VYSOKÉ UČENÍ TECHNICKÉ V BRNĚ

BRNO UNIVERSITY OF TECHNOLOGY

FAKULTA STROJNÍHO INŽENÝRSTVÍ
ÚSTAV KONSTRUOVÁNÍ

FACULTY OF MECHANICAL ENGINEERING INSTITUTE OF
MACHINE AND INDUSTRIAL DESIGN

DESIGN OF AN EXPERIMENTAL RIG FOR TESTING OF INTERNAL-COMBUSTION ENGINE JOURNAL BEARINGS

DESIGN REPORT

AUTHOR Bc. CSABA BEDEČ

SUPERVISOR Ing. MILAN OMASTA, Ph.D.

BRNO 2015

CONTENTS

1 INTRODUCTION

1

This report provides information about the developed test rig for journal bearings of internal combustion engines. The figure below provides schematic illustration of the main parts of the tester. The testing shaft (2) is supported by two support bearing assemblies (1) and is driven by a motor (7). The support bearing housings are fixed to the main frame (8), which rests on a support frame (9). Test bearings (3) are fixed in the test bearing housing (4), which is connected with the fork (6) by the piston pin (5). The hydraulic cylinder (10) supplies the loading force on the fork.

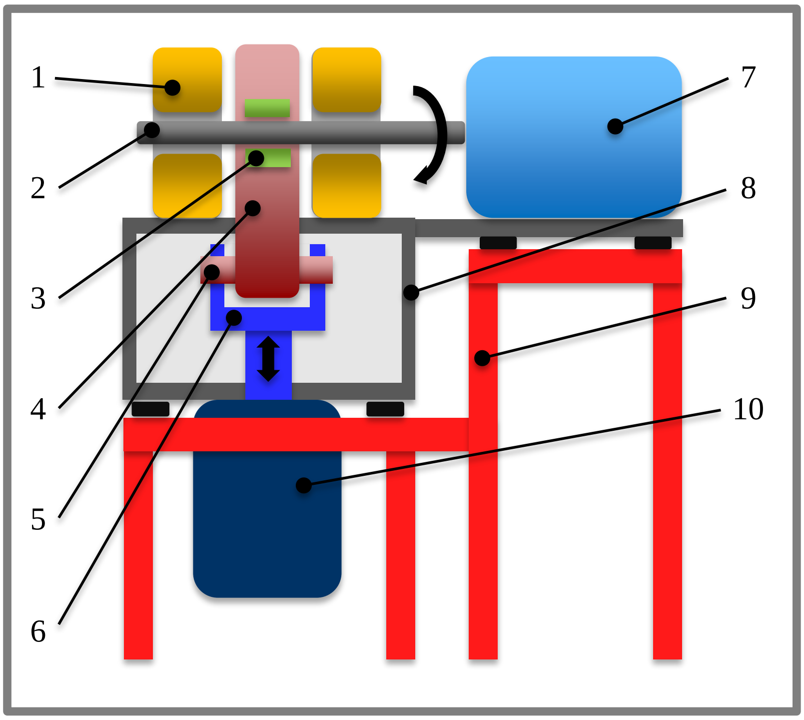

Fig. 1-1 Areas of interest, 1: support bearings, 2: testing shaft, 3: test bearings, 4: test bearing housing, 5: piston pin, 6: fork, 7: motor, 8: main frame, 9: support frame, 10: hydraulic cylinder

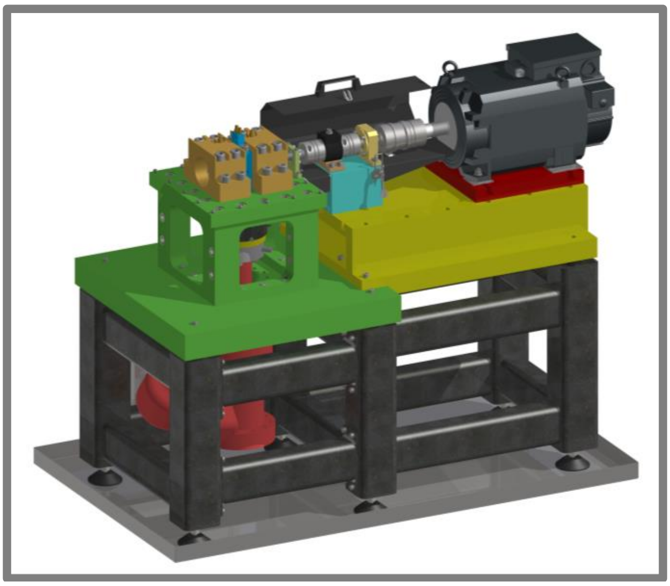

Fig. 1-2 Test rig, model

2 SUPPLIED COMPONENTS

2.1 Electric motor

Company SIEMENS supplies the electric motor. Series 1PH8 is widely used in motion control applications, for example in machining centers, cranes, etc. The selected motor is air cooled with forced air ventilation.

Specifications of type 1PH8133-1DG00-0LA1:

n_{rated} [rpm]	P_{rated} [kW]	M_{rated} [Nm]	I_{rated} [A]	n_{max1} [rpm]	n_{max2} [rpm]	n_{max3} [rpm]	$n_{max, Br}$ [rpm]	n_2 [rpm]	M_{max} [Nm]	I_{max} [A]	M_0 [Nm]	I_0 [A]
2650	24,0	86	41	8000	10000	15000	4500	7000	250	117	126	54

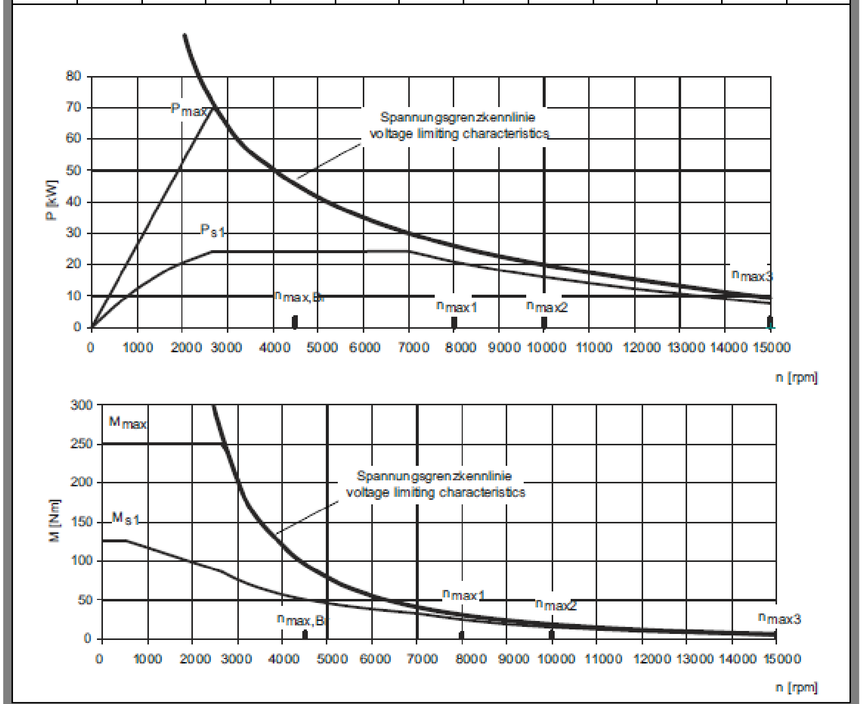

Fig. 2-1 Motor specifications, max. RPM n_{max2} [1]

