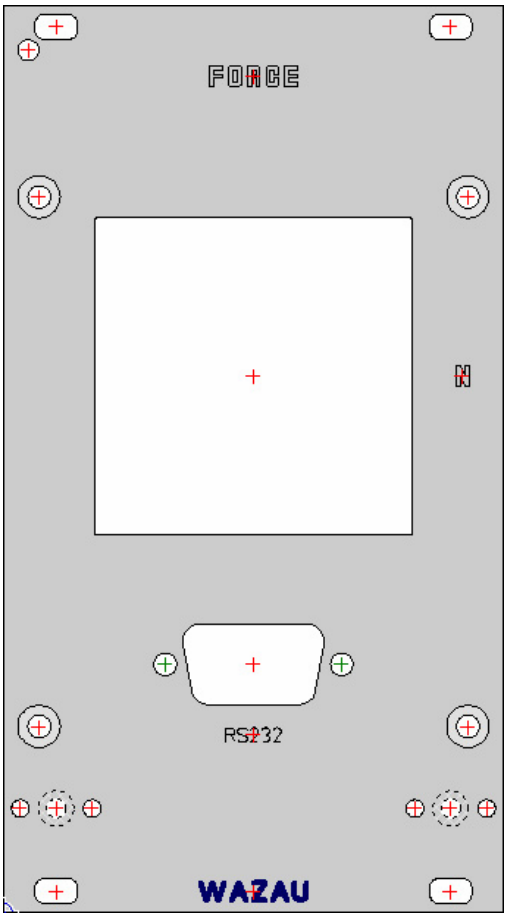
IMPORTANT! Do not assemble or disassemble the specimen holder at the air-bearing spindle as long as the compressed air does not supply the air-bearing spindle. Only if the LED Air shines green the air pressure is supplied.

IMPORTANT! Applying the emergency stop switch will cause an overload which is reset after the emergency stop switch was released.

IMPORTANT! Only operate drive, air-bearing spindle, and torque shaft if normal force (load) is applied on the specimen pairing. An idling run is not allowed!

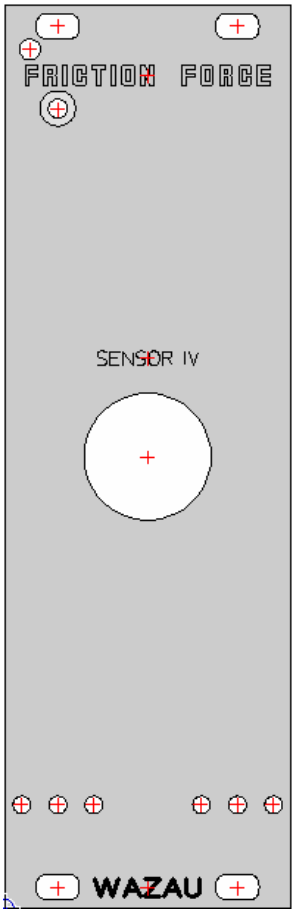
IMPORTANT! The controls of the air conditioning of the air-bearing spindle requires a pressure of 7 - 8 bar. The pressure has to be applied on the system spontaneously. A slow increase of the pressure leads to a malfunction of the switch thresholds so that the controls of the air conditioning won't start.

2.7 Module FORCE CONTROLLER



Control parameters and requested values are set on the software. Manual changes are not possible since the force controller is locked. The normal force sensor is secured against overloading by a limit switch. The alarm circuit shuts down drive and heater if a force is reached extending the maximum measuring range by 1% (1010 N or 202 N respectively).
The limit swith is always active. A re-start of the drive and the heater is only possible after the cause of error was eliminated and the button "Reset" on the software was pressed. The RS 232 socket connects to the computer via a USB hub, thus controlling the force controller.

2.8 Module FRICTION FORCE (option)



Pressing the tracer „Torque RMS“ on the software interface enables the root mean square (RMS) rectifier. In addition there is a 25 Hz low-pass enabled to disable interfering signals. The friction force sensor is secured against overloading by a limit switch. The alarm shuts down drive and heater if the the measured friction force exceeds the maximum measuring range by 1 % (± 101 N). The limit switch is always enabled. A re-start of the drive and the heater is only possible after the cause of error has been eliminated and the button “Reset” on the software has been pressed. The socket Sensor IV connects to the friction force amplifier.
The compressed air supply on the air-bearing spindle is released automatically. Once operating voltage and compressed air supplies the control the air will be conditioned for the membran dryer. It takes the membrane dryer up to 15 minutes until the air is optimally dried. After that process the compressed air is automatically applied on the air-bearing spindle. Hereafter the tribometer is ready for operation. Possible mountings on the sprecimen holder can then be carried out.

IMPORTANT! **Do not** assemble or disassemble the specimen holder at the air-bearing spindle as long as the compressed air does not supply the air-bearing spindle. Only if the LED Air shines green the air pressure is supplied and the air-bearing has been connected by a quick coupling.

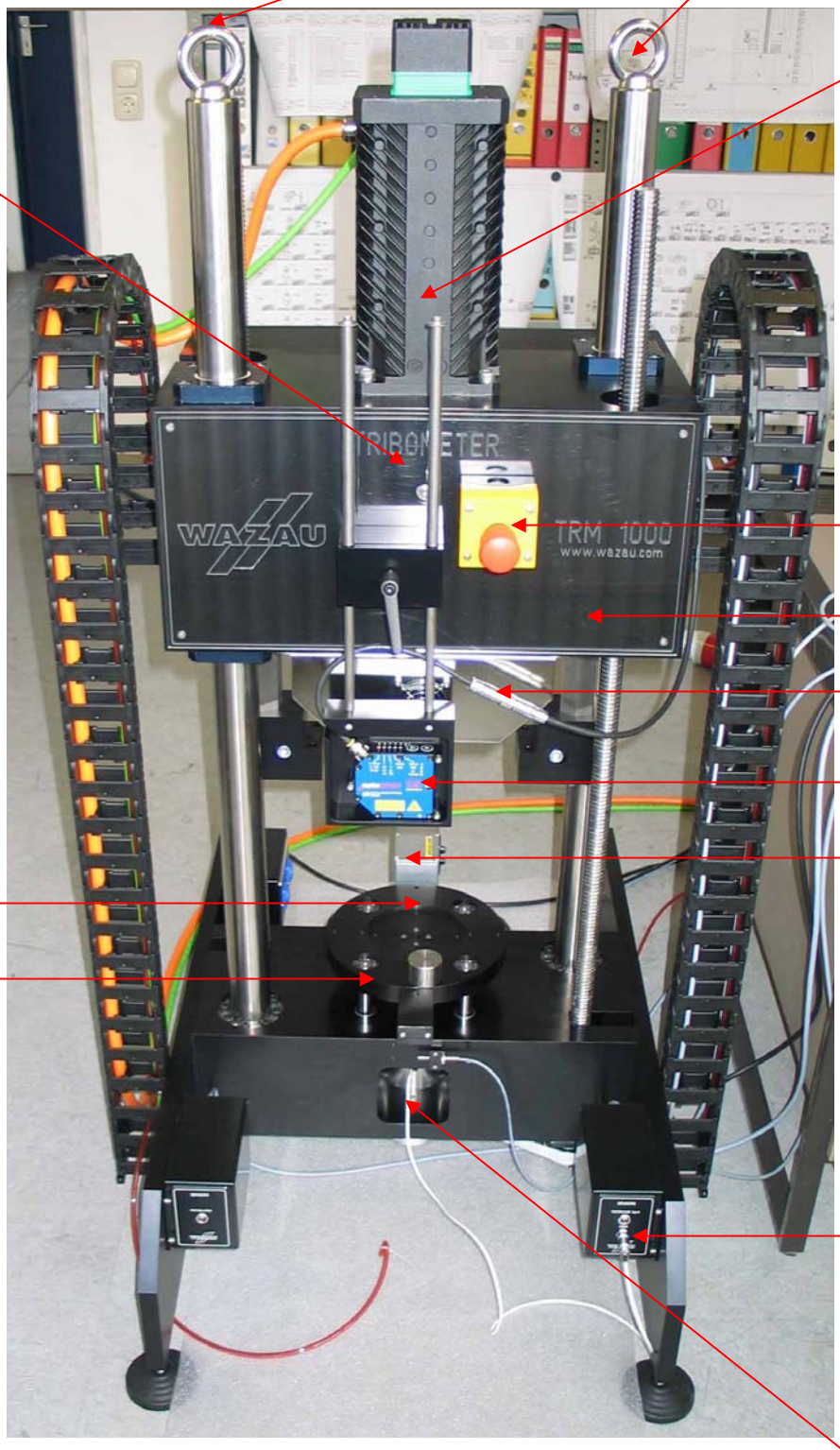
Sensor interface

FRICTION FORCE Friction force sensor input

The sensor inputs are automatically identified by its coded plugs and assigned to the corresponding measuring ranges of the software.

Plug in a sensor’s plug carefully to prevent the pins of the multi-pole plugs from bending which may cause a bad electrical contact or no contact at all.

3. Test Rig



Test Rig

3.1 Mounting the specimens

The test rig comprises the actual tribometer with all mechanical units.

There are standard mountings for pin/disc or disc/disc tests. Depending upon the geometrical specimen pairing the lower specimen test specimen has to be installed in the specimen pot. Special mounting plate components can also be installed.

To make sure that the friction areas of both specimens run flat one on the other when running disc/disc tests, the swash plate has to be used as the lower mounting. The swash plate is beared on a ball. It is fixed in the direction of rotation by a stop on each side.

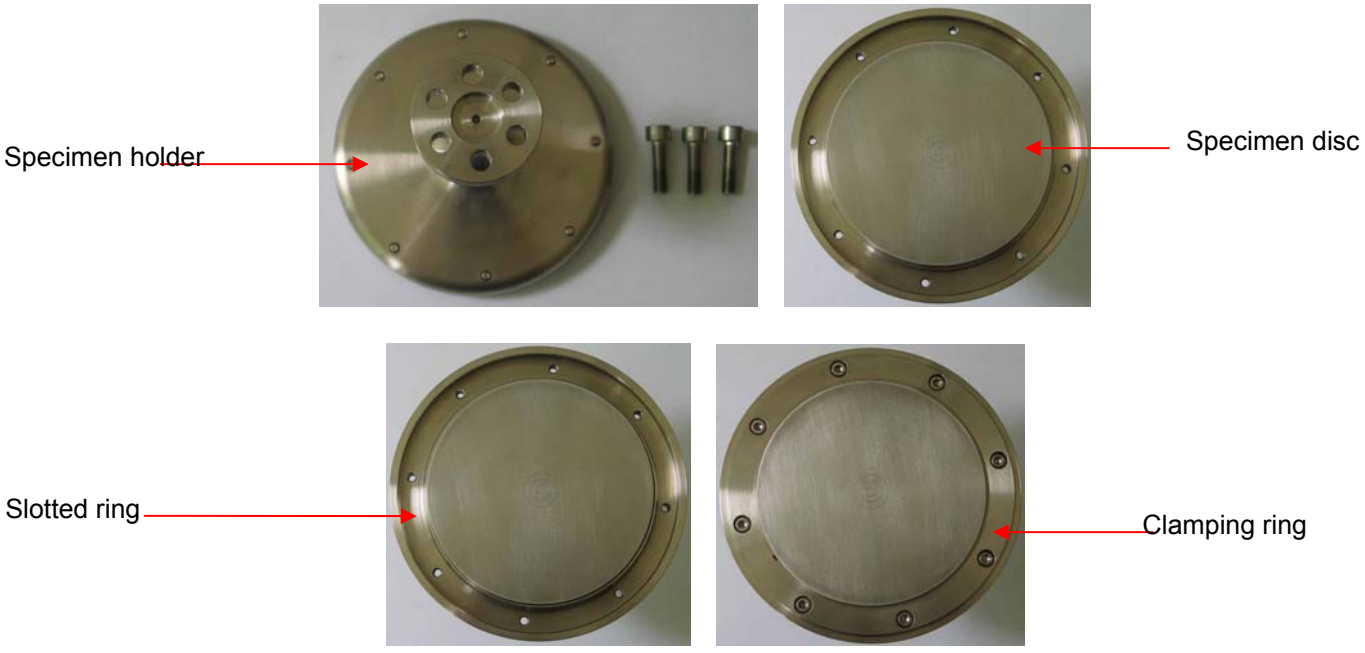
The specimens have to be mounted on the lower or upper specimen adapter and locked by screws. Make sure the screws have been drilled all the way into the specimen.

For pin-on-disc tests swash plate, stops, and ball have to be removed and replaced by the pin holder.

In order to avoid disturbances caused by possible oscillations of the pin it should be placed as deep as possible into the holder. Locking is made by the socket-head cap screws. Similarly to the disc/disc test system the upper specimen has to be put into the corresponding specimen adapter and fixed by the screws.

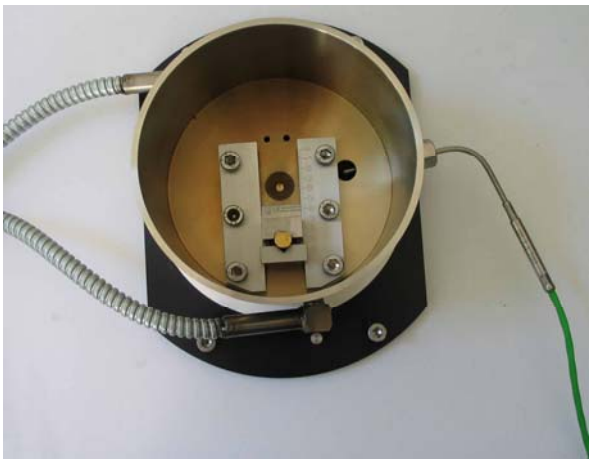
Specimen holder air-bearing spindle

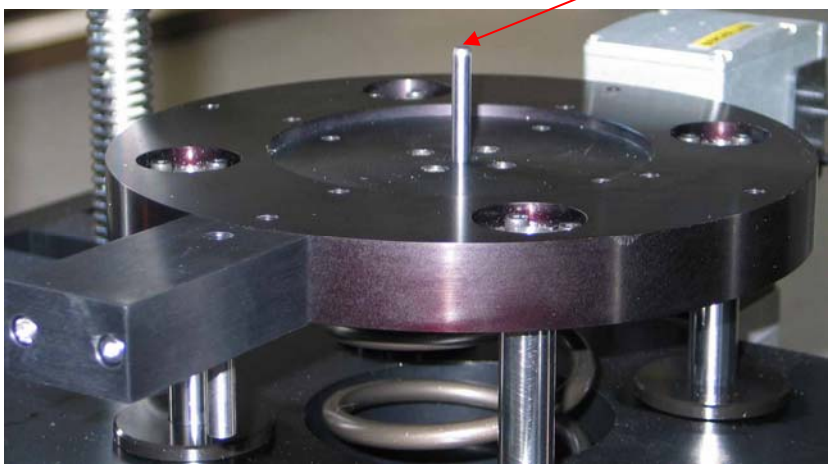
IMPORTANT! Do not assemble or disassemble the specimen holder at the air-bearing spindle as long as the compressed air does not supply the air-bearing spindle. Only if the LED Air shines green the air pressure is supplied.



3.2 Standard Specimen Pot for lubricated Tests

The specimen pot is mounted on the support containing the heater. Prior to that the centrepin has to be mounted on the linear table with the tip up. That way the specimen pot is centred on the linear table. The specimen pot is resistant to corrosive media so that tests with corrosive lubricants can also be conducted. The maximum temperature of the lubricant should not excced 150°C.





In this way the thermocouple sitting in a drilled hole has thermal contact to the lubricant. In this manner the thermocouple serves as a reference input for the PID controller of the software and to measure the lubricant's temperature if the specimen pot is not heated. In this way during tests with high values of friction torque leading to a temperature rise of the lubricant, the temperature of the lubricant can be measured. The heater inside the specimen pot is connected by leads on the sockets "Heater". The thermocouple is connected by means of the socket „Temperature Typ- K" on the sensor interface.

Safety hint: The operating personnel must not touch the wall of the specimen pot at any time as there is a risk of severe burn. Likewise make sure there is no easily combustible material or liquid near or inside the pot.

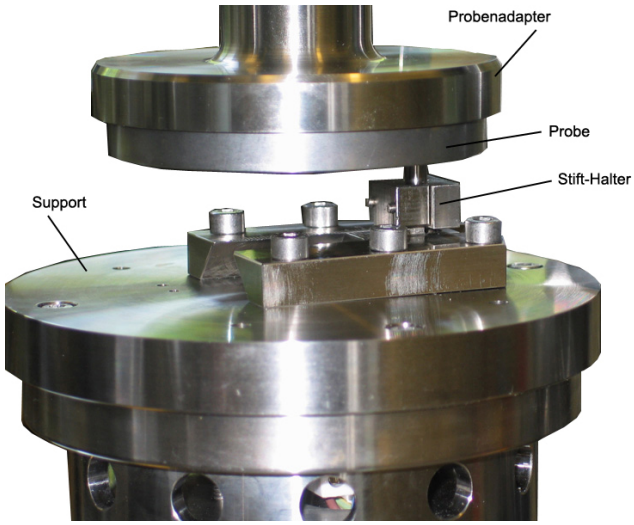
Berühren verboten

3.3 Ball holder / Pin holder

The pin holder fits pins of the diameter 6 mm, 8 mm, and 10 mm, with a length of 30 mm.

The ball holder fits balls of a diameter 5 mm, 6 mm, 8 mm, and 10 mm.

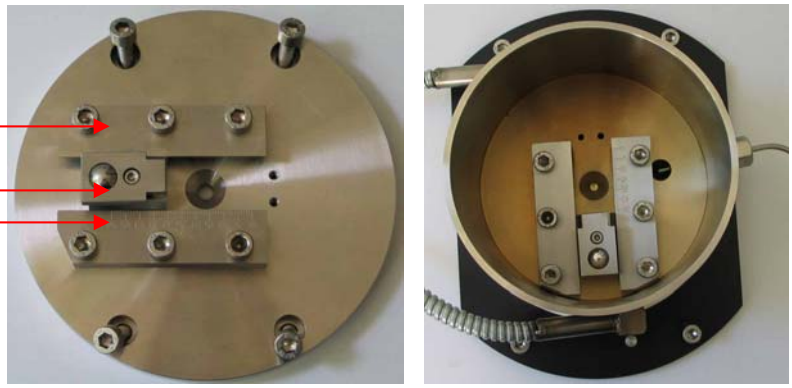
To change balls/pins unscrew the cover of the holder.



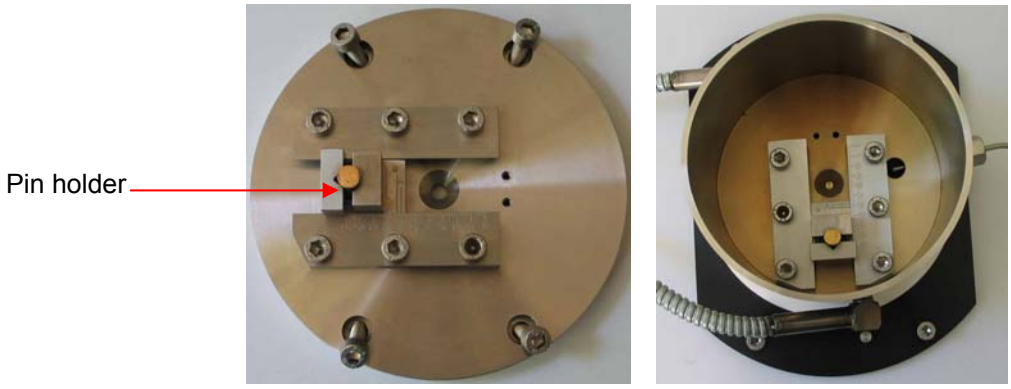
Unlubricated pin-on-disc test. Support with pin holder.

Trapezoid spanner

Ball holder
Scale
Friction radius



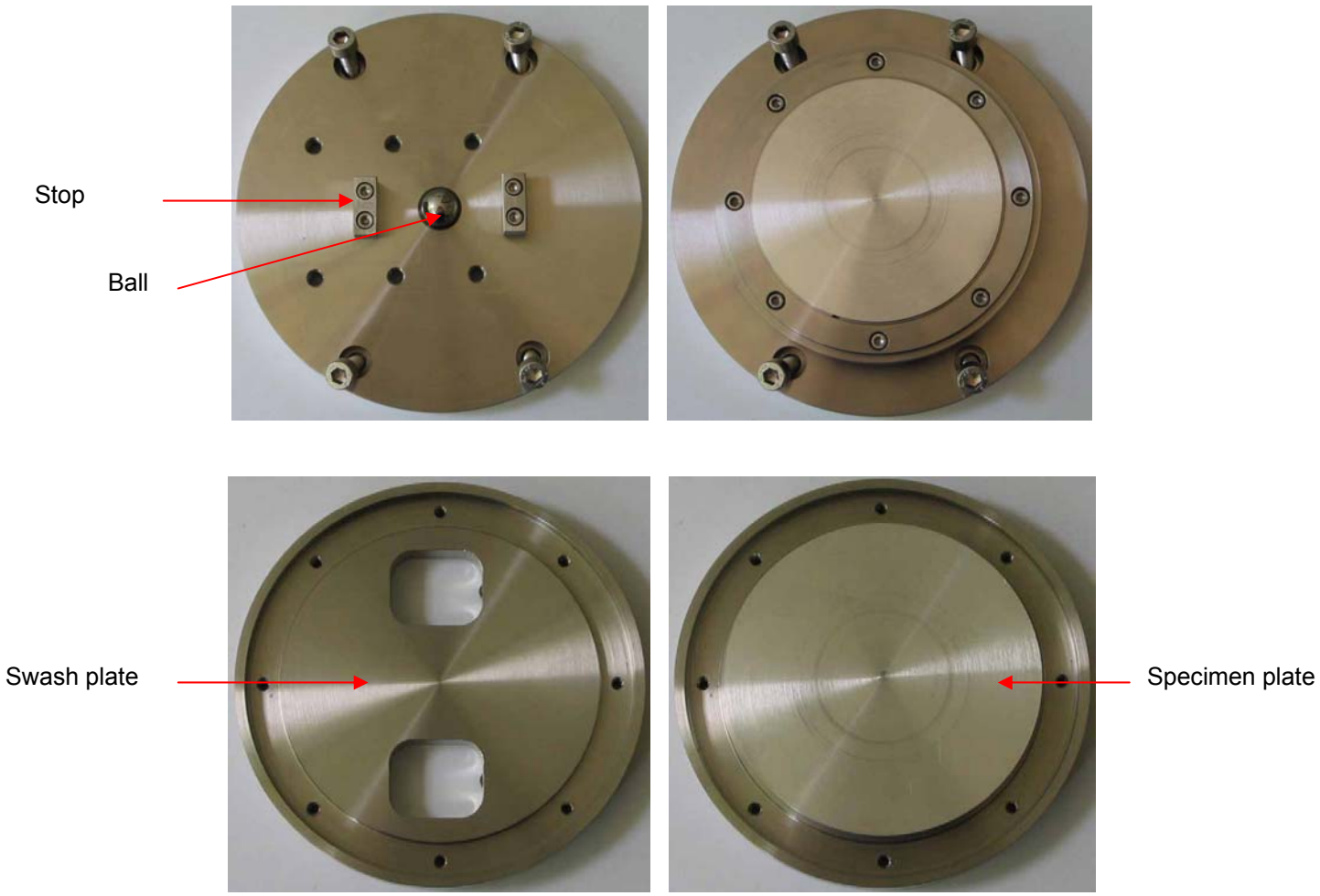
Ball-disc arrangement for lubricated and unlubricated tests.



Pin-on-disc arrangement for lubricated and unlubricated tests.

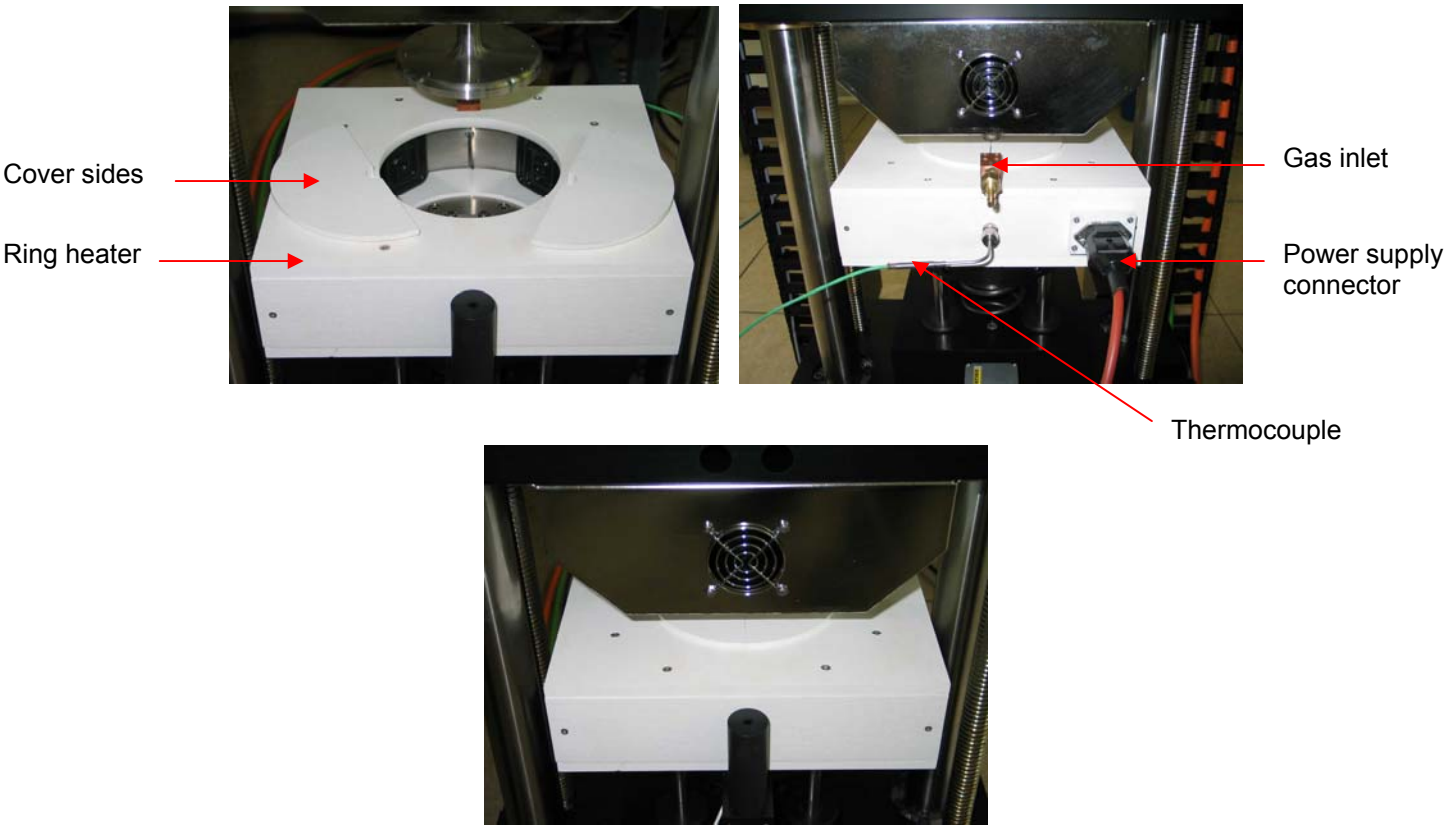
3.4 Disc Holder

To make sure that both discs are permanently in contact in the horizontal position a swash plate is mounted under the plate specimen. First mount the stops on the support und place the ball in the middle of the counterbore. Then place the mounted specimen with the swash plate on the support.



3.5 Mounting of the Ring Heater (option)

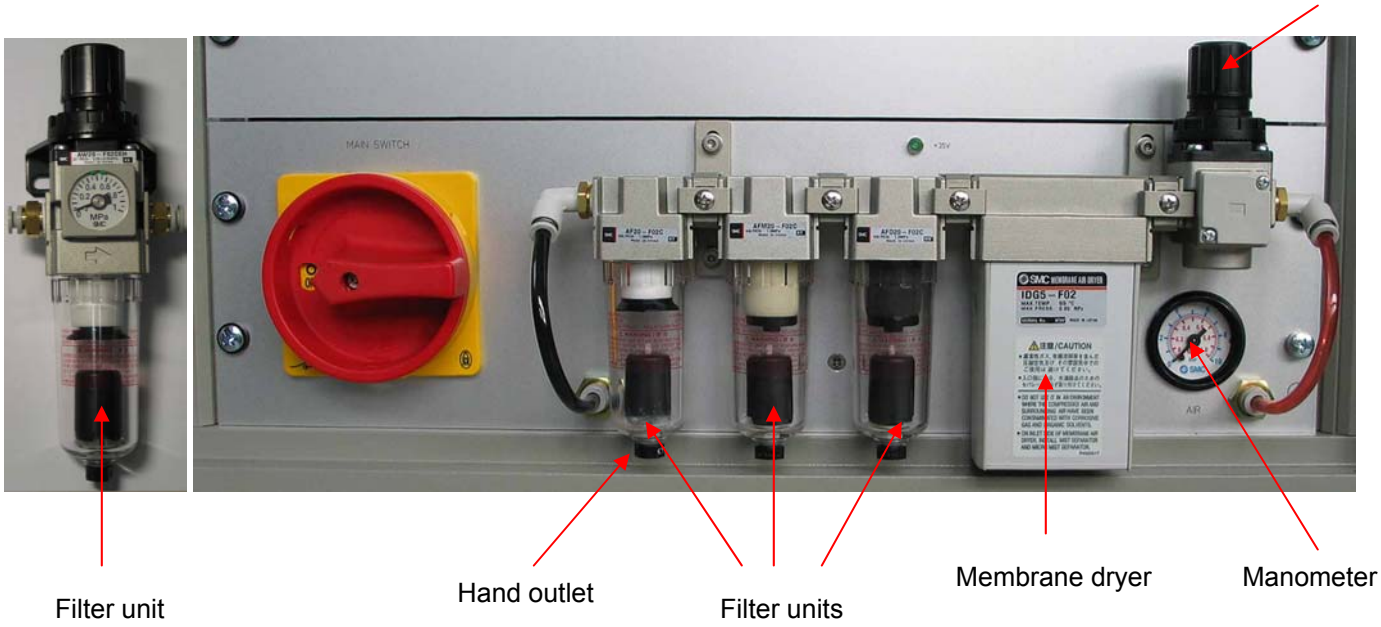
Let the drive block go up to the end switch in order to mount subsequently the specimen holder to the air-bearing spindle. To do that mount first the white insulation board on the tribometer support and centre it with the pin in the middle. After that install the pre-assembled specimen arrangement on the insulation board and mount to the tribometer support by means of the four screws. Now place carefully the the ring heater above the specimen arrangement and put both sides of the cover, as shown on the picture, on the ring heater. The weight of the cover sides will be taken into account for the offset adjustment of the normal force. Connect the thermocouple to the sensor interface and connect the ring heater's connector on its right side to the power supply. After the specimens touched each other and the normal force was applied, the ring heater has to be closed by the cover sides. Then set the desired temperature value on the software.



3.6 Compressed air conditioning

The air conditioning represents the air supply of the air-bearing spindle. The compressed air is filtered and dried before getting into the air-bearing. The input pressure of the filter unit should be 7 – 8 bar. 7 bar should be adjusted on the filter controller unit using the manometer. This filter unit has to be always operated between the compressed air input on the control rack and the supply line of the customer.

The compressed air has to be 5 bar and is pre-set ex works. Its value can be read on the manometer on the control rack. A 15 minutes dehumidification in the membrane dryer is executed automatically. Afterwards the compressed air is enabled for the air-bearing spindle. The manometer in the control rack should show then 5 bar. The filter units drain the water column autonomously. They can also be drained by means of the hand outlet.



4. Tribometer Software

The software mainly consists of three windows. The setup window gives an overview on the settings. On the control window the program execution can be set and observed. On the analysis window the test results can be viewed.

4.1 Software installation

On installation the following software is installed. These software packages are pre-installed ex-works.

- USB serial controller,

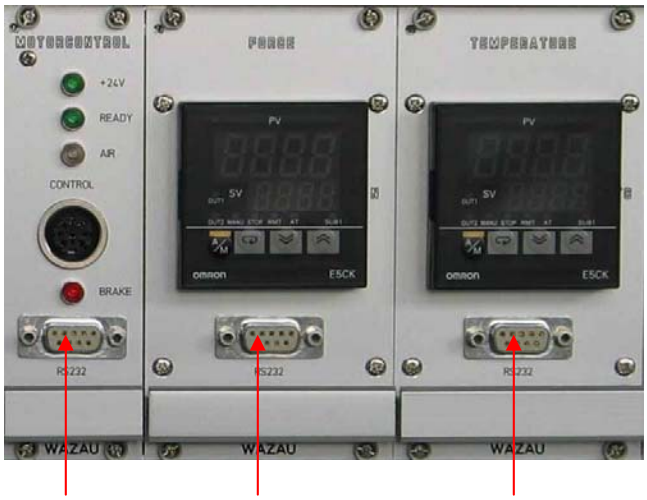
- MCC DAQ,
- TriboControl application software.

4.1.1 USB Serial Controller

On installation the USB serial controller the driver to adapt the converter cable from the RS 232 interface to the USB interface is installed.

Proceed as follows:

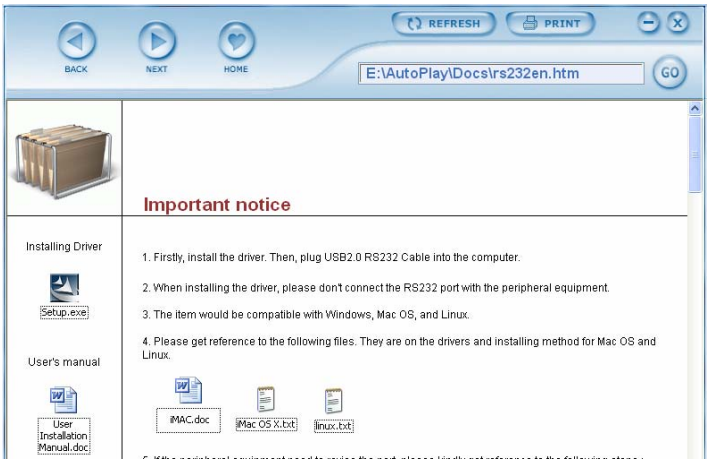
1. Insert the CD „Driver“ and „User’s Guide“ (Transfer Series) into the das CD/DVD ROM drive of your computer.
2. Choose the English version of the automatic starting program (picture 1).
3. Then choose „USB 1.1 TO RS232 Cable“ (picture 2).
4. Choose from „Installing Driver“ setup.exe and execute the file while the safety warning of Windows XP appears (picture 3/4).
5. Do the installation according to the requests of the installation routine (picture 5/6).
6. Then connect the RS 232/ USB converter cables from the RS 232 interface of the the slide-in unit to the US interface of the computer. All three cables have to be connected separately.