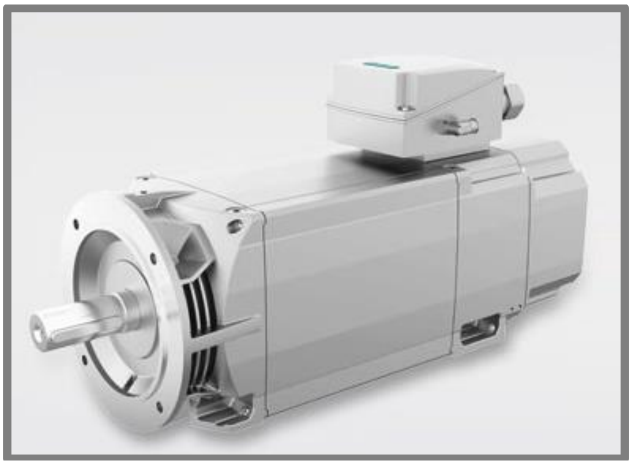

Fig. 2-2 Motor SIEMENS [2]

2.2 Tilting motor 2.2

The correct positioning of the test bearing housing is maintained by the tilting motor. It is a stepper motor, which contains a linear transmission. Maximum force needed on this motor is 216 N, while the recommended limit according to the manufacturer is 220 N. In case of insufficient force this motor can be changed to another type with the same dimension, but with higher force rating, but the step length will be increased, which decreases precision.

Specifications of type 43J1U-V:

- Recommended force limit: 220 N
- Step length: 0.0015 mm
- Tilting angle step: 0.001º
- Power rating: 7 W

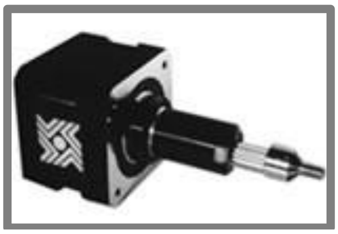

Fig. 2-3 Linear stepper motor [3]

2.3 Torque sensor 2.3

As the torque sensor HBM T22 is selected with range 50 Nm. This torque sensor is cost effective, if specified can contain rotational speed sensor. This model has contactless transmission of measurement signals.

Specifications of the selected type:

- Rated torque: 50 Nm
- Rated rotational speed: 12 000 RPM
- Accuracy class: 0.5
- Voltage output: 5 V
- Load limit: 200%

Fig. 2-4 Torque sensor HBM T22 [4]

2.4 Torque limiter

As the torque limiter MAYR EAS-HSC is used, on one end contains flexible coupling ROBA-DS. This torque limiter is disengages, when the set torque is exceeded. This limiter is most suitable in high-precision applications, when rotating speeds are high.

Specifications:

- Max. rotational speed: 10 000 RPM
- Available in torque ranges: 20 – 50 Nm, 40 – 100 Nm, 50 – 125 Nm
- Integrated flexible coupling ROBA-DS on the other side
- Clamping hubs to ensure precise connection
- Manufacturer balances the clutch on request

Fig. 2-5 Safety clutch Mayr EAS-HSC [5]

3 TESTING AREA

3

3.1 Test bearing housing

3.1

The test bearing housing is designed according to supplied drawings from Japan. The housing is split into three parts: the bottom part is a spherical plain bearing, which ensures relatively easy rotation to tilt the housing into correct position. This bearing is lubricated with high temperature grease, which works in temperatures up to 150 ºC. The middle and the upper parts are replaceable to accommodate different sized test bearings and to set different connecting rod lengths. The piston pin is fixed by two screws.

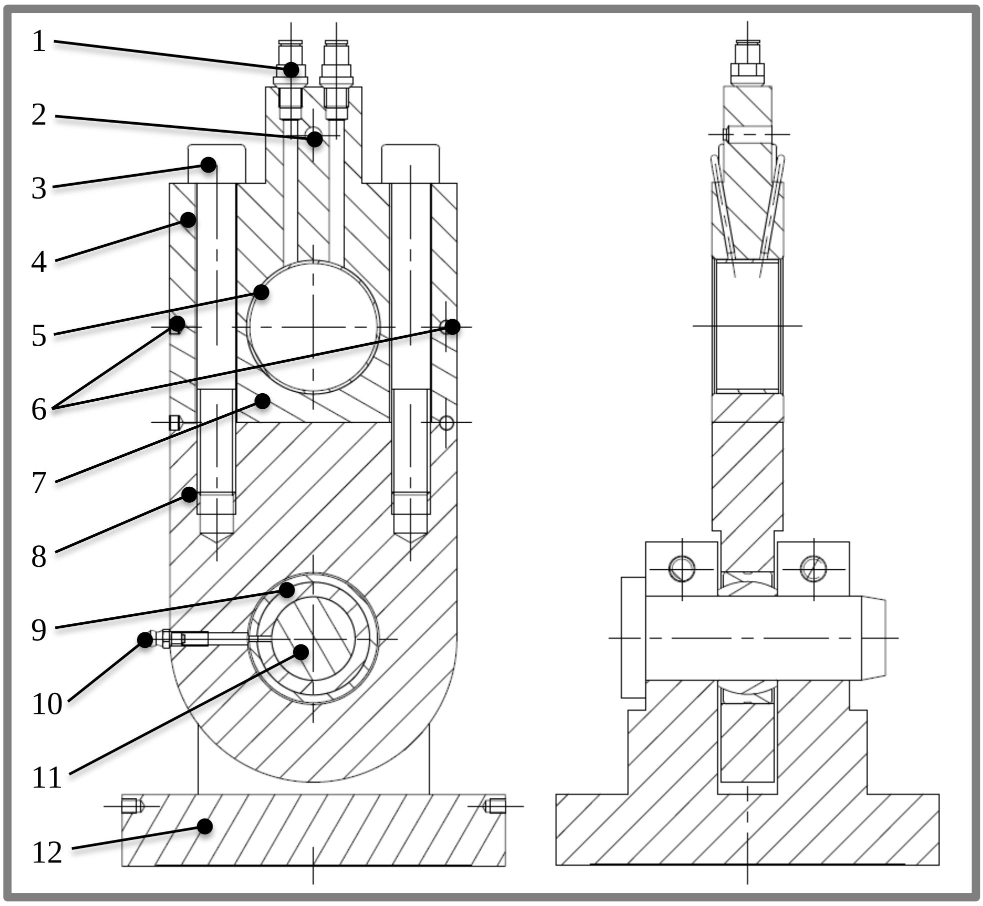

Fig. 3-1 Support bearing housing and fork, 1: lubricant inlet, 2: tilting otor connecting point, 3: fixing screws, 4: upper part of the housing, 5: test bearings, 6: centering pins, 7: middle part of the hoisng, 8: bottom part of the housing, 9: spherical plain bearing, 10: lubricant inlet for the spherical bearing, 11: piston pin, 12: fork

3.2 Hydraulic cylinder mounting

3.2

The hydraulic cylinder is mounted on its flange to ensure maximum stiffness. The hole in the bottom plate ensures proper centering.