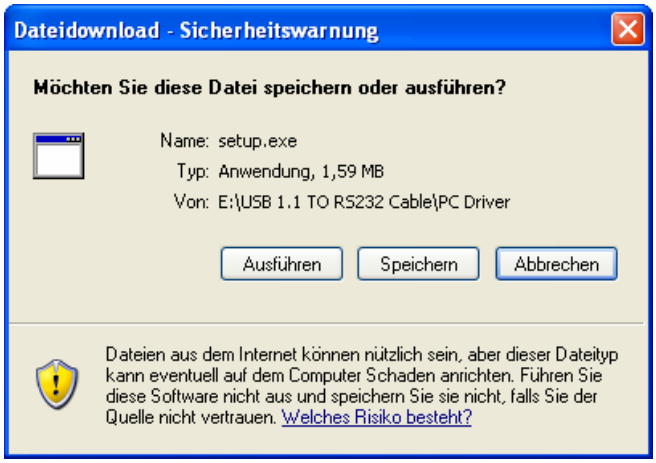
Drive COM Force COM Temperature COM

Picture 1

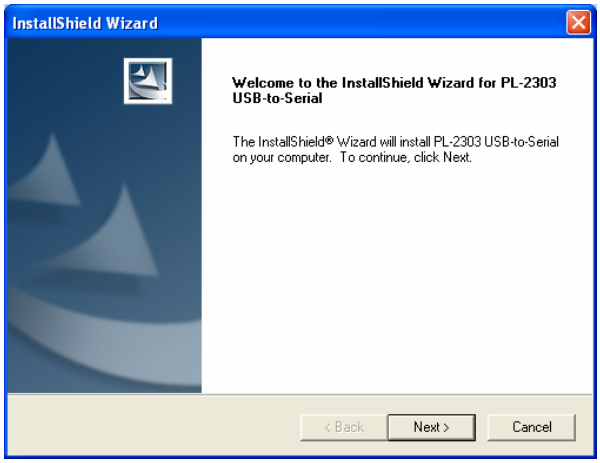
Picture 2



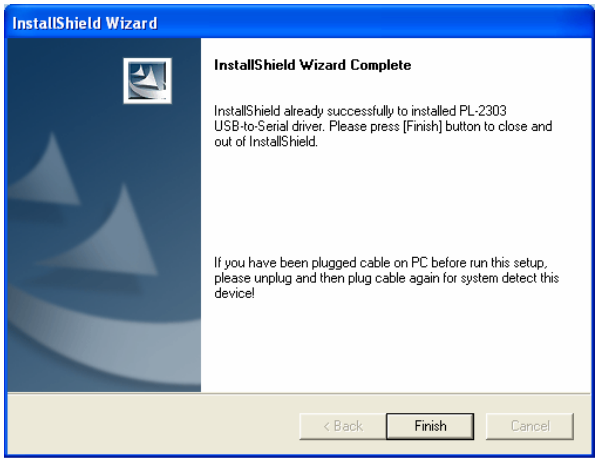
Picture 3



Picture 4



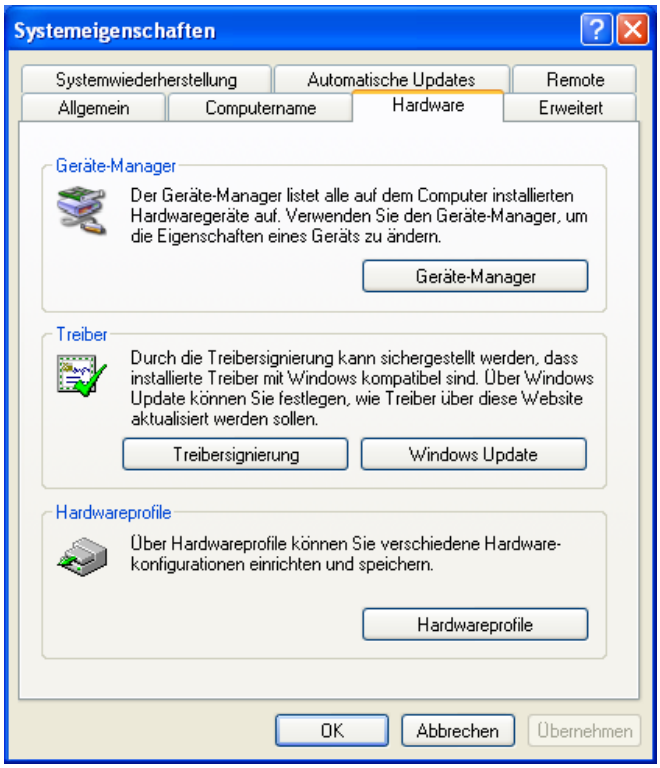
Picture 5



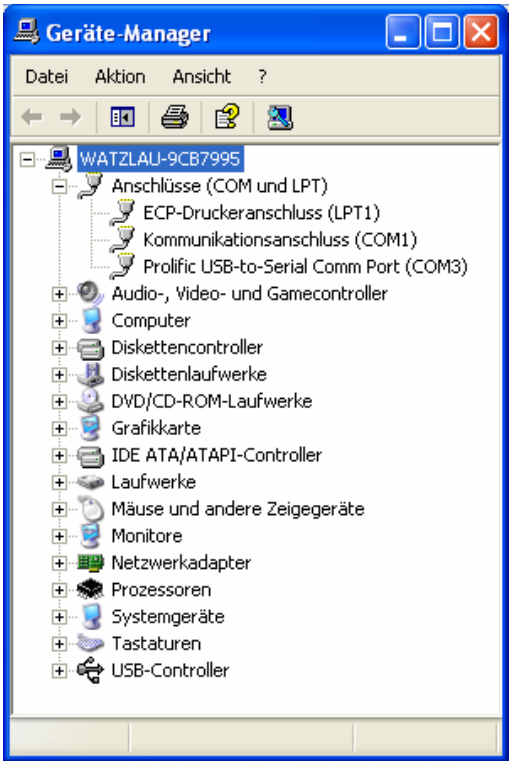
Picture 6

Picture 7

7. Windows recognizes now the new hardware and starts the assistant to search new hardware (picture 7).
8. Start then the under „System Control“ the menu „Hardware“ and „Device Manager“ of the Windows operating system (picture 8).
9. On the „Device manager“ click on connections (COM and LPT, picture 9).



Picture 8



Picture 9

10. The RS 232/ USB converter cable is now displayed as “Prolific USB-to-Serial Bridge” (COM3). Note the assigned COM port of the RS 232/USB converter cable to the slide-in unit on the control rack (Drive COM, Force COM and Temperature COM). In this example it is COM3. This port is used after the software TriboControl was installed. Connect then the remaining RS 232/ USB converter cables from the RS 232 interface to the USB interface on the computer.
11. Quit the Device Manager and System Controls.

4.1.2 MCC DAQ

The software contains the driver fort he USB measuring module and is required to run the application software TriboControl.

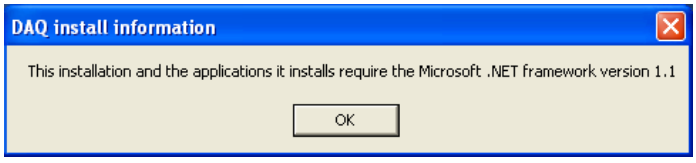
Proceed as follows:

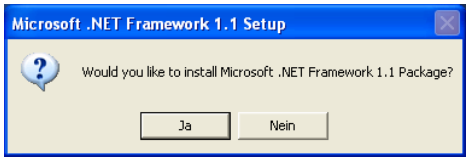
Connect the USB cable from the slide-in Module OUTPUT to the USB interface of the computer.

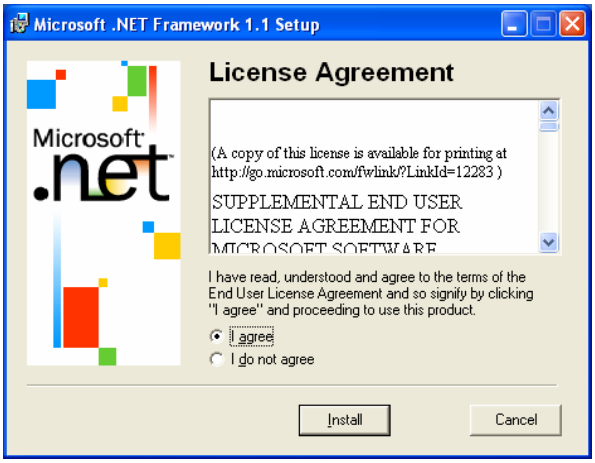
12. Windows recognizes the new hardware and starts the assistant to search new hardware.

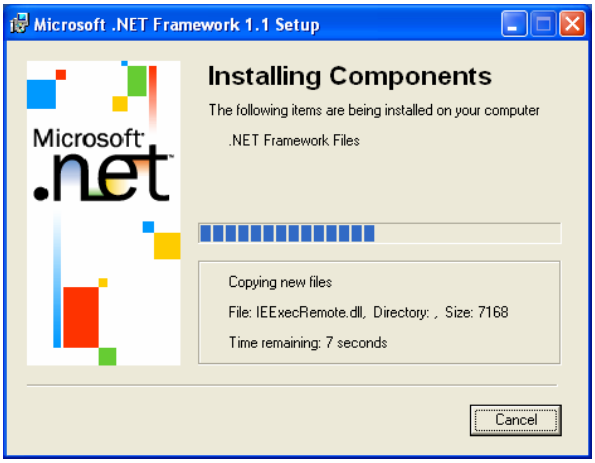
Picture 10

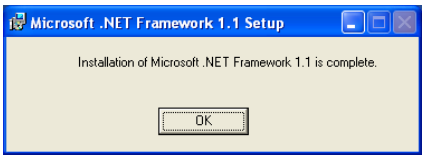
13. Insert the CD of the company „Measurement Computing“ into the CD/DVD ROM drive of your computer and install the program. Before the installation it might be necessary to install NET framework on your Windows operating system if not already installed. To do that install according to the automatic starting assistant.



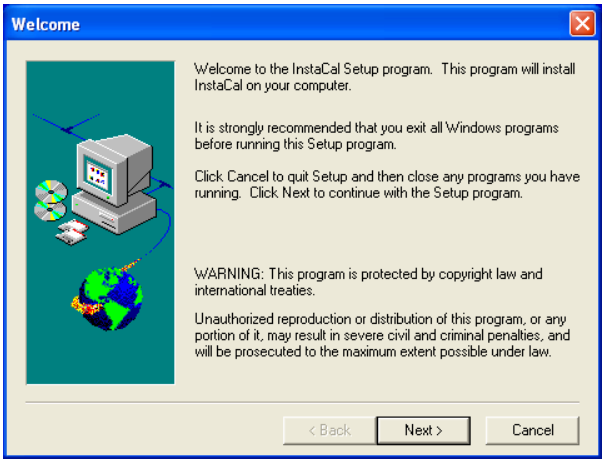




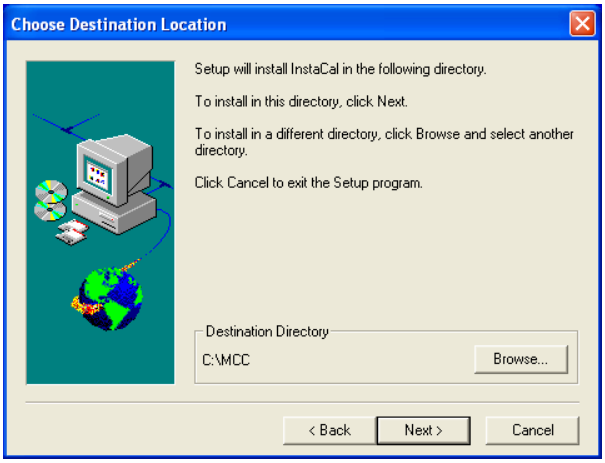




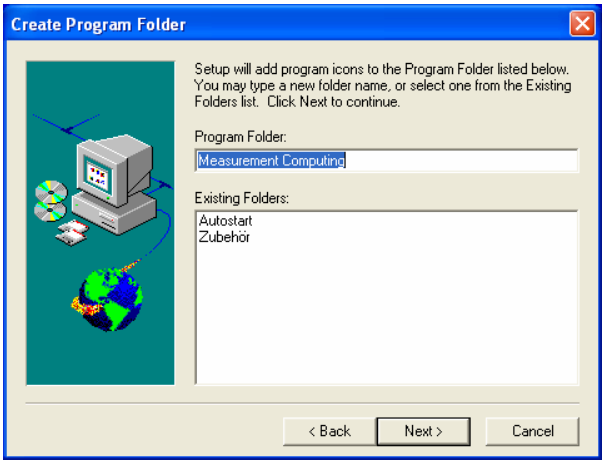
15. Execute the installation in accordance with the requests of the installation routine (pictures 11, 12, 13).

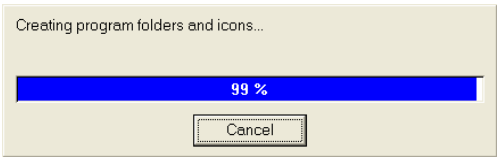


Picture 11



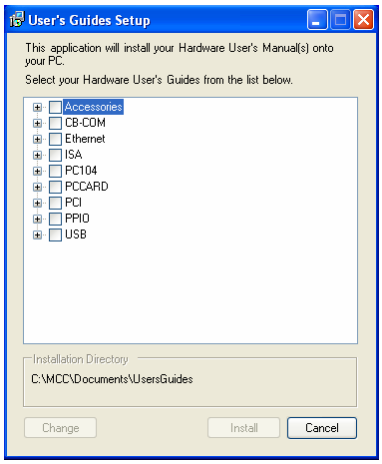
Picture 12



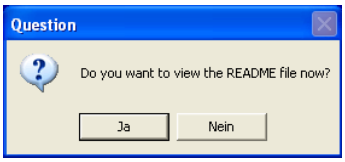


Picture 13

16. After the installation you may install different PDF documents of the manufacturer. Click the button **Cancel** to close the window (picture 14). After that click **NO** in order not to display the Readme file (picture 15).



Picture 14

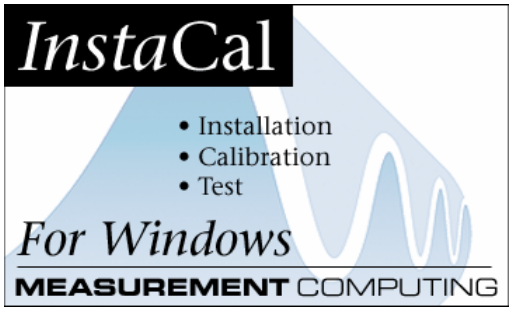


Picture 15

17. After the installation re-start the computer when requested to (picture 16).

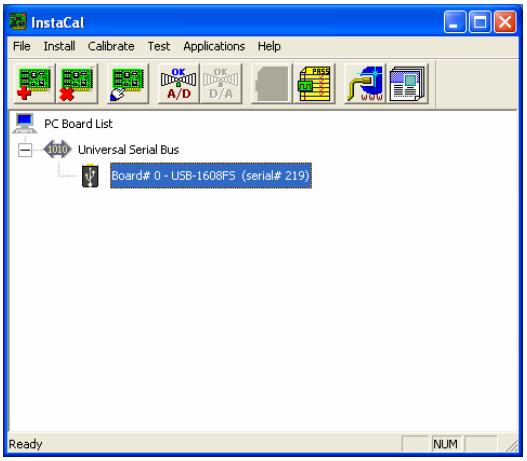
Picture 16

18. Start then the program by „Start/Programme/Measurement Computing/InstaCal“ (picture 17).



Picture 17

19. The program recognizes now the connected USB module with the corresponding serial number. Push **OK** and close the program. The board number is 0.



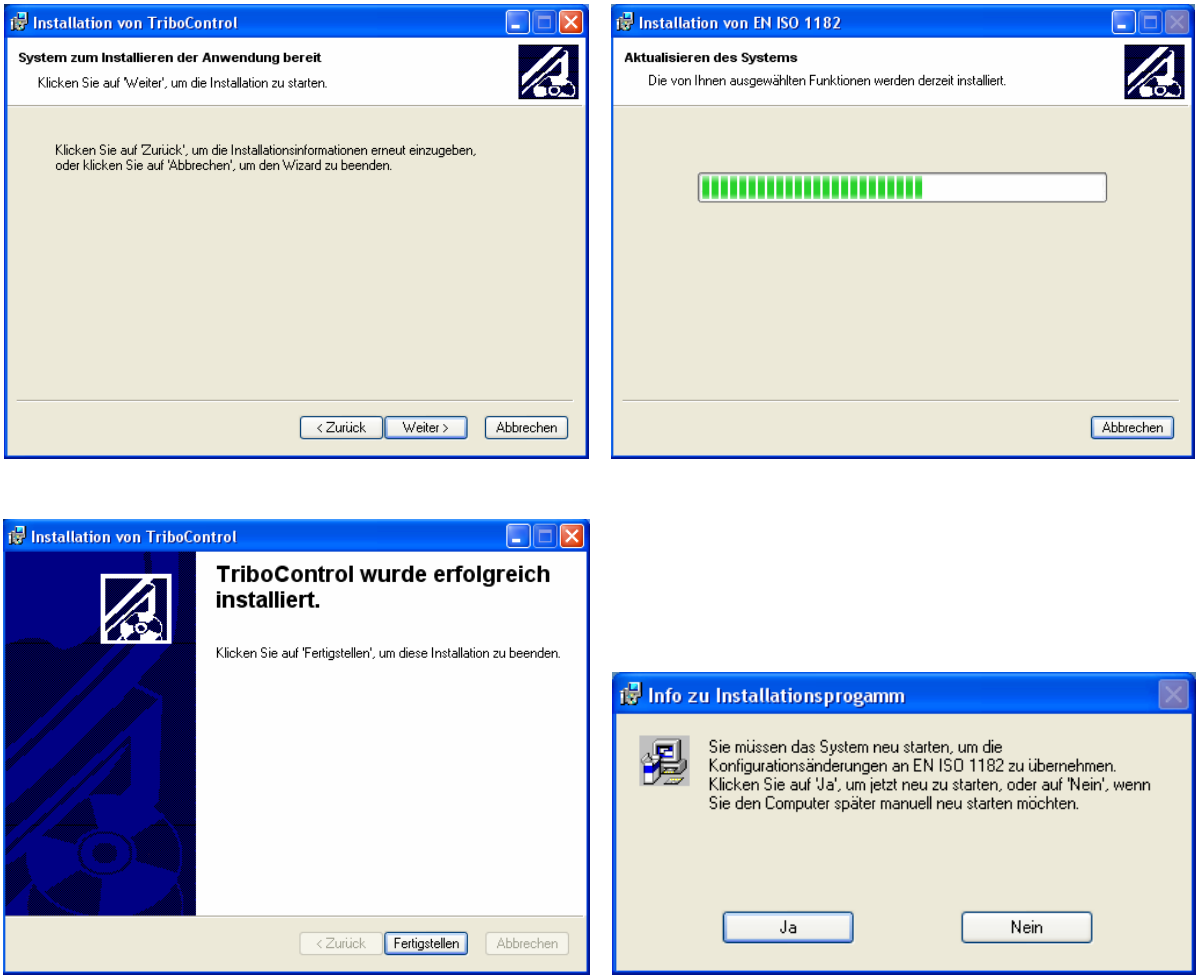
4.1.3 TriboControl

The software TriboControl represents the actual program to control and measure.

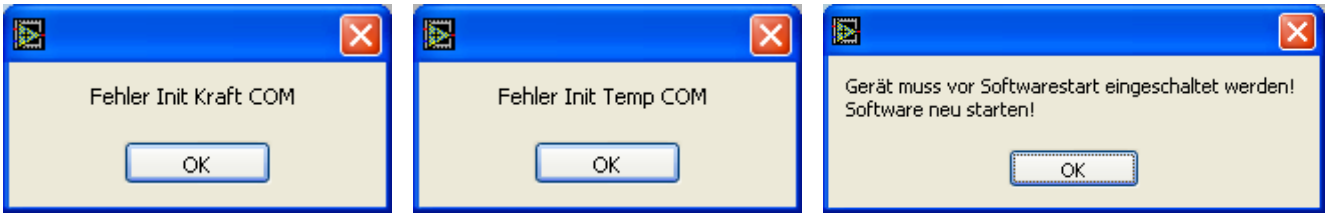
Proceed as follows:

Insert the CD TriboControl into the CD/DVD-ROM drive of your computer. Start the file setup.exe in the directory Installer on the CD. The installation program installs the TriboControl Software and the LabVIEW 7.1 Runtime which needs to be installed on the system. To install the the software TriboControl click on the button **Weiter** (proceed) and **Fertigstellen** (complete) respectively.

After the installation re-start the computer when promted to do so.