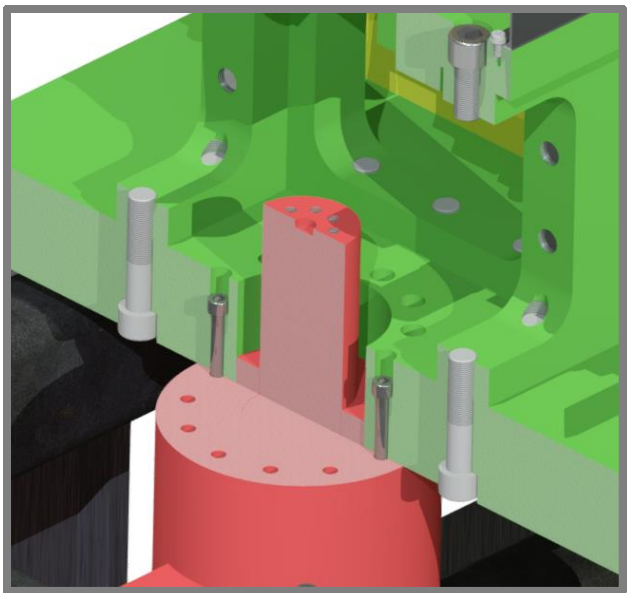

Fig. 3-2 Hydraulic cylinder mounting

3.3 Main frame

The main frame is screwed together from thick steel plates – the top and side ones are thick 6 cm, the bottom plate's thickness is 8 cm. To ensure maximum stiffness and precise placement of the testing shaft, their contact surfaces are milled with high precision and screwed together with M20 screws.

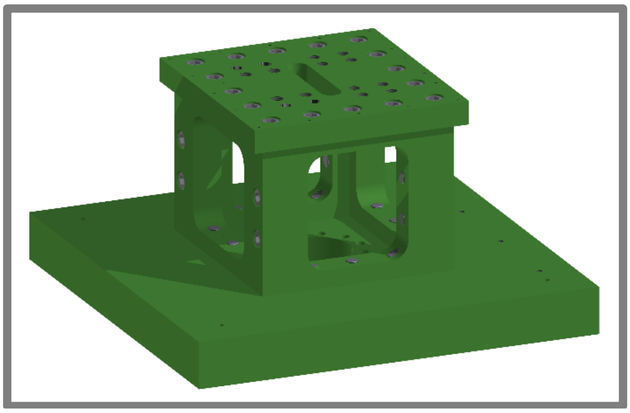

Fig. 3-3 Main frame

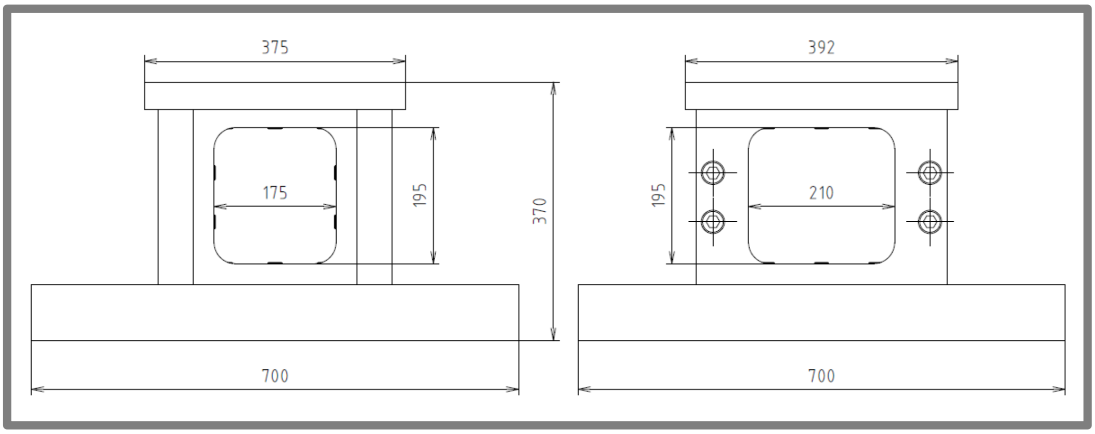

Fig. 3-4 Main frame, dimensions

3.4 Support bearings

As support bearings SKF NU 2210 ECML bearings are selected. These are lubricated with the same lubricant, as the test bearing. Predicted life of these bearings is almost 60 hours under maximum load. When the lubricant temperature or the load is lower, than the maximum (100 ºC and 100 kN constant), the life will be much higher.

If the life will not be sufficient, these bearings can be changed to 2311 ECML with predicted life of almost 1000 hours under maximum load, but the bearing housings have to be modified, because these bearings are larger, test shaft will have diameter 55 mm, connecting rod has to be longer too.

If the test bearing is not precisely concentric with the shaft, axial forces will appear on the shaft. These axial forces are transferred to a small deep groove ball bearing on another shaft via a ROBA-DS coupling. In case, this will be not sufficient, the NU bearing configuration can be changed to NJ or NUP. In this case, the flexible coupling will be loaded only statically, which will be sufficient.

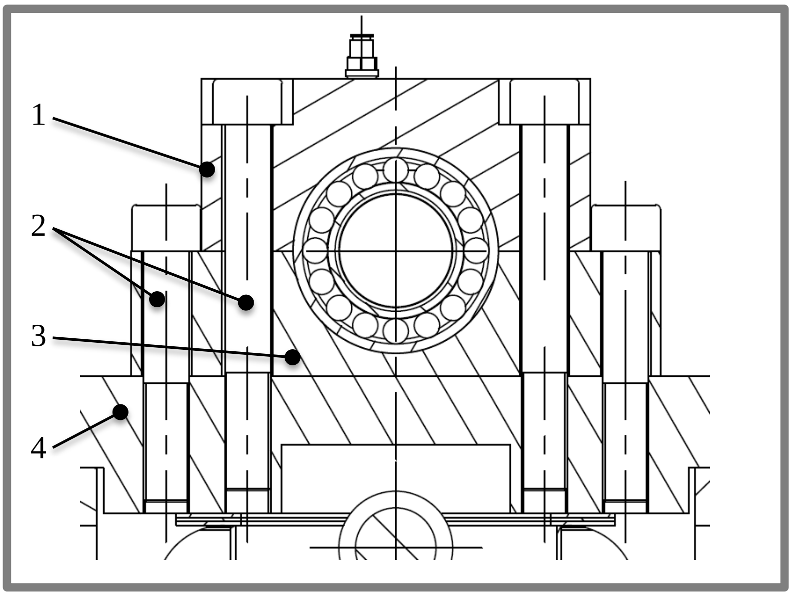

Fig. 3-5 Support bearing assembly, 1: upper part of the housing, 2: fixing screws, 3: bottom part of the housing, 4: upper plate of the main frame

3.5 FEA analysis

Maximum deformation of the full assembly is ±0.25 mm, with maximum bearing clearance. In real conditions, the bearing clearance is decreased due to temperature, because of this deformation ±0.2 mm is achievable.