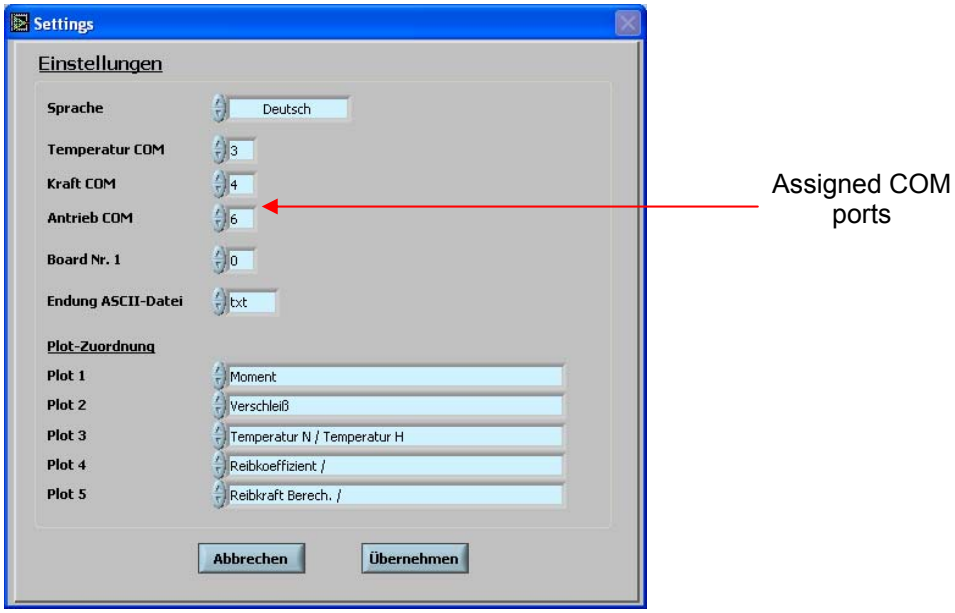


20. Start the software using the software „Start/Programme/TriboControlV5/TriboControlV5“. Starting the software for the first time will require:
    - ☐ To assign the COM-ports on the software.
    - ☐ The software will start with the messages „Fehler Init Kraft COM (error Init Force COM)” etc. and
    - ☐ “Gerät muss vor Softwarestart eingeschaltet werden! Software neu starten! (tribometer has to be turnt on before starting the software)“ (picture 18)



Picture 18

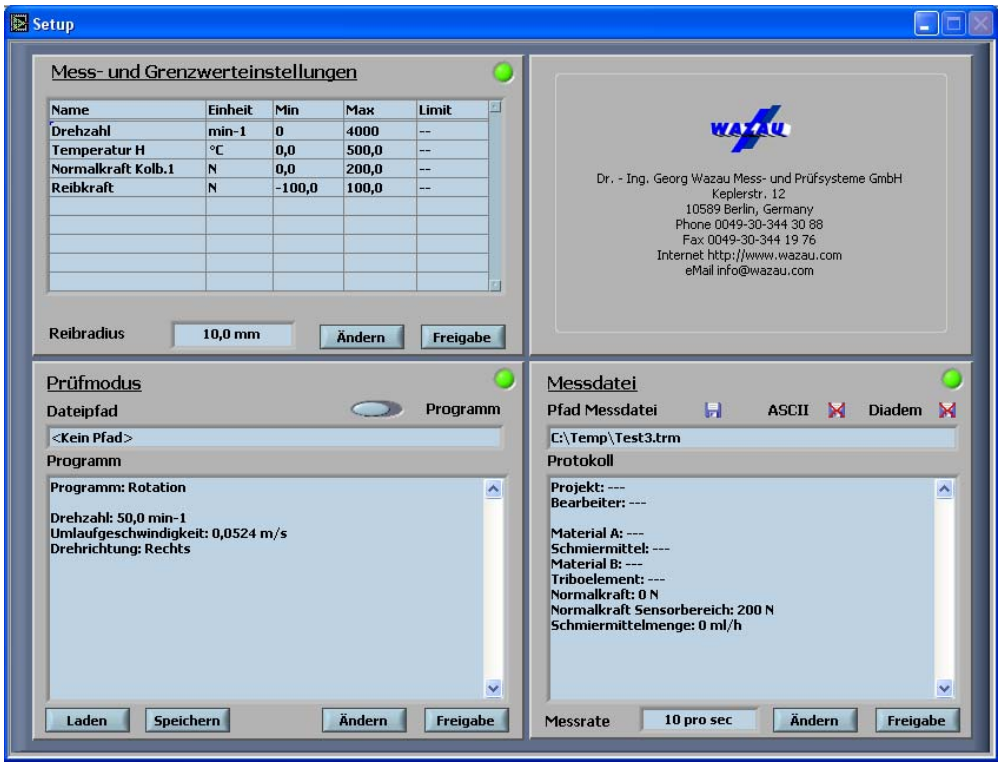
21. Push always the button **OK** and open on the software on the window „Control“ the window „Einstellungen“ (settings) under „Optionen“ (options) (picture 19). Now enter in the Device Manager the determined COM ports of the RS 232/USB converter cables in the corresponding fields.Push the button **Übernehmen** (accept) and quit the software TriboControl. Re-start the software. It will start without the messages popped up before and is ready to use. You can change the language from German to English in the field “Sprache” (language). That setting is enabled after the software was quit. The field “Board Nr.” (board no. of USB measuring module) is used to execute different software versions on the computer.
22.



Picture 19

4.2 Setup Window

On this window in three sectors are displayed: measuring ranges, limits, test program with operating parameters and file settings. In each sector setting can be changed by pushing the **Ändern** button (change). That action opens an input window in which the desired parameters can be entered.



The sector **Mess- und Grenzwerteinstellungen** (measuring and limit settings) shows the active measuring ranges and the enabled limits. Moreover the friction radius for the rotary movement and the stroke for the linear (translational) are displayed as an input field.

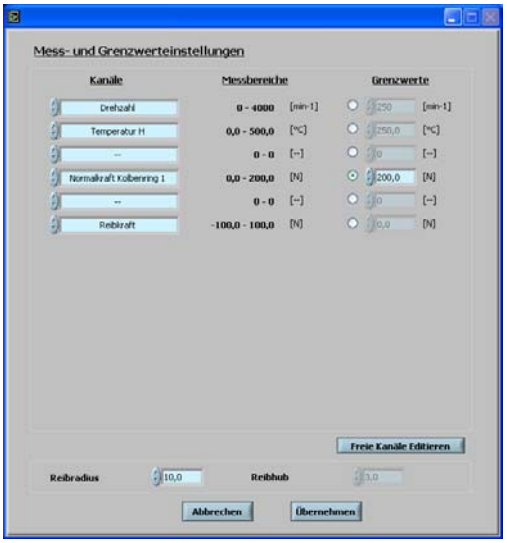
In sector **Prüfmodus** (testing mode) test programs can be created, saved or loaded. By means of the **Laden** (load) or **Speichern** (save) buttons respectively a dialogue is opened to load or save a program. The current is shown on the text area.

In sector **Messdatei** (measuring file) the file settings with protocol information and sample rate is displayed. The sample rate refers to the measured values wear (displacement), friction torque, friction force, and normal force. The measured value temperature is sampled max. at 2 Hz, rotational speed max. at 5 Hz.

Before a test program can be started the settings of all three sectors have to be enabled by pushing the button **Freigabe** (enable). The enable status is indicated by the green lights in the upper right corner of each sector. After any change of a setting the corresponding sector has to be enabled again.

4.3 Measuring settings and limits - Subwindow

In this window measuring settings and limits can be altered.



Here limits of the measuring channels, friction radius and the length of the stroke can be set. Since some measuring channels may be engaged several times by sensor switching there is a selection field to choose from the possible measuring values of that channel. For each measuring value a limit can be set that is saved. That way the limit doesn't need to be changed after a sensor switch. When opening the window the current configuration is displayed so that is not necessary to use the selection fields. The limits are entered as positive values. They apply to positive and negative direction. For example a limit of 500 applies to +500 and -500.

The friction radius at rotating movement and the stroke at linear movement are used to calculate the velocity of circulation and the glide path, entered in "mm". The program automatically recognizes by the module installed on the tribometer which value has to be used. After entering all values are saved and loaded when the software is started next time.

4.4 Program Selection Subwindow

In sector **Prüfmodus** (testing mode) test programs can be created, saved or loaded. Different operation modes can be chosen from. The standard modes provided by any tribometer are **Rotation** (rotation), **Rampen** (ramps) and **Oszillation** (oscillation). Other modes require the corresponding add-on modules. They cannot be chosen until the module has been connected. In the register field of each test mode the test prameters as well as the abort conditions for the program can be entered. Possible abort conditions are friction coefficient, test duration, number of revolutions, glide path, and wear (displacement).

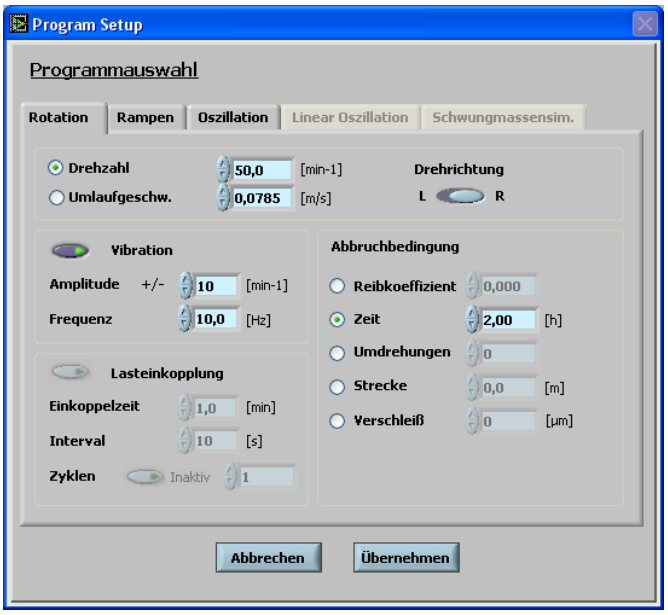
4.4.1 Mode Rotation

The test is conducted at the defined direction. Either velocity of circulation or rotational speed (rpm) can be set. The value of the indicated parameter can be entered. The other value is automatically calculated. The calculation satisfies the equation:

$$v = 2 * \pi * r * n / (60 * 1000)$$

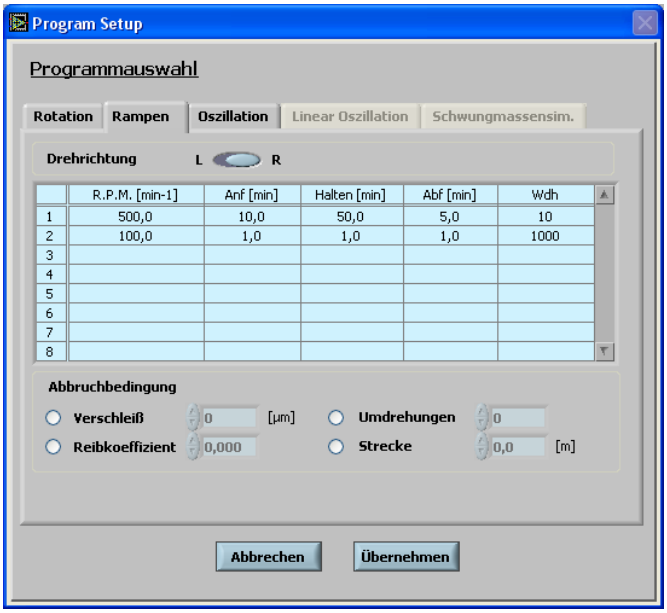
with v = velocity [m/s]
r = radius [mm]
n = rotational speed [min^{-1}]

The regular rotation can be superimposed with a vibration which is generated by a sinoidal fluctuation around the base value. The amplitude of the vibration is the max. deviation from the base value of the rotational speed. The overlayed frequency is a sinus frequency in “Hz”. For example the base value is 500 min^{-1} and the amplitude 50 min^{-1}, the rotational speed will deviate between 450 and 550 min^{-1}. Moreover abort conditions can be set.



4.4.2 Mode Ramps

In this program mode a set value of rotational speed increases within a defined period of time, is hold for a defined time and decrases within a defined period of time down to zero rpm. It is possible to enter 10 different ramps into the table. Each ramp can be repeatedly executed. The times of the ramps are entered in minutes and limited to 500 minutes. If a repeating value of 0 is entered, the ramp is executed only one time. For a value of 2 a total of 3 ramps is executed. An abort condition is not required since the test is automatically stopped after all ramps have been completed. Other abort condition (**Abruchbedingung**) can be set.



4.4.3 Mode Oscillation

The oscillation movement takes place at a defined rotational speed within a segment of circle specified by an angle. At the angle boundaries the direction of rotation reverses. Values for rotational speed or the velocity of circulation as well as the angle of rotation or the frequency have to be set. Once one value is entered the other corresponding value is automatically calculated. The rotational speed of this mode is limited to a max. value of 300 rpm or 5 Hz respectively. If the entered values exceed the limits of this test mode the highest possible value is automatically set. Moreover other test conditions can be set.

The calculation angle or frequency satisfies the following equation:

$$f = n / 60 * 360° / \varphi * 2$$

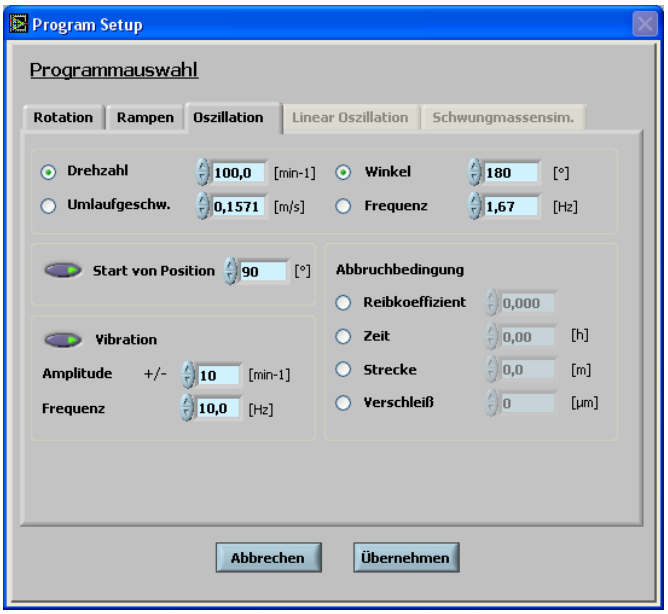
with f = frequency [s^{-1}]
n =rotational speed [min^{-1}]
φ = angle [°]

For the equation of how to calculate rotational speed and speed of circulation see **Mode Rotation**.

Oscillation applies to a defined position or to the current position. If a position is defined (0 - 360°), this position will be approached at low speed before oscillations actually starts. When an oscillation being executed is aborted by the software the segment of circle will be not left.

Oscillation can be overlayed by vibration which is generated by a sinoidal fluctuation around the base value.

The amplitude of the vibration is the max. deviation from the base value of the rotational speed. The overlayed frequency is a sinus frequency in “Hz”. For example the base value is 100 min^{-1} and the amplitude 20 min^{-1}, the rotational speed will deviate between 80 and 120 min^{-1}.

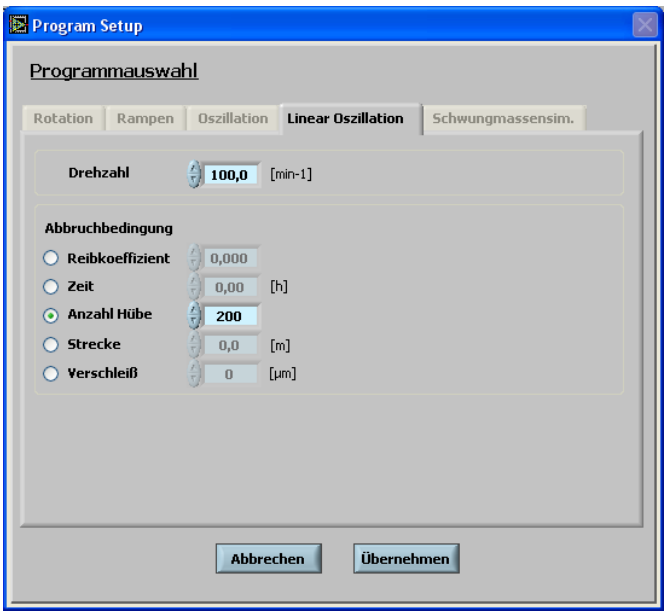


4.4.4 Mode Linear Oscillation

In this mode a rotating movement is transformed into a translational movement on a linear way by means of the Linear Oscillation Module. On this mode only the rotational speed can be set. The max. value of the rotational speed is 300 rpm, corresponding to 5 Hz. The distance, not depending from the rotating angular, satisfies the following equation. The calculated distance is the mean value of the rotating movement.

$s = n * 2 * H * t/ (60 * 1000)$

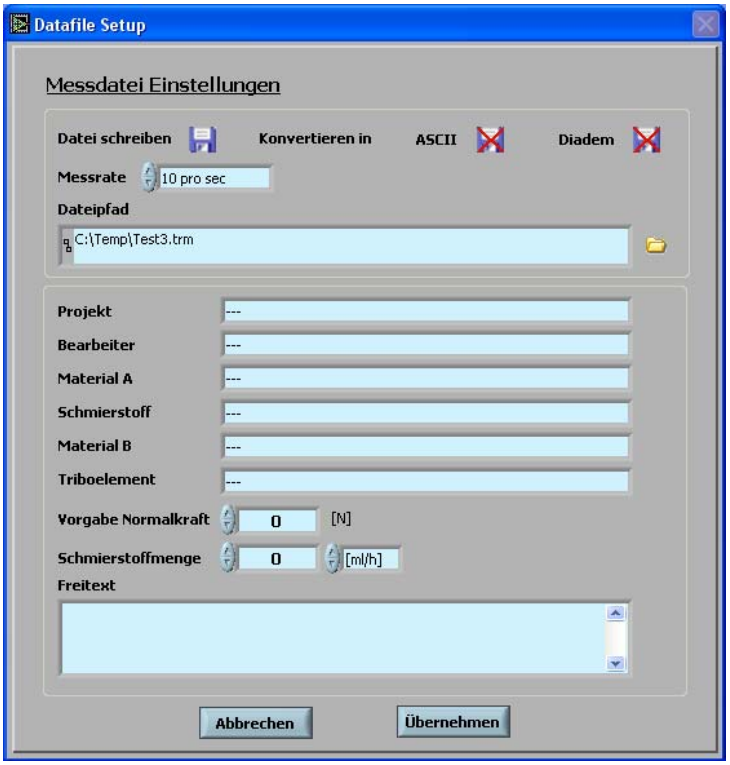
with s = displacement[m]
n = rotational speed [min^{-1}]
t = time [s]
H = stroke [mm]



To assemble and disassemble the Linear Oscillation Module you can travel to a defined position. After pushing the button “Anfahren (travel)” the position is automatically traveled to.