Maximum Von Mises stress is in the test bearing housing, under the screw heads (220 MPa) and near the contact with the spherical plain bearing (187 MPa). The selected material has a maximum yield stress of 305 MPa, static safety coefficient is equal to 1.38.

Tab. 3-1 Summary of deformations

	Tension [μm]	Press. [μm]	Sum [μm]	Frequency [Hz]
Main frame, sup. bearing housing	73,3	103,8	**177,1**	346
Test bearing housing	105,6	82,0	**187,6**	-
Test bearing	25	25	**50**	-
Support bearings	20	20	**40**	-
Spherical bearing	25	25	**50**	-
Sum	**248,9**	**255,8**	**504,7**	**-**

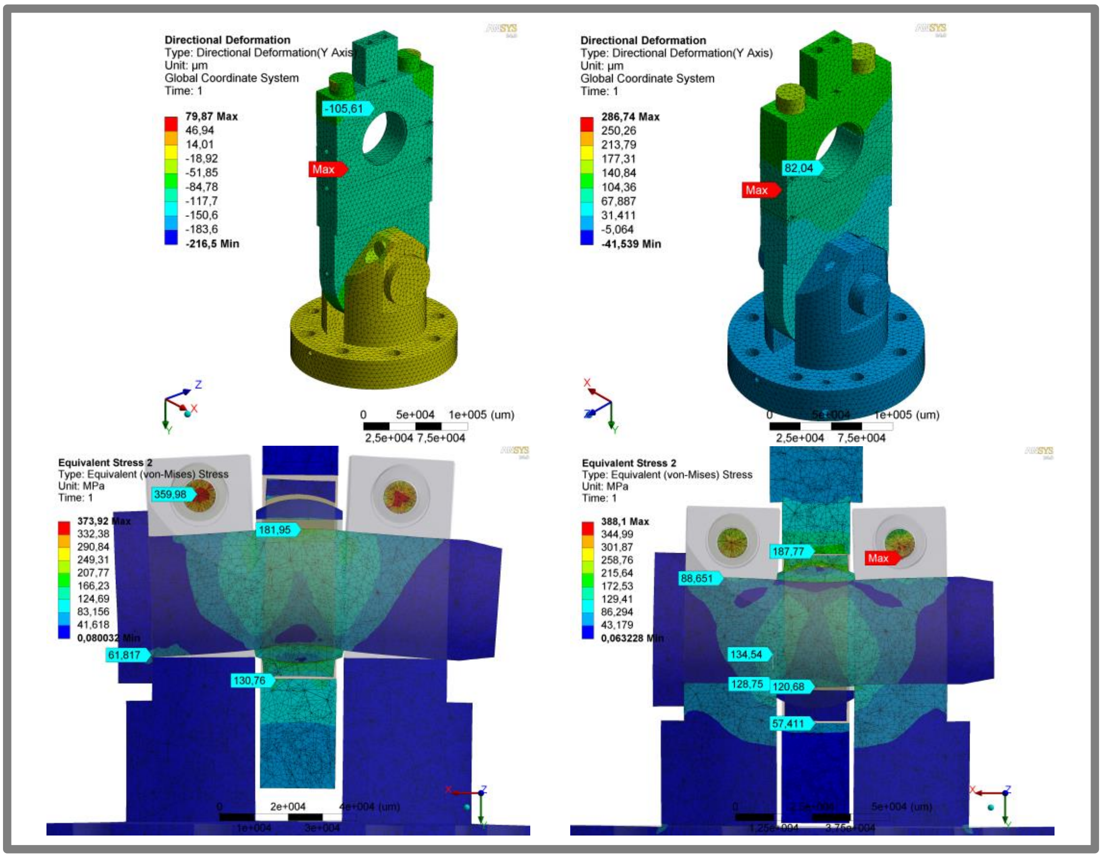

Fig. 3-6 Deformation and stress of the test bearing assembly, left: tension, right: pressure

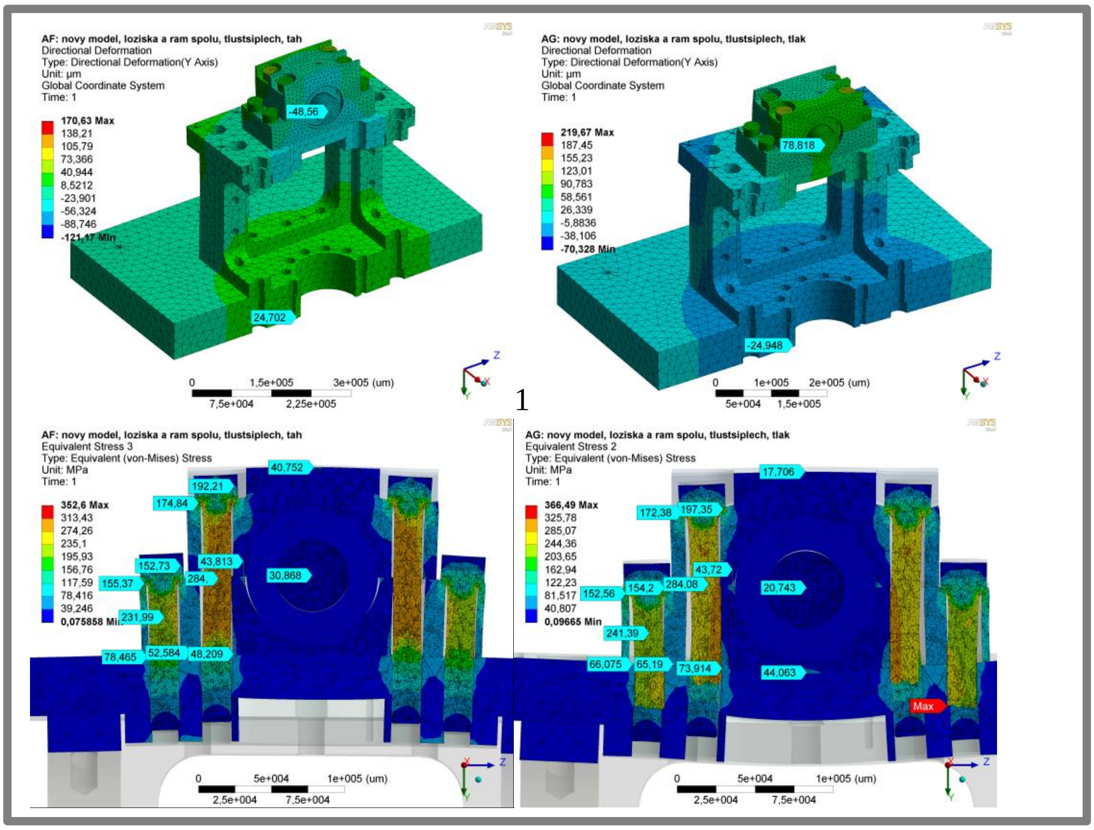

Fig. 3-7 Deformation and stress of the support bearing and main frame assembly, left: tension, right: pressure