4.5 Data file Setup Window

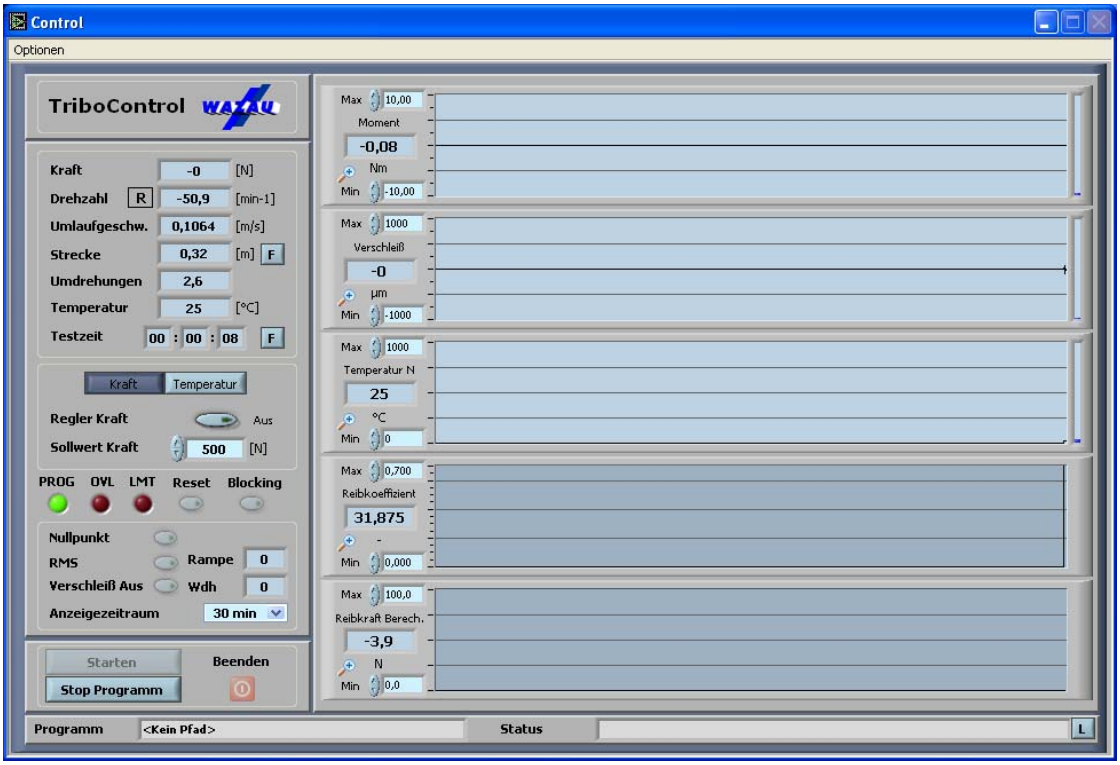
In order to generate a measuring file and a protocol file a path has to be named and the disk symbol enabled (it is enabled if no cross appears). The measuring values are binary saved in a *.trm file (tribometer measured values). They can be viewed using the Analysis tool. It can be defined if the measured values should be subsequently converted into different formats by enabling the disk symbol. Possible formats are ASCII and Diadem. During converting into ASCII format the measured values are written into a textfile with tabulator separation. Diadem of National Instruments is professional software to analyse data and generate reports. Converting can also be done subsequently using the Analysis Tool.
In the protocol file testing data such as project, operator, materials, lubricants, normal force and tests specimen as well as a header can be entered. These data is saved together with the test program as ASCII text into a *trl file (tribometer logfile). This kind of file can be opened by any program able to read *.txt files.



The sample frequency can be chosen from 100 samples per second (100 Hz) and one sample per 100 seconds (0.01 Hz). Please consider that a high sample rate will lead to a very big measured value file for long-time tests. For memory reasons a file that big may not be opened by the Analysis Tool. The maximum data size depends on the system and on the number of recorded measuring channels.

4.6 Control Window

On this window test programs can be started and measured and calculated data be viewed. Moreover with the heater installed temperature and normal force can be set.



If all entries on the setup window are enabled and the wear (displacement) sensor is within its working range, a test program can started by pushing the “Starten (start)” button. During program execution measured values and calculated values are displayed on the numerical fields and the plots. If no program is enabled data is only displayed on the numerical fields. The refreshing rate is 1 Hz. The period of time of the measurement on the plots can be changed using the option field. The minimum is 10 minutes, the maximum is 12 hours. To change the y-axis, upper limits and lower limits can be entered on the fields „max“ and „min“.

4.6.1 Plot Columns

The measured values shown on the plot columns can be chosen from the submenu “Einstellungen (preferences)” on the test menu. The assignment is based on the measuring channels that can be shared. If the set size is not possible due to the system configuration, the plot columns is dimmed displayed. The bar at the end of the plot columns shows the ratio of the current value to the measuring range. The plots can be displayed in a bigger size using the magnifier symbol.

The values friction coefficient and friction force at rotating movement are calculated values satisfying the following equation:

Friction coefficient at rotating movement:

$\mu = M * 1000 / F_N * r$

with μ = friction coefficient [-]
M = friction torque [Nm]
F_N = normal force [N]
r = radius [mm]

Friction coefficient at linear movement:

$\mu = F_R/F_N$

with μ = friction coefficient [-]
F_N = normal force [N]
F_R = friction force [N]

Friction force at rotating movement:

$F_R = M *1000 / r$

with F_R = friction force [N]
M = friction torque [Nm]
r = radius [mm]

4.6.2 Numerical Display

The numerical fields in the left area show calculated and measured values. Normal force and rotating speed are measured. Velocity of circulation, glide way and revolutions at constant rotary movement or oscillation of the Linear Oscillation Module are calculated values. The direction of rotation is displayed in the rectangular box next to the rotational speed. “R” means right, “L” means left.
If the values of time and glide way shall not start at zero but continue at the last value, the button “F” next to the numerical display has to be enabled. That way the total of time and glide way for a specimen can be saved if a test is interrupted or different test programs are executed.

4.6.3 Further Buttons and Displays

There are three LEDs for Overload (OVL), Limit (LMT) and program execution (PROG).
If an overload occurs the button “Reset” has to be enabled to enable the drive. The button „Blocking“ blocks the drive to change the specimens.
With the button „Nullpunkt (zero point)” the offset adjustment for normal force and torque is executed.
The button „RMS“ enables the root mean square (RMS) rectifier. To run a test without wear (displacement) measurement the button „Wear Off“ has to be enabled.
These buttons can only be enabled if no program is running.
If a program is running the current ramp, the repeating number, the currently running test program, and status messages are displayed at the lower edge of the window. The status line can be deleted with the button „L“.

4.6.4 Controller Temperature

If a heater is installed it can be turnt on and desired values set by means of the corresponding button. The software automatically recognizes which temperature module is connected (high temperature or standard) indicated by the rectangular box. “N” indicates the normal heater “H” indicates the high temperature heater. In this field desired values for temperature controlling can be entered. The heater is enabled according to the set desired temperature by enabling the tracer “EIN (on)”.

4.6.5 Controller Force

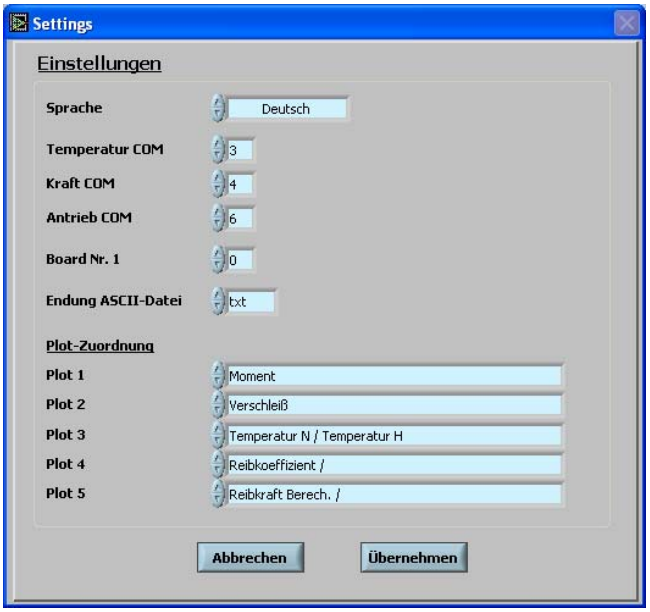
By means of this field the desired value for force can be entered. The normal force controller is enabled according to the set desired force by enabling the tracer “EIN (on)”. This is done after or shortly before the specimens are pressed against each other by means of the lift controller. The max. control speed is ten times smaller than the max. speed of the lift unit.

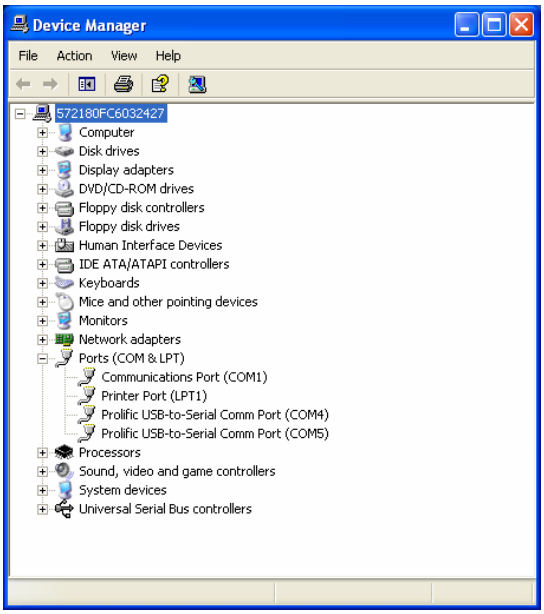
4.6.6 Menu Options

The menu point „Optionen (options)” of the runtime menu allows the user to enter settings, save surface settings, travel to defined positions and open the Analysis Tool.

4.6.6.1 Settings

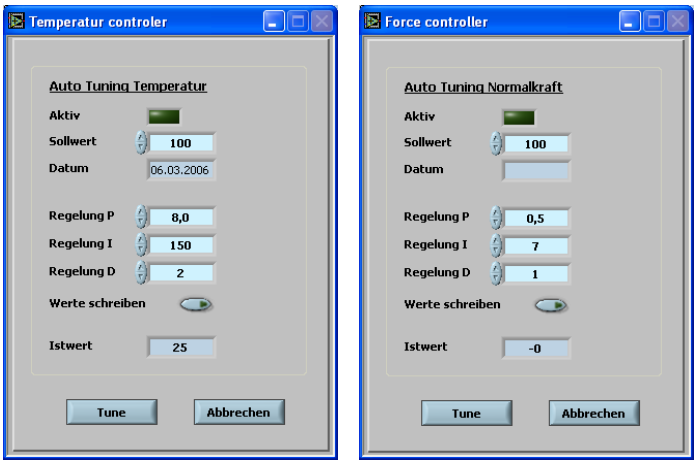
By means of this menu point language, COM connections and plots can be chosen or assigned respectively. Once the COM device is connected to the computer the assignment of the COM connection is displayed on the device manager. The settings for language and COM connections are not enabled until a re-start of the computer. It can be chosen between English and German. To trigger the temperature controller and the drive the connections have to be assigned to the corresponding COM ports. It can be specified which suffix the ASCII file should have, *.txt or *.asc. The plot assigment is executed immediately. The type of measured values are separated by the symbol „/“.





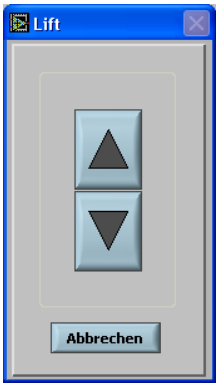
4.6.6.2 Autotuning Temperature / Normal Force

By means of this menu point autotuning for the temperature and force controller can be conducted. To do that a sub window has to be opened which shows the current PID parameters of the controller and the date of the last tuning. To start the autotuning mode a desired value has to be set, that was reached before through a regular desired value setting and controlling, around which the temperature fluctuates. From the response behavior of the temperature another PID parameters are determined and saved. If different heaters are available each heater has to be tune individually. Using the tracer “Werte schreiben (enter values)” allows the user to enter manually PID parameters. Autotuning for normal force should not be done until the user has contacted a Wazau specialist. The parameters for normal force and temperature control are set ex works, providing an optimized setting for most applications.



4.6.6.3 Lift Operation

By means of this menu point the drive block can be moved. The downward movement is controlled by the force sensor and stopped if both specimens touch each other. The upward movement is controlled by a limit switch. The upward or downward movement is controlled by the arrow buttons. Pushing the button enables this mode until it is released again. Pushing the down button executes the offset adjustment before the block starts moving downwards. Therefore the movement of the block is time-displaced to the activation of the button.

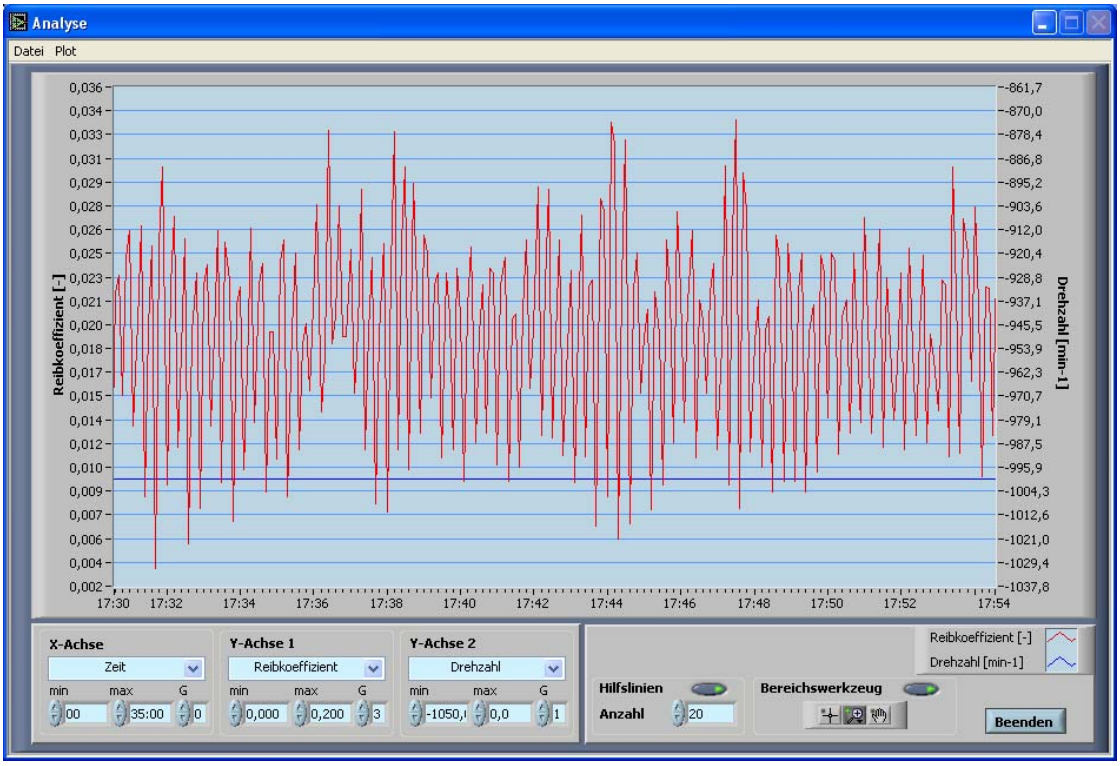


IMORTANT! The spindle must never be removed from the ball circulation unit. The unit is prestressed and must not be taken apart. Disassembling the block is not allowed!

4.7 Analysis Window

By means of this tool the saved binary data is visualized and converted into other formats. To open a *.trm file choose “Datei öffnen (open file)” from the runtime menu. Then x-axis and y-axis have to be assigned. It is possible to display two y-axis over the time or the glide way.

The axis sections can be specified by the min/max fields if the option “Bereichswerkzeug (section tool)” is disabled. In field “G” the number of decimal digits can be entered. Using the “Bereichswerkzeug (section tool)” several functions to display the plots (pictogram croos, hand, magnifier) can be chosen from. The option “Hilfslinien (auxiliary lines)” generates the stated number of horizontal lines.



The Runtime Menu

By means of the menu point „Date (file)” the binary data can be converted by the „Konvertieren (convert)” sub menus to the corresponding data formats (ASCII, Diadem).

All files are generated with the same name in the same directory.

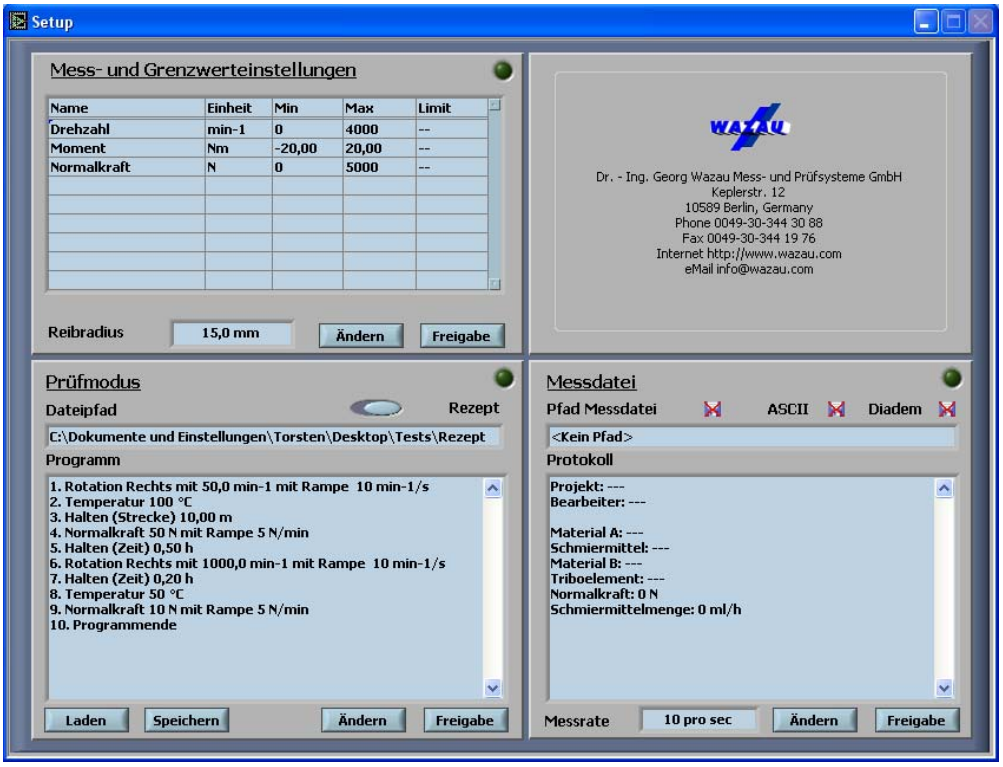
Using the menu point “Plot” saves the displayed data as graphic data in Bitmap (BMP) or Portable Network Grafic (PNG).

The displayed data can be printed by means of menu point „Drucken (print)”.

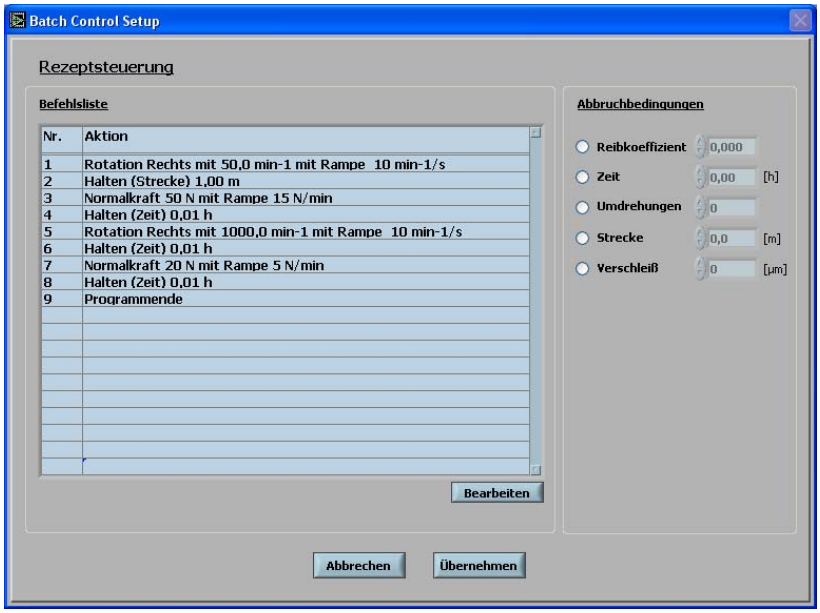
4.8 Recipe Controller

As alternative to the control program the controlling can be executed in recipe steps. Operating parameters can be entered in a list that is executed sequently. A step is considered executed if the desired operating parameter has been reached, e.g. rotating speed, normal force or temperature has reached the desired value or the entered holding times or gliding ways.

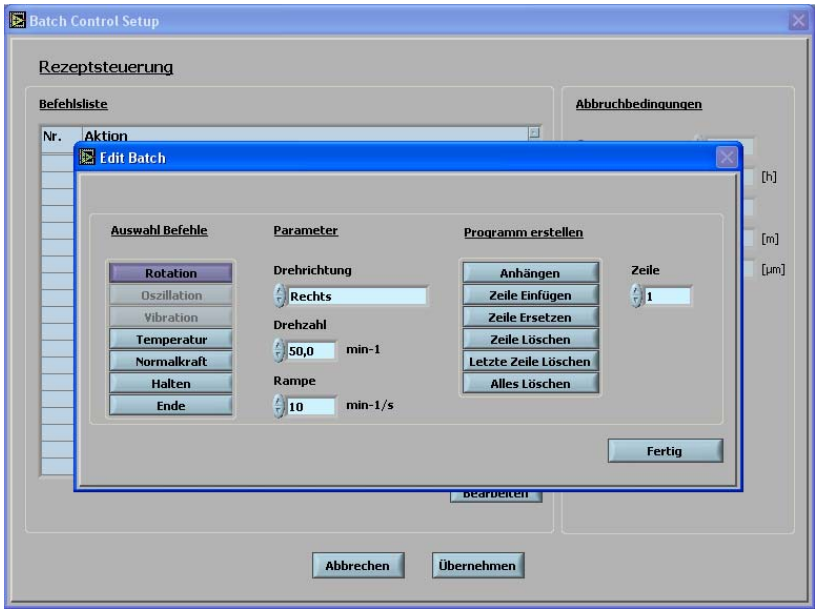
To enable the recipe controller the button on the section “Prüfmodus (test mode)” on the setup window has to be set to “Rezept (recipe)”. There the programmed recipe steps are displayed.



Recipe programs can be loaded and saved. If a saved program is to be loaded the tribometer configuration has to support the determined recipe steps. To change a recipe program enable the button “Ändern (change)”. A sub window will open in which the program can be edited and abort conditions be set.



By means of the button „Bearbeiten (edit)” in a sub window recipe steps can be altered, added or deleted. The button “Übernehmen (accept)” accepts an altered program. “Abbrechen (abort)” will reject the changes. Other abort conditions can be set to end the recipe program safely.



On the left side the edit window shows a selection of possible recipe Steps. Thereby the current tribometer configuration is considered so that only functions that can be executed are enabled. On the right side the corresponding configuration parameters are displayed. With the option field on the right a recipe step can be added to the program. To do this use the numerical field “Zeile (line)”.

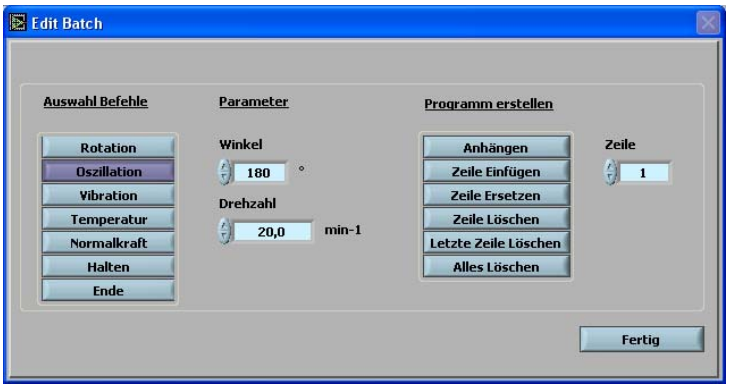
The different recipe steps are explained hereafter.

Rotation

Setting direction of rotation, rotational speed, and rotational speed ramp. On changing the direction of movement of the drive the rotational speed ramp goes down to zero. Then it speeds on the other direction at the set rotational speed ramp.

Oscillation

In the oscillation mode the rotational speed and an oscillation angle is set. If the set values exceed the allowed frequency the settings are automatically adapted.



Vibration

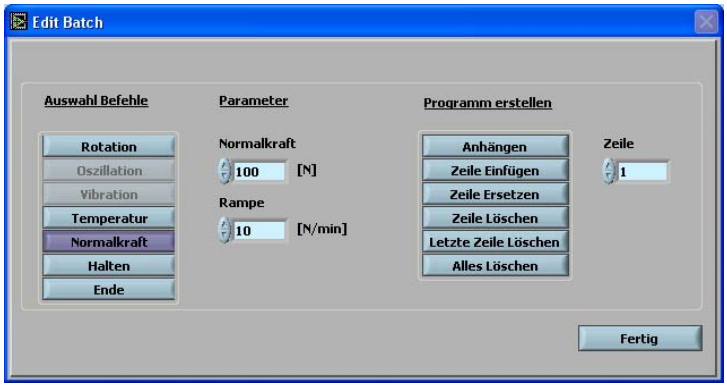
The vibration is generated by an overlayed sinoidal rotational speed fluctuation. If an amplitude bigger than zero is set vibration is enabled. If zero is entered vibration is disabled.

Temperature

Temperature Steps are considered finished if the current temperature differs from the desired temperature by no more than 1°C.

Normal force

On the normal force control system the change of the force can be entered with a ramp. The step is finished if the normal force differs from the desired value by 1 N. If “0” is entered in the field “Rampe (ramp)” the desired force value is directly activated by the control system.



Hold

This recipe step inserts a holding time in between two steps. That can be done by entering a value for time or gliding way. Time can be entered in minutes or hours.

End

This command ends the recipe program. That means saving the measured values is finished, normal force and rotational speed have a value of zero, the heater is turnt off. If the “Ende (end)” step is not added the tribometer remains in the last set state (rotational speed, temperature, normal force) with ongoing recording of the measured values.

5. Starting a Test

5.1 Turning on and off

Turning on:

1. Turn on the computer and load Windows XP completely.
2. Turn on the main power switch on the control rack and start the software TriboControl after 5 seconds.
3. Control rack, test rig and computer should warm up before the first test for at least 20 minutes to make sure all electrical components reach a uniform temperature.
4. Mount your specimens and make all necessary settings on the software.

Turning off:

1. Quit the test and controller enablings for heater and normal force.
2. Quit the software and turn off the main power switch on the control rack after 5 seconds.
3. Quit Windows and shut down the computer.

5.2 Installing specimens / Offset adjustment

1. Installing the specimens

1.1 Mount the specimens to the suitable jig/adapter such as specimen pot or specimen support.

1.2 Mount the specimens to the specimen holder of the air-bearing spindle outside of the test rig. Mounting the specimen to the air-bearing spindle is only allowed if the compressed air is applied. This is indicated by the green shining of the LED Air. For lubricated tests pour the lubricant into the specimen pot.

2. Adjusting the offset for force and torque (friction force)

2.1 See description of the Module Force.

3. Adjusting the normal force

3.1 Set the normal force by means of the desired value entry and enable the controller on the software.

4. Adjusting the offset for wear (linear wear amount/displacement)

4.1 See description “Setting up the Wear Measuring System”.

5. Start of the Test

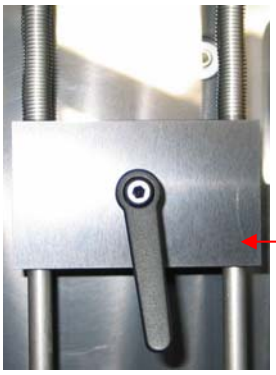
Enter the desired test conditions in the software and enable then „Start“ on the software to start the test.

6. Setting up the Wear Measuring System

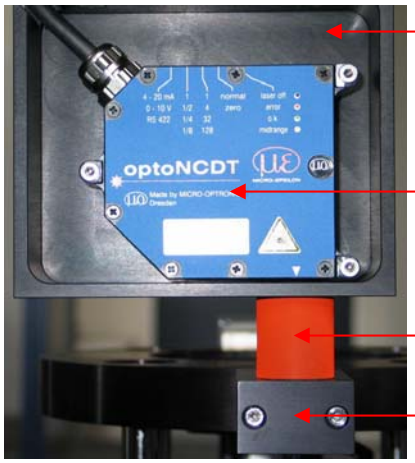
To adjust the wear measuring system the normal force has to be applied on the specimens so that they are pressed against each other. Let the control system adjust the normal force completely. That means the desired value is equal the actual value. Place the red bar spacer on the edge of the linear table which is also the measuring reference point of the wear (displacement) measuring system (picture 1). Bring the wear measuring unit carefully down to the red bar spacer by loosening the clamping lever (picture 2, 3). Then fix the clamping lever again. Remove the red bar spacer from between the wear measuring system and the edge of the linear table (picture 4). Turn on the wear measuring system by disabling the button “Wear Off”. Now the laser diode is enabled. Enter the parameters on the window “setup” of TriboControl and enable all three LEDs with the button “Freigabe (enable)”. Now change to the window “Control” of the software. If the button “Start” is enabled in the software the measuring range of the laser-optical sensor is in the middle position of the total measuring range (picture 5).

The state of the middle position of the measuring range is also indicated through the yellow shining LED “State” (picture 6).The offset adjustment occurs automatically after the button “Start” was enabled before the drive was started. If the wear measurement is turnt off by the button “Wear Off” the adjustment is obsolete. A program can be executed in the software any time. Hence setting up the wear measuring system is not necessary and wear cannot be measured.

Picture 1



Picture 2



Picture 3

Picture 4

Picture 5

LED State - Functions

off	Laser diode OFF
red	Error or displacement sensor out of measuring range
green	No error or displacement sensor within measuring range
yellow	No error or displacement sensor within middle position of the measuring range

Picture 6

LED State
Functions

IMPORTANT! After each test, before moving the drive block upwards, move the unit back to its initial position (picture 6). That means that the unit is considerably moved off the measuring position. That way the space for mounting specimen holders and assemblies is increased. Make sure the normal force **DOES NOT** apply by means of the unit on the displacement sensor before the specimens touch each other when the lift moves the drive block downwards.

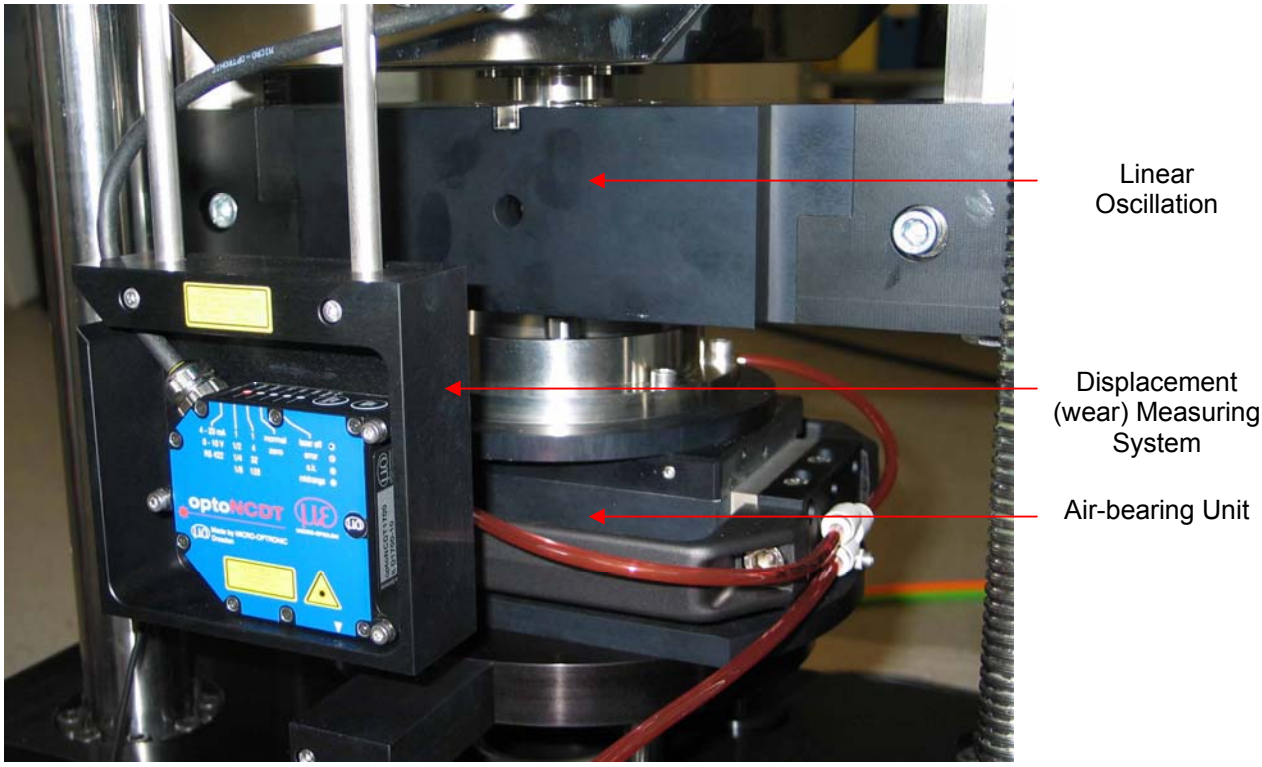
IMPORTANT! Loosen carefully the clamping lever so far as it can be shifted.
Never loosen the clamping lever so far as the measuring system drops out damaging the laser-optical displacement sensor.

Initialposition
Wear Measuring
System

Picture 7

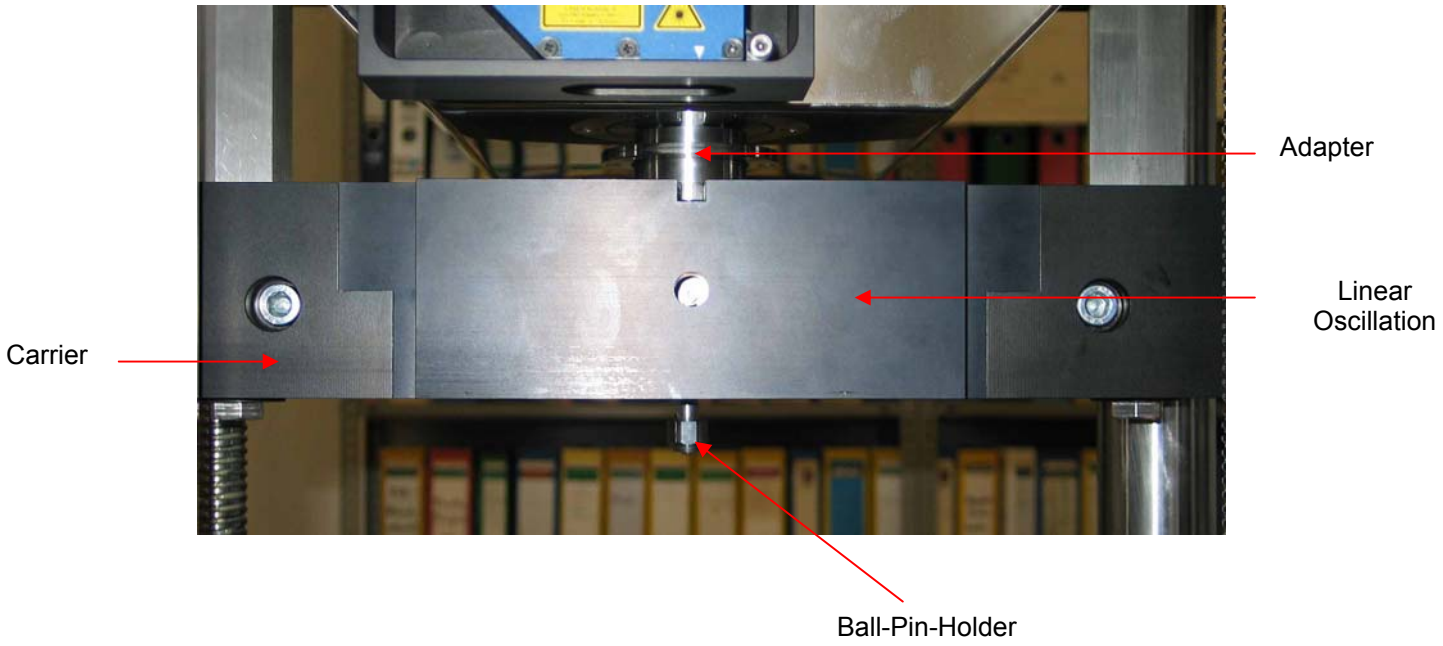
7. Linear Oscillation (option)

The linear oscillation contains two modules used in combination. There is the module air-bearing unit to measure friction force and the module linear oscillation to transform the rotary movement into a linear movement. Setting up the test parameters such as normal force and rotational speed as well as setting up the wear measurement is done analog to the other modules as specimen pot and specimen support.