4 OTHER PARTS

4.1 Support frame

The support frame is welded from square steel tubes. Two beams can be screwed off, to ensure easy mounting of the hydraulic cylinder.

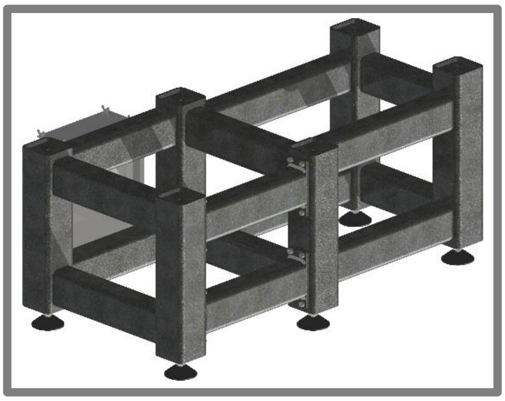

Fig. 4-1 Support frame

4.2 Drivetrain

The drivetrain is fixed to its base frame. The motor and the table for the torque sensor can be set into position via T-grooves. The torque sensor and the motor is connected by a connecting shaft, on which is the torque limiter, which state is monitored by a limit switch. Rotational speed sensor monitors the rotation of the shaft, if the safety clutch disengages. Covers are protecting the staff from the rotating parts.

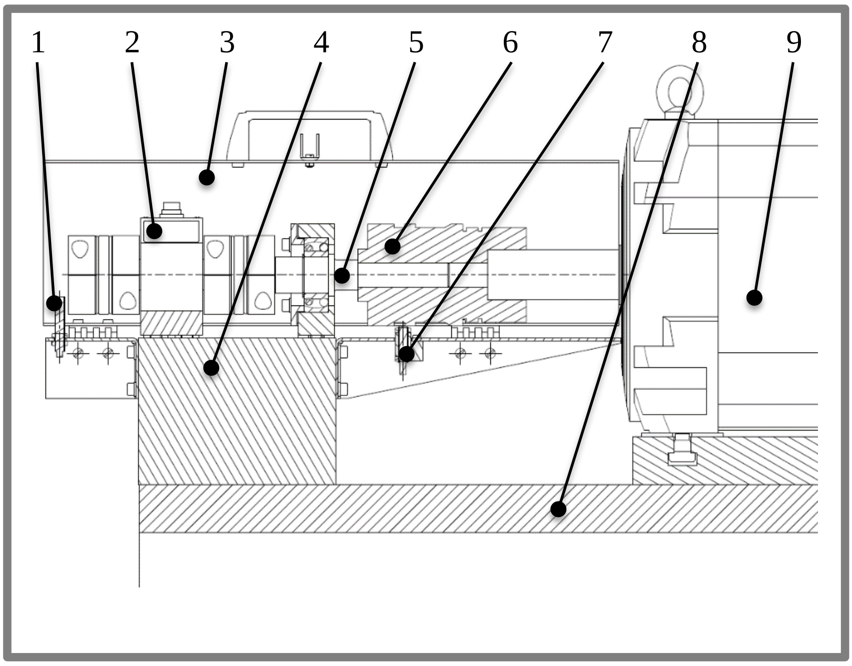

Fig. 4-2 Drivetrain assembly, 1: rotational speed sensor, 2: torque sensor, 3: casing, mall table for drivetrain, 5: connecting shaft, 6: safety clutch, 7: safety clutch limit switch, 8: drivetrain frame, 9: motor

5 ASSEMBLY AND USAGE

5.1 First assembly

First the bottom plate of the main frame is put on the supporting frame, then the hydraulic cylinder is screwed to it. The force transducer is then screwed on the piston. Then the side plates of the main frame are fixed to their place. The fork is then screwed to the force transducer. It is advised, that the bottom part of the test bearing housing is fixed into position by the piston pin before the upper plate of the main frame is screwed into its place. The middle part of the test bearing housing can be put into its position with the first part of the test bearing in position.