7.1 Linear Oscillation

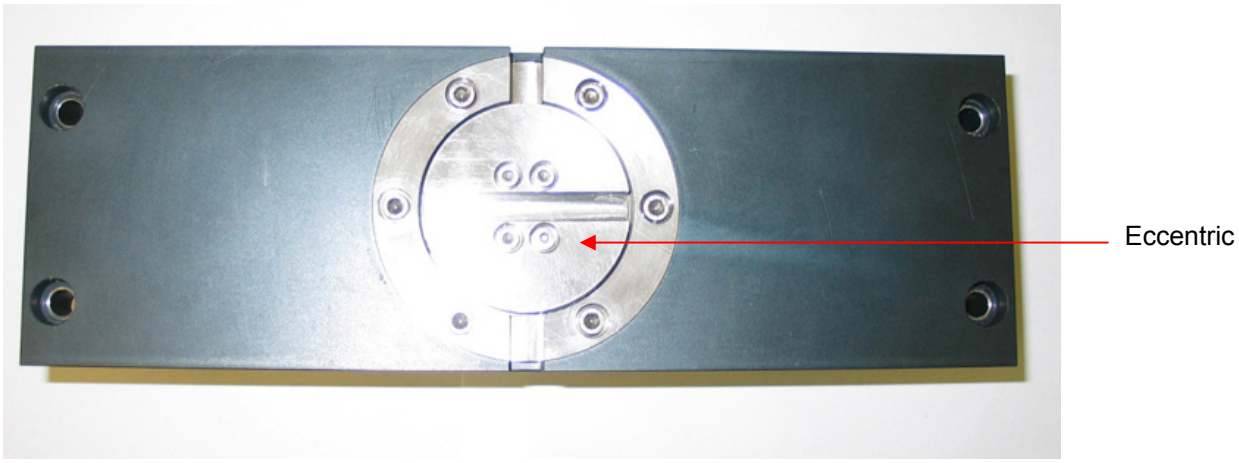
The module is composed of an adjustable eccentric which transforms the rotary movement into a linear movement, moving the ball-pin carrier (option) in a linear (translational) way. The max. amplitude of the Linear Oscillation is ± 10 mm



IMPORTANT! The max. rotational speed is 300 rpm (5 Hz). The max. normal force for the Linear Oscillation is 200 N. The max. amplitude is ± 10 mm.

7.1.1 Adjusting the Amplitude

1. Turn the eccentric until the adjustment screw inside the eccentric opening becomes visible (picture 1, 2).
2. The adjustmen screw can be adjusted using a socket wrench.
3. If the amplitude adjusted before is not known turn the socket screw all the way to the right.
4. Then the amplidude is 0 mm. Turning the screw to 360° equals an amplitude of ± 0.5 mm.
5. The maximum range of ± 10 mm is reached after having turnt the socket screw 20 times to 360°.

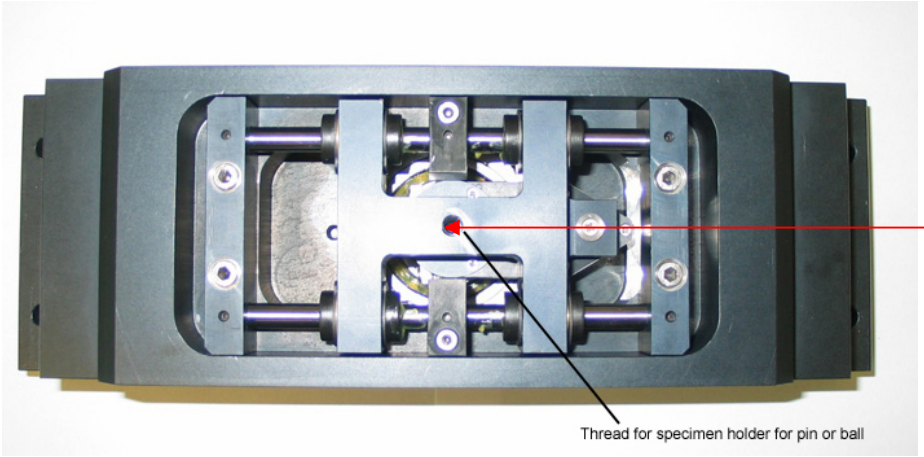


Picture 1

Picture 2

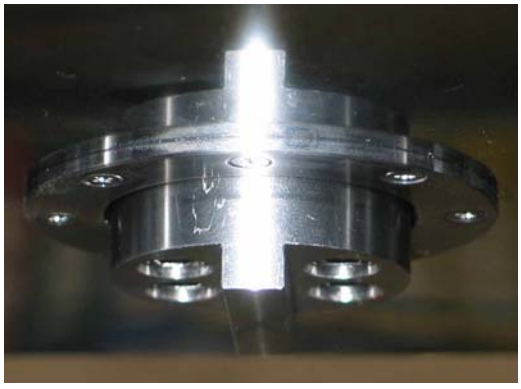
7.1.2 Assembly of the Linear Oscillation

1. Mount the ball-pin carrier to the linear oscillation. Fix a ball or a pin to the carrier (picture 3). The scope of delivery provides a 10 mm ball holder.
2. On the software menu „Optionen (options)" go to „Position anfahren (travel to position)". Press the button "Anfahren (travel)" and close the window (picture 4). The drive moves now the the air-bearing spindle to a defined position in order to assemble or disassemble the linerar oscillation.
3. Without changing the position of the air-bearing spindle, mount the adapter so that it is assembled as shown on picture 5. To simplify the the assembling of the adapter you may press the button „Blocking" on the software to keep the air-bearing spindle in position.
4. By turning adjust the eccentric of the linear oscillation so that the groove of housing and eccentric is in one line (in picture 6 the groove doesn't match!).
5. Place carefully the linear oscillaton on the corresponding support of the tribometer (picture 7). Fix the linear oscillation by the four corresponding fixing screws on the support of the tribometer.

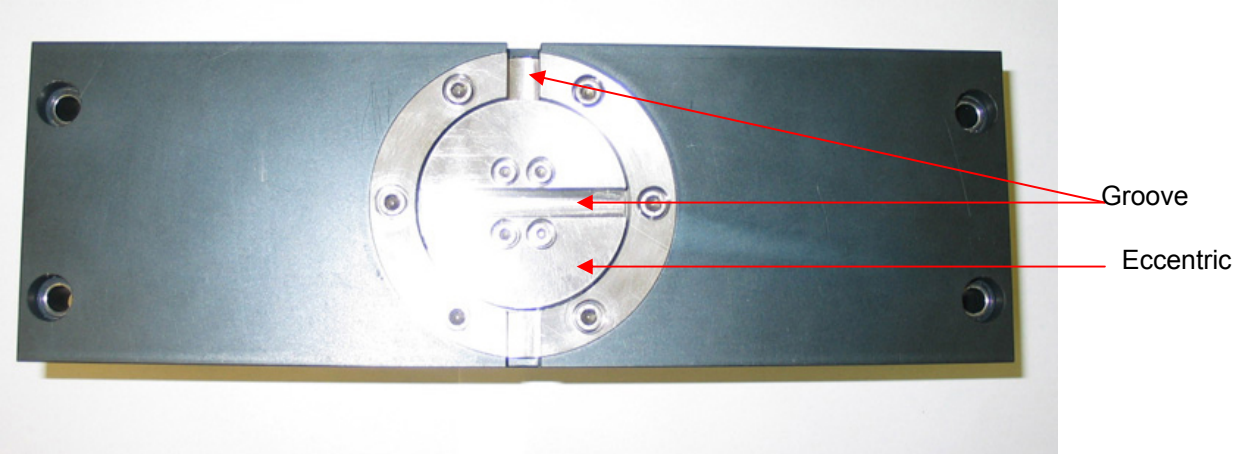


Picture 3

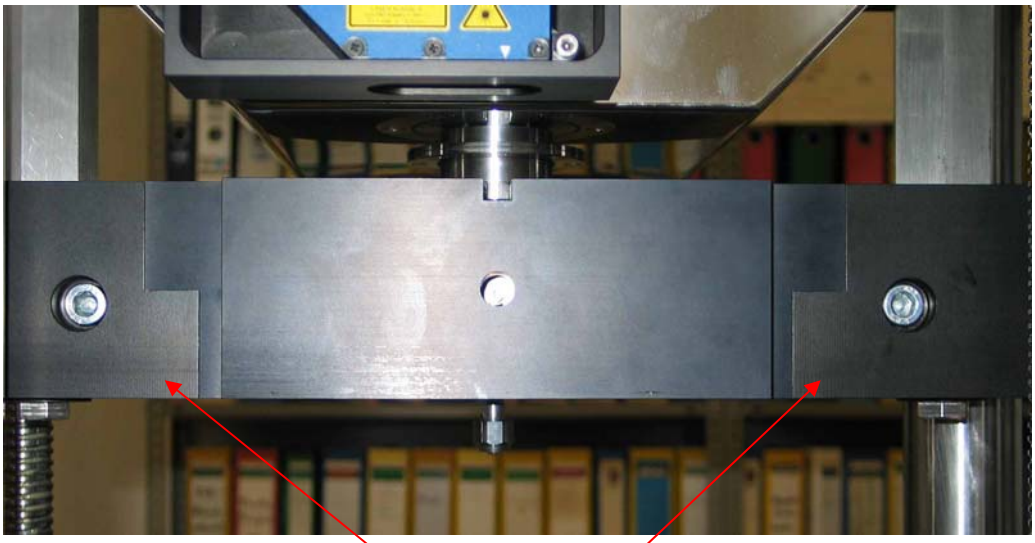
Picture 4



Picture 5



Picture 6



Picture 7

7.1.3 Disassembly of the Linear Oscillation

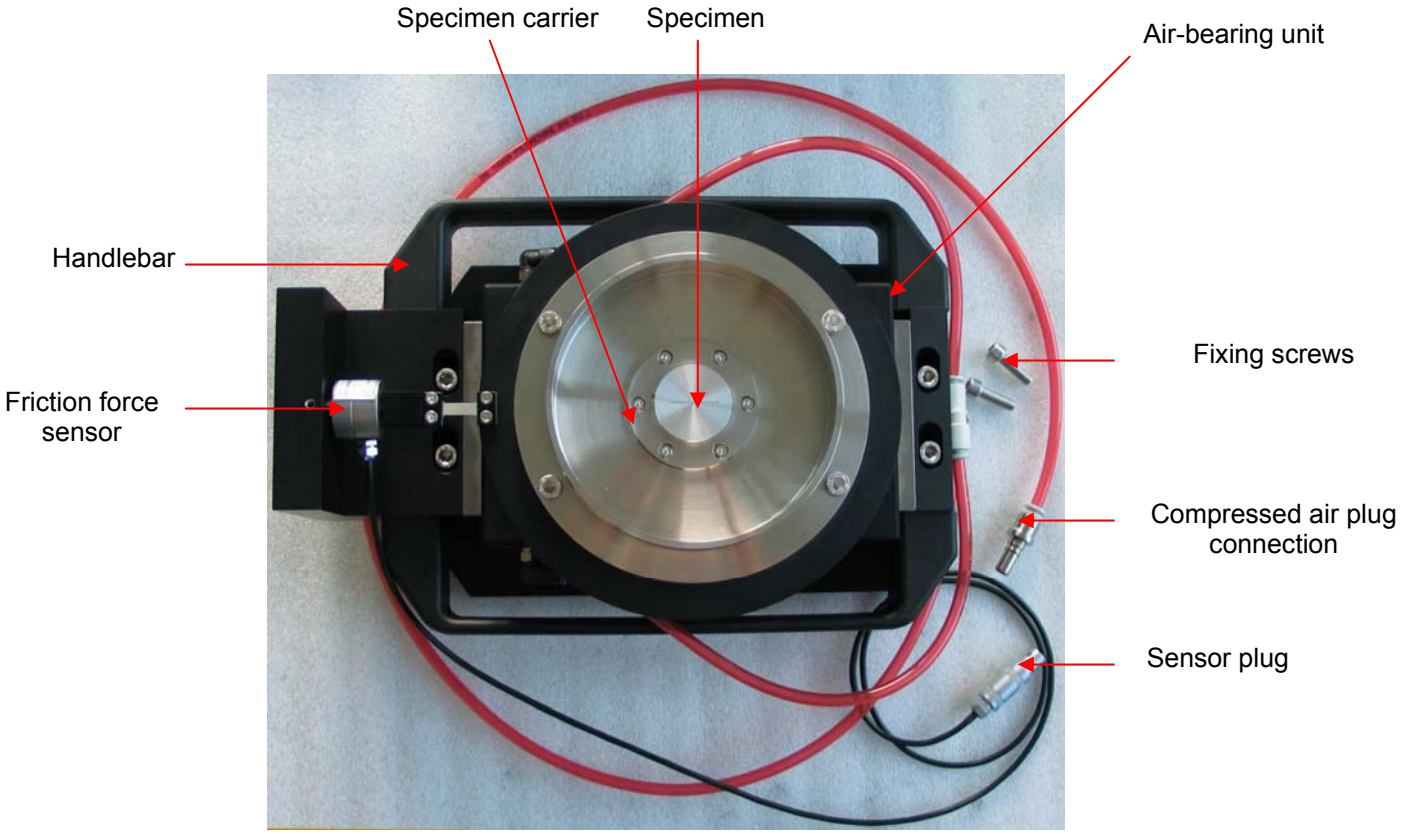
6. On the software menu „Optionen (options)" go to „Position anfahren (travel to position)". Press the button "Anfahren (go to)" and close the window (picture 4). The drive moves now the the air-bearing spindle to a defined position in order to assemble or disassemble the linerar oscillation.
7. Loose the four fixing screws on the support of the tribometer.
8. Take carefully the linear oscillation from the support of the tribometer (picture 7).
9. Disassemble the adapter from the air-bearing spindle (picture 5). To simplify the the assembling of the adapter you may press the button „Blocking" on the software to keep the air-bearing spindle in position.

7.2 Air-bearing Unit

The air-bearing unit is composed of a linear air-bearing supporting the specimen carrier, and a friction force sensor. By means of a leaf spring the linear air-bearing is connected to the friction force sensor.

Only use the air-bearing unit for tests if sensor plug and compressed air plug connection are connected to the test rig and the compressed air conditioning is complete.

Only use the air-bearing unit together with the normal force sensor with the measuring range ≥ 1000 N. The max. allowed normal force applied on the air-bearing unit is 200 N. The friction sensor provides a measuring range of ± 100 N.

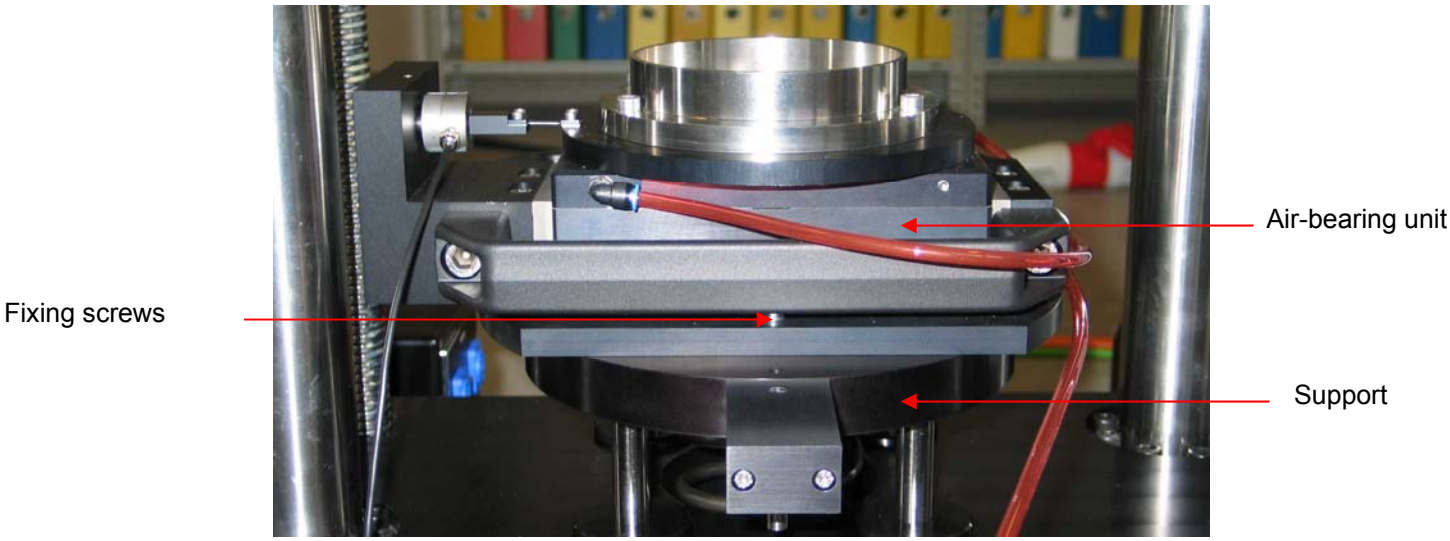


7.2.1 Assembly Air-bearing Unit

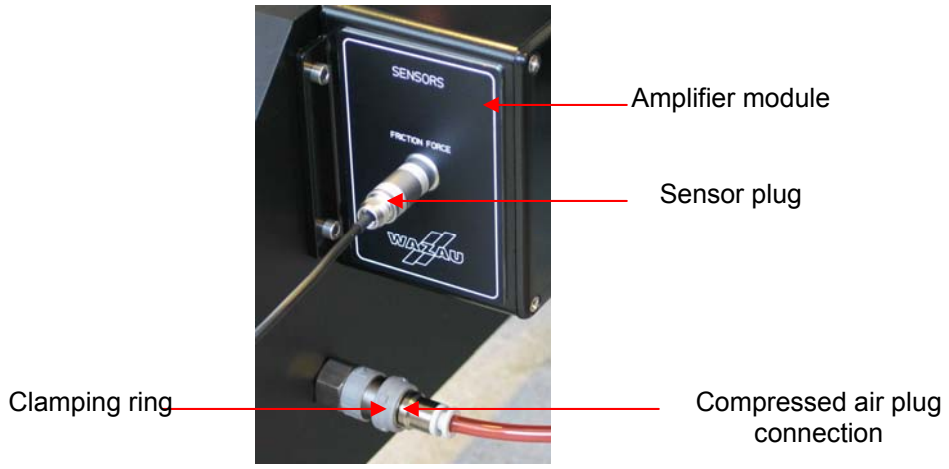
10. Mount carefully the air-bearing unit on the support of the tribometer (picture 8). In doing so move the air-bearing unit carefully by means of the handlebars.
11. Tighten the air-bearing unit to the linear table (support) of the tribometer by means of the fixing screws.
12. Connect the sensor plug to the friction force socket on the amplifier module as well as the compressed air plug connection to the socket next to the amplifier module (picture 9). The compressed air plug connection can be loosened by moving the clamping ring backwards. This can be done under pressure or pressureless.
13. Assemble or disassemble the specimen to the specimen carrier on the specimen support of the air-bearing unit.

IMPORTANT! The max. normal force of the air-bearing unit is 200 N.

IMPORTAN! Assembly or disassembly of the specimen on the specimen carrier **must not be done** as long as there is no compressed air applied on the air-bearing spindle. The air pressure is applied if the LED “Air” is shining green and the air-bearing unit is connected to the tribometer by means of the compressed air plug connection.



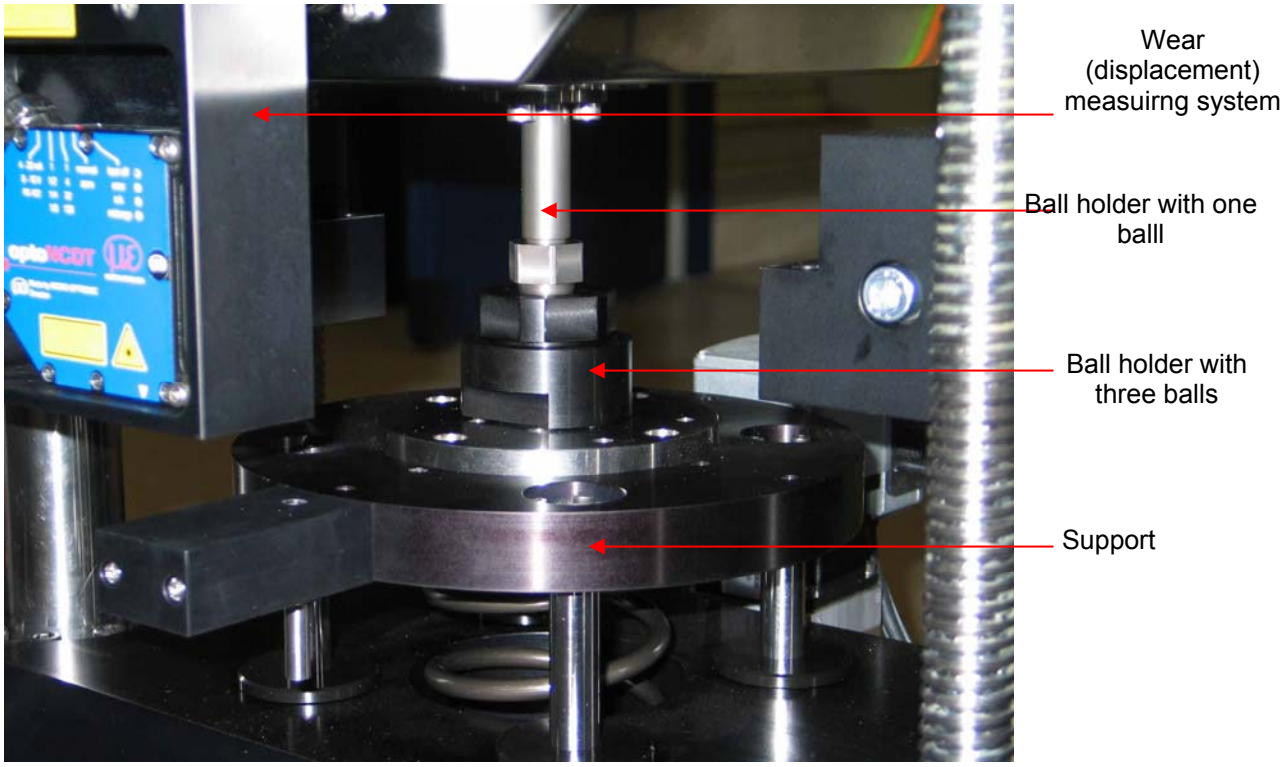
Picture 8



Picture 9

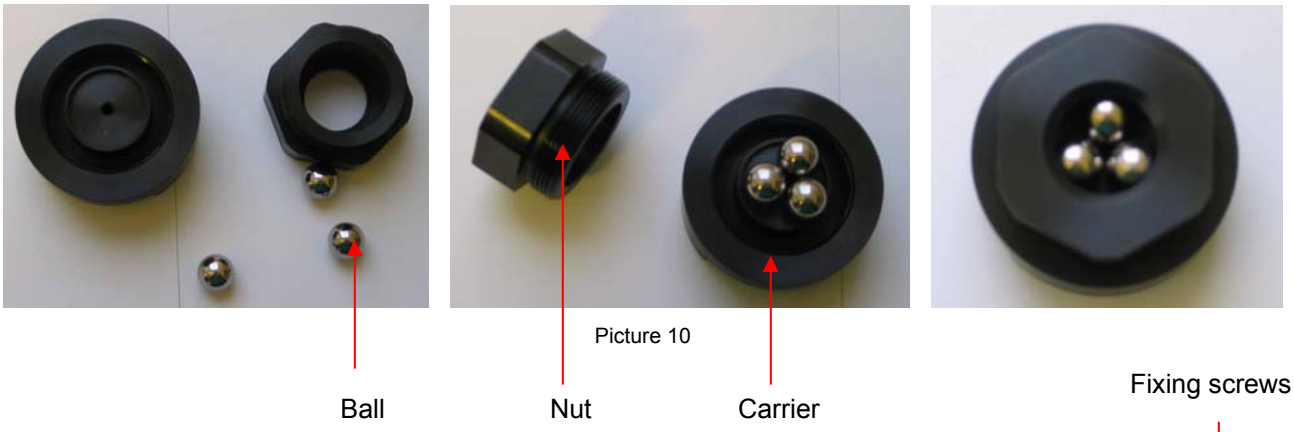
8. Four-Ball Apparatus (option)

By means of the four-ball apparatus friction mechanisms on loaded balls until welding can be investigated. The diameter of the four balls is 12.7 mm each. The applied load may range to the max. measuring range of the tribometer. The mode of motion on this module is rotation. The setup of the test parametes such as normal force, rotational speed as well as the setup of wear (displacement) measuring is conducted analog to the other modules as specimen pot and specimen plate. In order to avoid impact areas on the balls don't use the Lift function to bring the balls completely together, but use the Lift function to approach the balls and stop it before they touch each other. Align the ball carrier, set the desired normal force on the software, and turn on the normal force controller (see chapter 4.5.6). That way the balls are slowly pressed on each other.

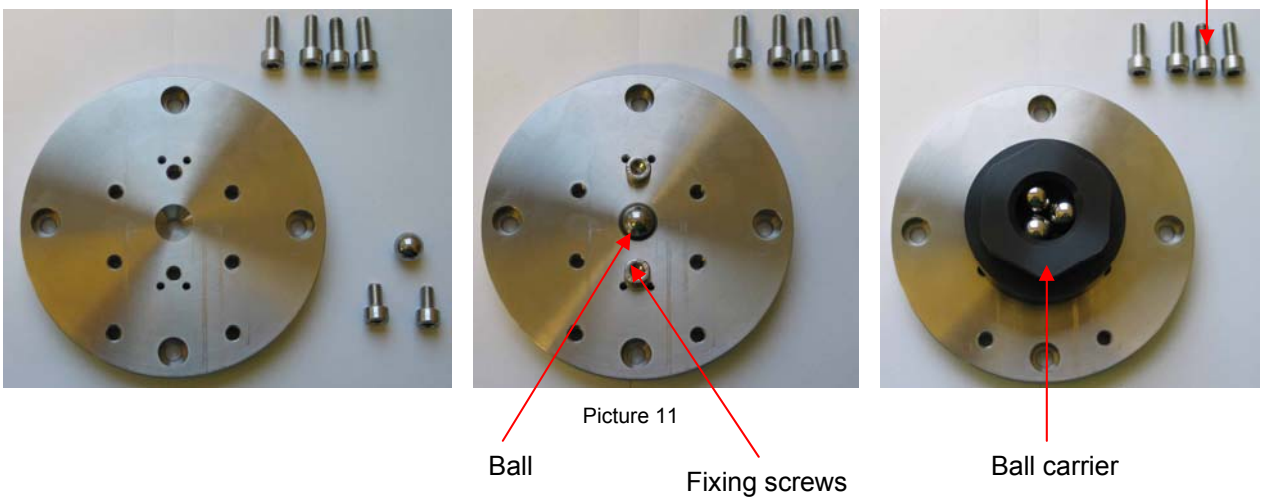


8.1 Mounting Ball Carrier

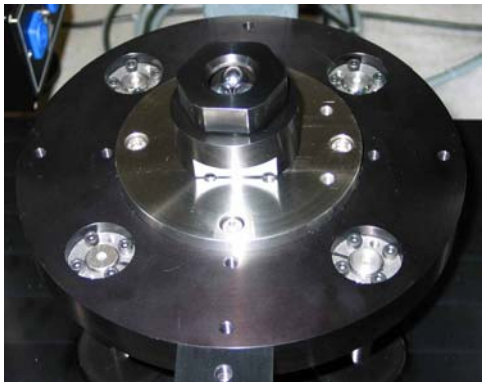
Place the three balls into the carrier and tighten the unit by means of the nut. Assemble carefully the nut with the unit using both open-end wrenches (picture 10). To make sure that all four balls are in permanent contact in a horizontal position, a ball is mounted under the ball support. To do that first mount the fixing screws on the support and place the ball in the middle of the counterbore. Then place the assembled ball carrier on the support (picture 11). Tighten the specimen plate on the support by means of the fixing screws (picture 12).



Picture 10



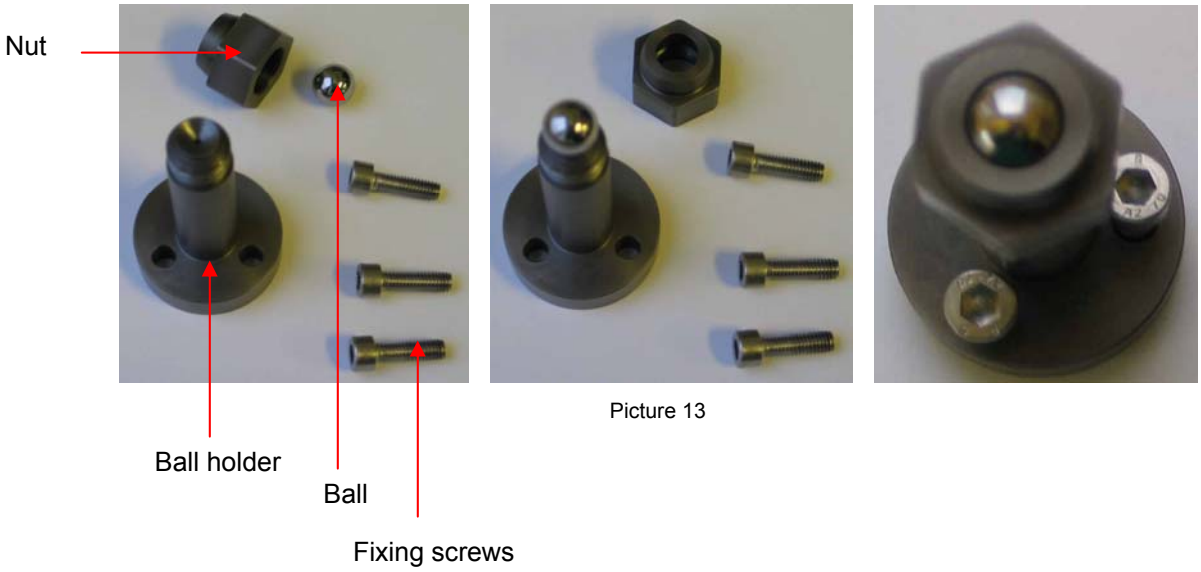
Picture 11



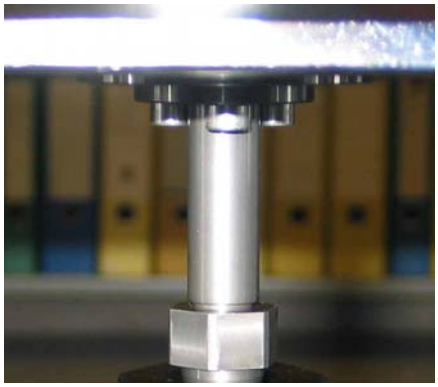
Picture 12

8.2 Assembly Ball Holder

Place the ball into the carrier and tighten the unit by means of the nut. Assemble carefully the nut with the ball holder using the open-end wrench (picture 13). Mount the ball holder to the air-bearing spindle of the tribometer (picture 14).

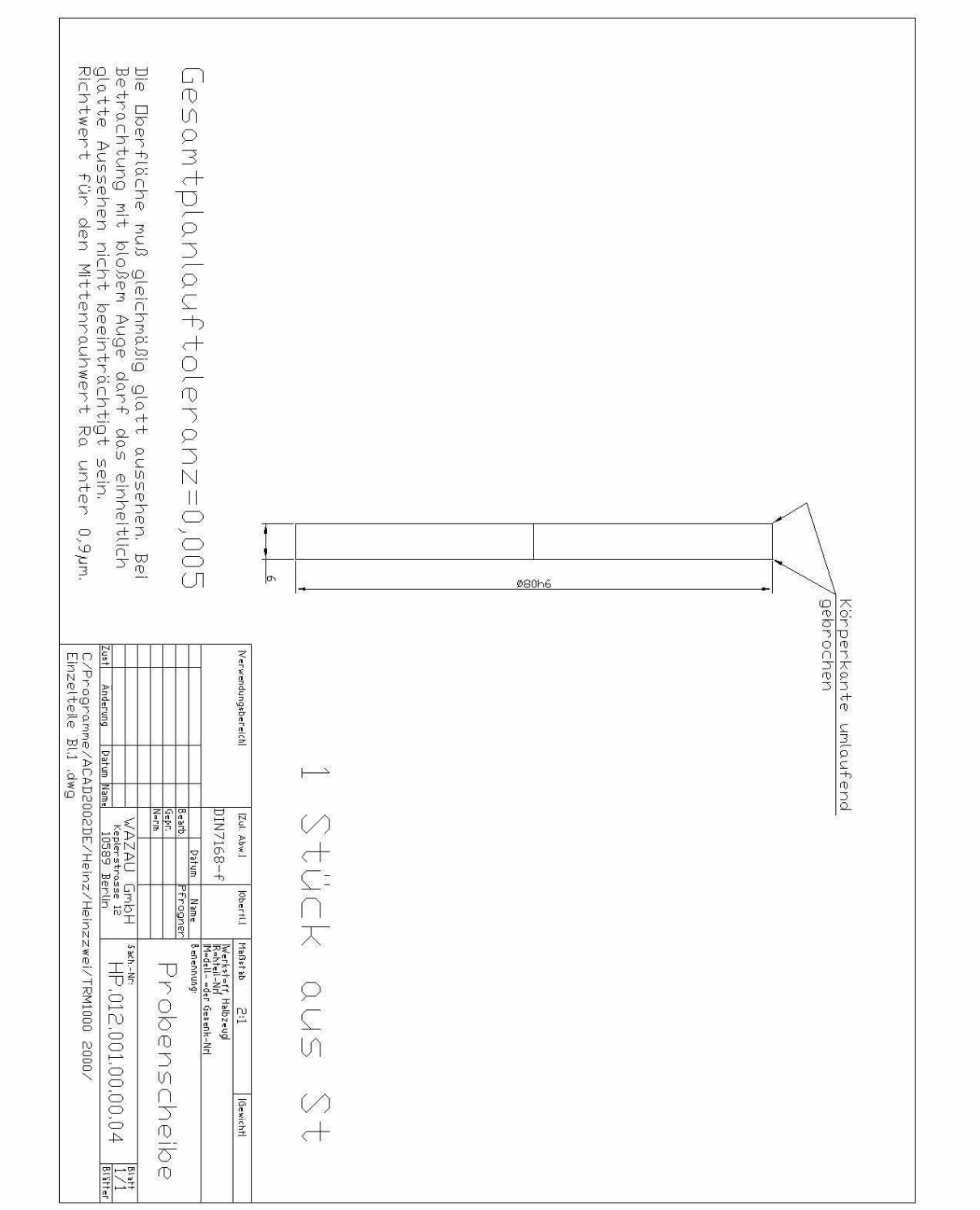


Picture 13



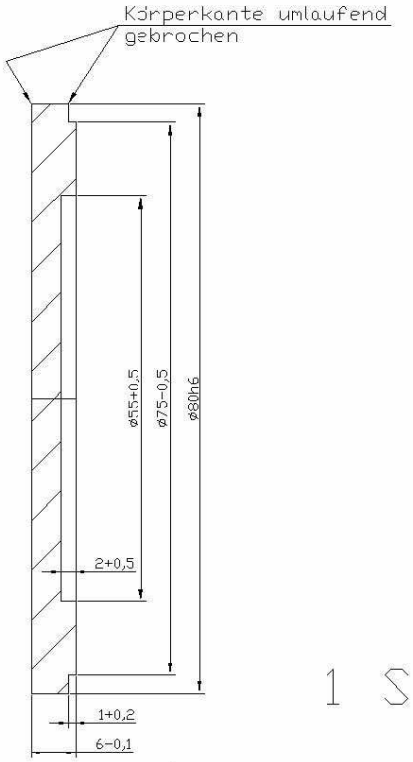
Picture 14

9. Specimen Dimensions



Specimen disc for specimen holder (air-bearing spindle)

Specimen disc for swash plate



1 Stück aus Al

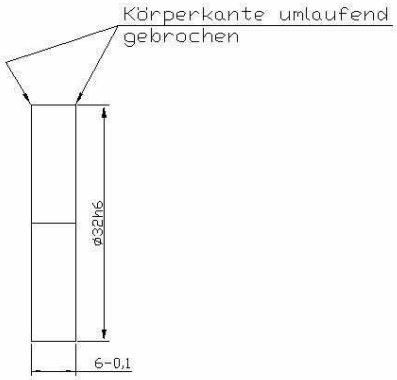
Gesamtplanlauftoleranz=0,005

Die Oberfläche muß gleichmäßig glatt aussehen. Bei Betrachtung mit bloßem Auge darf das einheitlich glatte Aussehen nicht beeinträchtigt sein. Richtwert für den Mittenrauhwert Ra unter 0,9µm.

Verwendungsbereich				Zul. Abw.		Oberfl.	Maßstab 2:1		Gewicht		
				DIN7168-f			Werkstoff, Halbzeug R-Teil-Nr. Modell- oder Gesenk-Nr.				
					Datum	Name	Benennung:				
				Bearb.		Pfragner	Probenscheibe				
				Gepr.							
				Norm							
				WAZAU GmbH Keplerstrasse 12 10589 Berlin			Sach.-Nr.: HP.012.001.00.00.05			Blatt 1/1	
Zust.	Änderung	Datum	Name							Blätter	

C/Programme/ACAD2002DE/Heinz/Heinzzwei/TRM1000 2000/
Einzelteile Bl.1 .dwg

Specimen disc for air-bearing unit (linear oscillation)



1 Stück aus Al

Gesamtplanlauftoleranz=0,005

Die Oberfläche muß gleichmäßig glatt aussehen. Bei Betrachtung mit bloßem Auge darf das einheitlich glatte Aussehen nicht beeinträchtigt sein. Richtwert für den Mittenrauhwert Ra unter 0,9µm.

Verwendungsbereich				Zul. Abw.		Oberfl.	Maßstab 2:1		Gewicht
				DIN7168-f			Werkstoff, Halbzeug Rohteil-Nr. Modell- oder Gesenk-Nr.		
					Datum	Name	Benennung:		
				Bearb.		Pfragner	Probenscheibe		
				Gepr.					
				Norm					
				WAZAU GmbH Keplerstrasse 12 10589 Berlin			Sach.-Nr.: HP.012.001.00.00.06		Blatt 1/1 Blätter
Zust.	Änderung	Datum	Name						

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