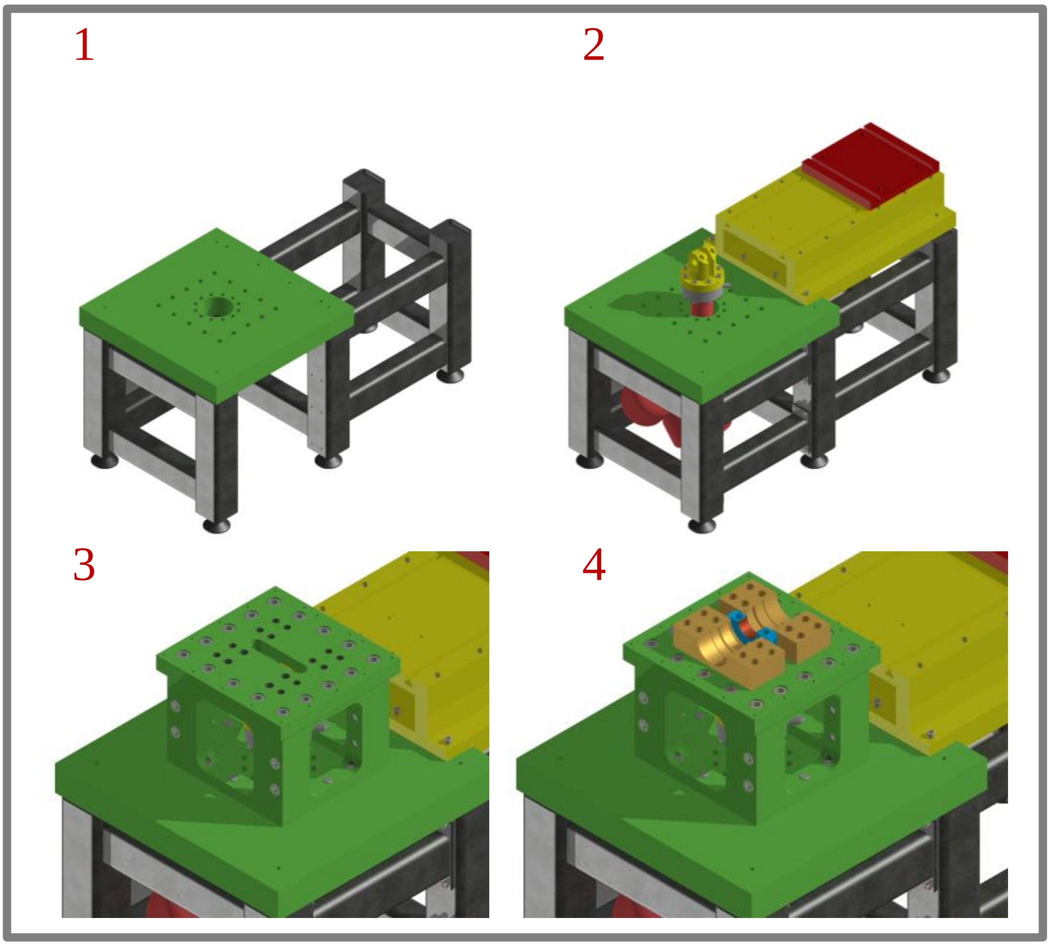

Fig. 5-1 Assembly of the main frame and drivetrain frame

In parallel the test shaft can be assembled: two retaining rings are put in the two middle slots, the support bearings and the spacer rings are pressed into their place and are secured with the last two retaining rings. Then half of the ROBA-DS clutch can be put on the small end of the testing shaft.

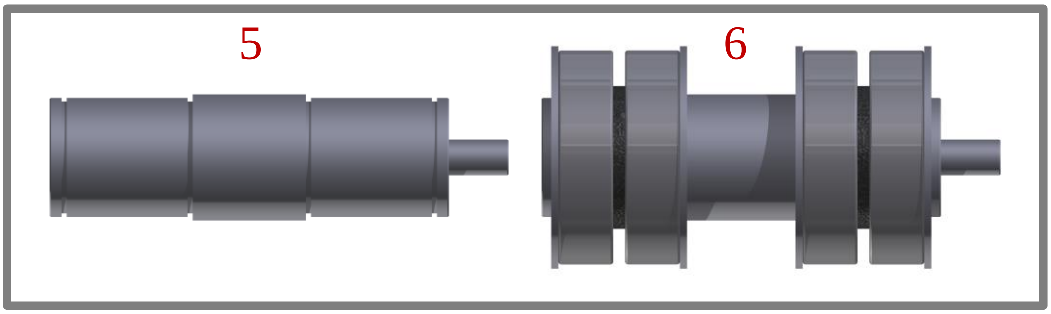

Fig. 5-2 Testing shaft assembly

Then the bottom parts of the supporting bearings are put on the upper plate of the main frame, but the housings are not fixed to the plate yet. The testing shaft with the support bearings is acting like a centering element, to ensure correct alignment of the two support bearing housings. Then the upper part of the support bearing housing is put on the bottom part, then the retaining rings are put into the support bearing housings. Finally, the fixing screws can be tightened with torque 320 Nm.

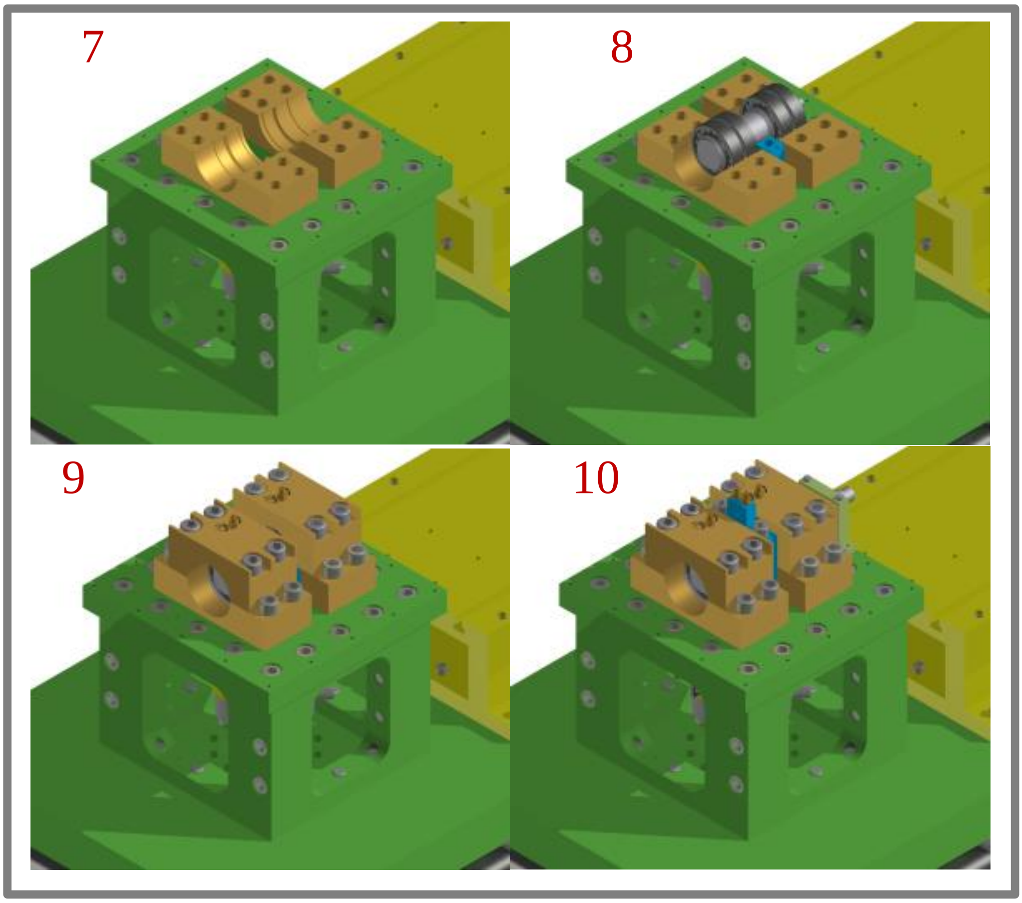

Fig. 5-3 Assembly of the support bearing and test bearing housings

Then the small bearing, its housing and the bottom part of the enclosure are put in place with acceptable concentricity according to the specifications of the ROBA-DS coupling. The other rotating parts should be then centered in relative to this connecting shaft. The table for the torque sensor, the self-aligning ball bearing and its housing can be set into position, then the torque sensor and the self-aligning ball bearing housing are adjusted to be in correct concentricity in relative to the small connecting shaft. The motor then can be set into its position. Finally, the enclosure of the drivetrain is put in place.

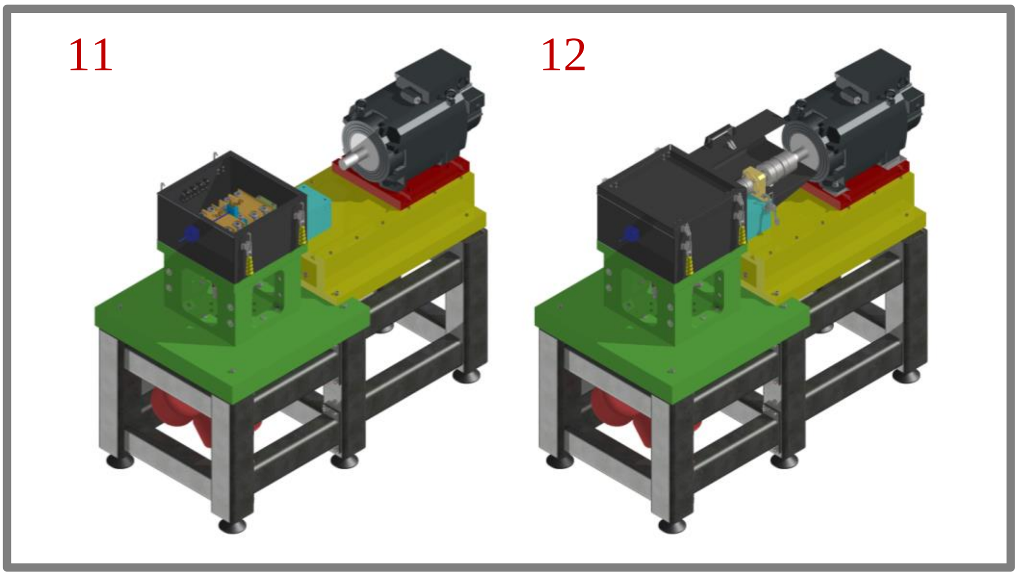

Fig. 5-4 Assembly of the drivetrain and casing

The assembly of the test bearing housing can be continued. The upper part of the test bearing housing and centering pins can be put in place, with the second test bearing part in position. The fixing screws of the housing is then tightened with torque 320 Nm. Now the tilting motor can be connected to the housing. Now all of the cables and hoses are connected and the testing enclosure can be closed. Finally, the shield on the fork is screwed into place with silicone rubber plates to ensure good sealing of the lubricating oil.

5.2 Test bearing, connecting rod and shaft replacement

5.2

First the casing of the testing area is opened, then the tilting motor is disconnected from the upper part of the test bearing housing. Now the tilting motor can retract its screw, to make enough space for the disassembly. After the upper part of the test bearing housing can be disassembled.

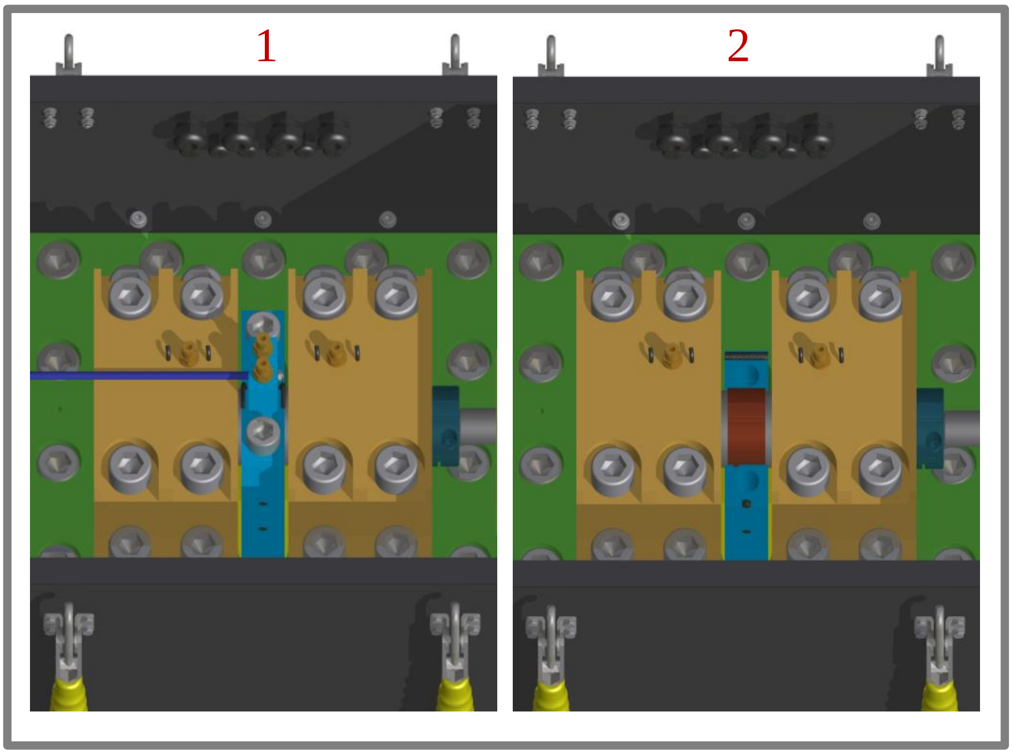

Fig. 5-5 Test bearing housing disassembly

Then the upper part of the support bearings housings are disassembled, together with the ROBA-DS coupling. The bottom part of the support bearing housings are staying in their place, these are secured into place with a different set of screws. The testing shaft assembly is now taken out of the support bearing housings. The testing shaft is disassembled using a press. If the support bearings are in good enough condition, these can be reused and pressed onto a new shaft. The test bearing housing upper and middle part can be changed to different size, to accommodate different sized test bearings, according to the current test specifications.

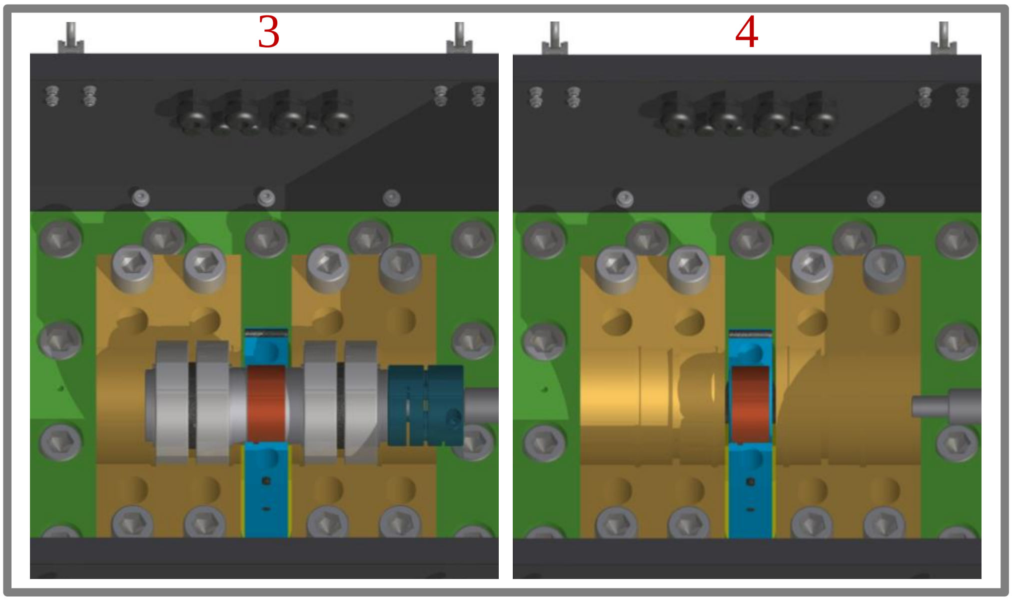

Fig. 5-6 Testing shaft disassembly

5.3 Connecting rod, fork and force transducer replacement

First the piston is retracted to the bottom position, then the fork casing is removed, together with the sealing plates. By loosening the screws securing the piston pin, the pin can be pulled out of the assembly. Now it is possible to change the bottom part of the test bearing housing, to simulate different connecting rod lengths.

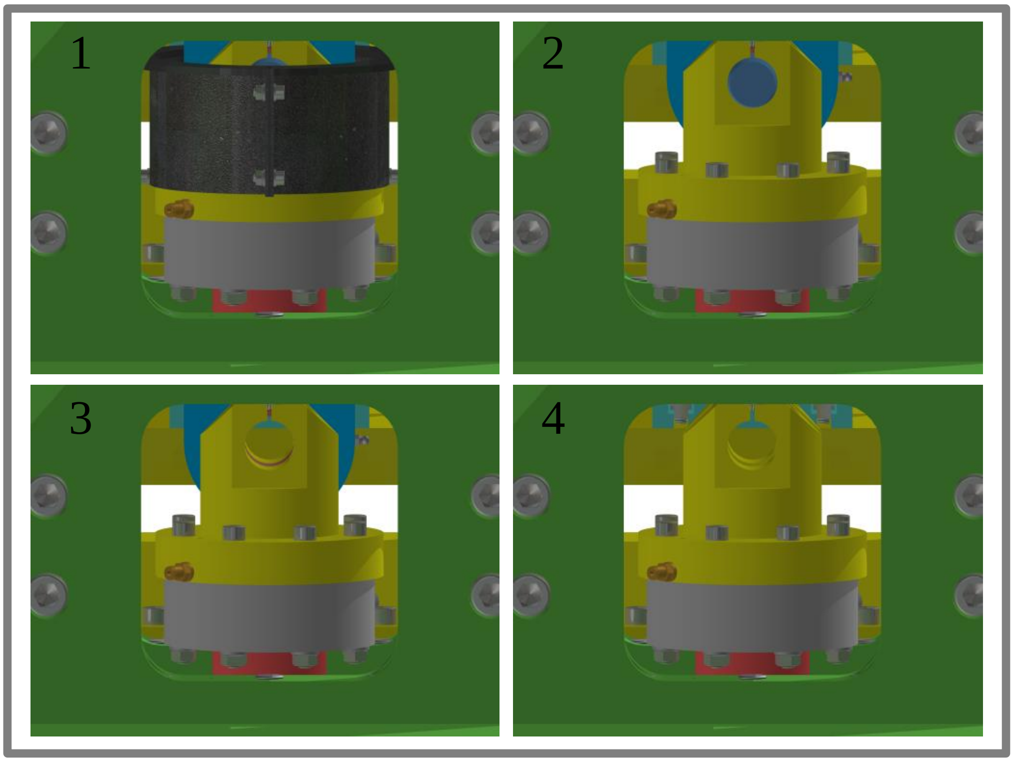

Fig. 5-7 Test bearing housing and fork disassembly

To change the fork, 8 screws on its bottom has to be loosened, the holes on the main frame are big enough, to make disassembly easy. Different forks can accommodate different connecting rod lengths and thicknesses.
The maximum operating temperature of the force transducer is 120º. When lubricant of the support bearings is heated to 100 ºC with oil flow 5 l/min and the test bearing lubricant is heated up to 150 ºC with oil flow 1 l/min the sum of the oil temperatures should not exceed 110 ºC, but the temperatures should be monitored.
To change the force transducer, other 8 screws has to be loosened. For correct assembly a pin on the piston centers the transducer, the fork is centered on the force transducer.

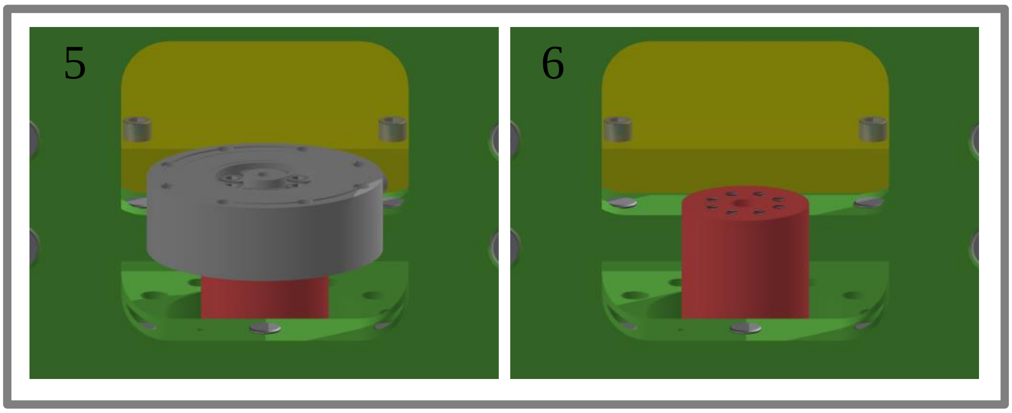

Fig. 5-8 Force transducer disassembly

6 REFERENCES

[1] Simotics M 1PH8 Main motor configuration manual. *Siemens* [online]. 2015 [cit. 2015-05-11]. Available at: https://support.industry.siemens.com/cs/document/46484744?dti=0&lc=en

[2] SIMOTICS M-1PH8 Main Motors. *Siemens* [online]. 2015 [cit. 2015-04-11]. Available at: http://w3.siemens.com/mcms/mc-solutions/en/motors/motion-control-motors/simotics-m-main-motors/simotics-m-1ph8/pages/simotics-m-1ph8.aspx

[3] Krokové aktuátory. *Servo-drive* [online]. 2015 [cit. 2015-04-11]. Available at: http://servo-drive.com/krokove_aktuatory_vysokorychlostni_vysocepresne_nema17.php

[4] T22. *HBM Měřící technika* [online]. 2011 [cit. 2015-04-11]. Available at: http://www.hbm.cz/Prospekty/Moment/t22/p_t22_e.pdf

[5] Documentations torque limiting clutches. *MAYR* [online]. 2009 [cit. 2015-04-11]. Available at: http://www.mayr.com/en/service/documentation/torque-limiting-clutches/

7 LIST OF FIGURES