

Performance and endurance test of CWD 49 D pump

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**PERFORMANCE AND ENDURANCE
TEST OF CWD 49 D PUMP**

J. DIEPENS

June 1989

R 1907 D

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CONTENTS

Page

1. Introduction	1
2. Description of teststand	3
3. Description of tested configurations	5
4. Results performance measurements	11
5. Results endurance test	16
6. Conclusions and recommendations	20

ANNEXES

I	Configuration 37
II	Configuration 38
III	Configuration 39
IV	Configuration 40
V	Configuration 41
VI	Configuration 42
VII	Analysis of errors in measured signals

1. INTRODUCTION

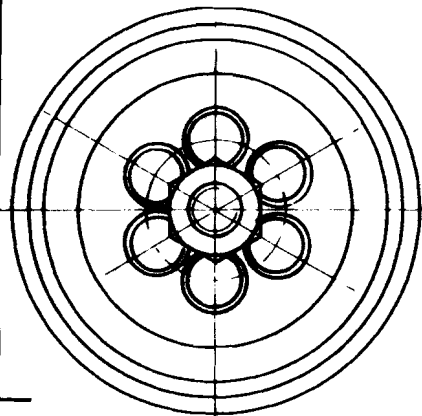
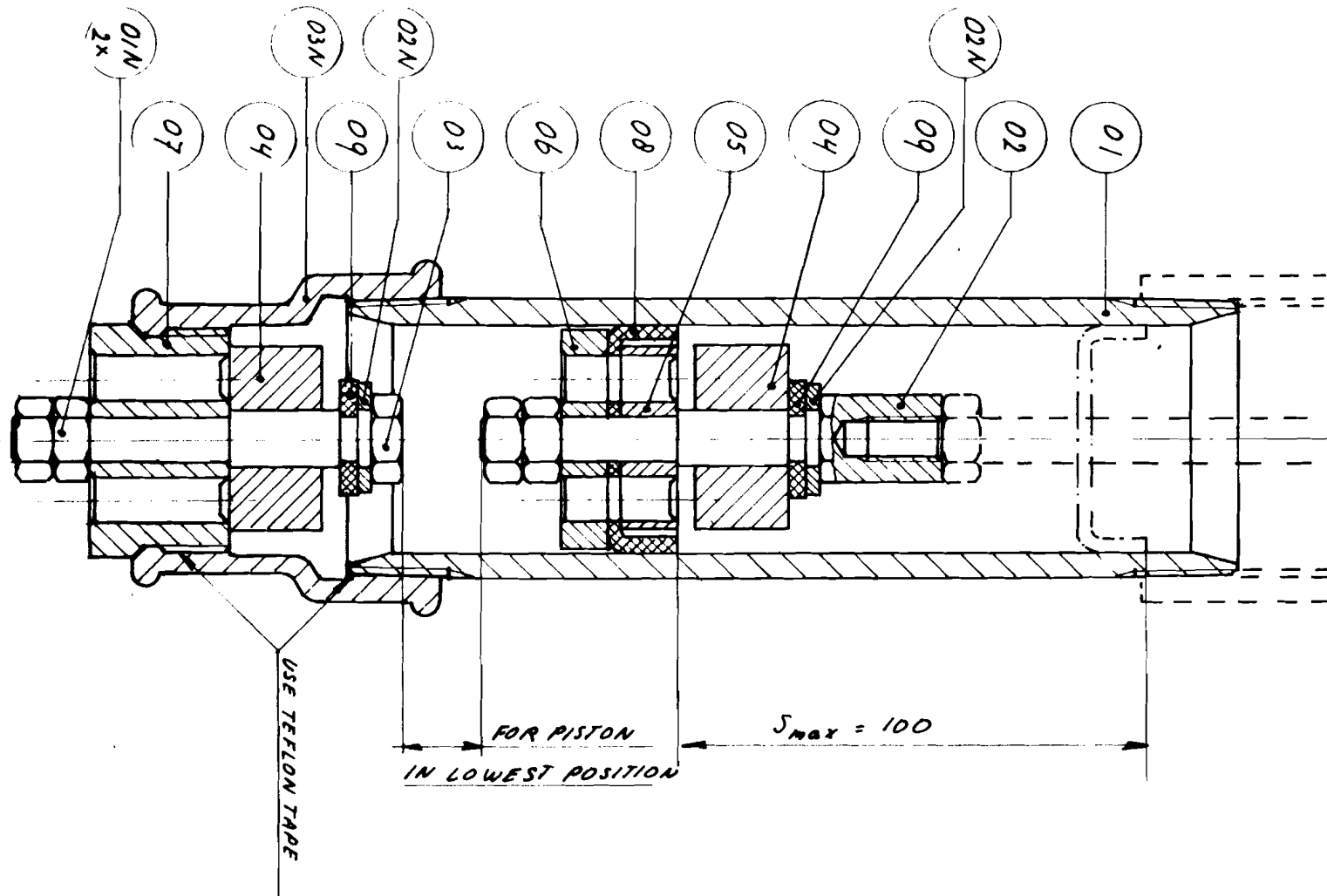
Within the CWD the need is felt to test the developed pumps for a long period under heavy loaded conditions. For this purpose two pump test stands are built at the testfield of TUE Eindhoven. A program has been set up to endurance test all CWD-pumps in the near future.

The first pump tested in this series is the so called CWD 49 D pump (drawings E8710 and E8711) which is especially developed for use with the CWD 2000 windmill. This pump is somewhat different from the other CWD pumps, instead of a airchamber an expansion tube is used as soft element.

The pump is tested in the configuration which gives the highest loads possible in the combination CWD 2000/CWD 49 D. From field measurements it is known that the maximum rotational speed of the CWD 2000 is 3 rps. The pump is tested with 3 rps during $27,6 \times 10^6$ cycles.

Some extra measurements have been done like:

- pump without expansion tube to check the influence of the expansion tube
- pump with floating valve of epoxy foam
- pump with polypropreen valve.



The following documents are annexes of this drawing
PARTS LIST : non standard parts
PARTS LIST : standard parts
MATERIAL QUANTIFICATION SHEET
 For specifications of parts see **PARTS LISTS**

Item nr ○ (figures only) refers to **PARTS LIST** / non standard parts
 Item nr ○N refers to **PARTS LIST** / standard parts

For total amount of construction material required for this drawing, including standard parts, see **MATERIAL QUANTIFICATION SHEET**

If not shown apply		Tolerance	Welds	Roughness	Modification description		Date	Initials	Mod
CONSULTANCY SERVICES WIND ENERGY DEVELOPING COUNTRIES		P.O. BOX 66 3600 AB AMERSFOORT THE NETHERLANDS		Material	Subject CWD 49 D PUMP ASSEMBLY		Quantity per assembly	Drawn by A. KRAGTEN Date 18.4.88	
This drawing is the property of CWI and can only be used in regard to issues to others, wholly or in part, with our prior written permission. This drawing has been carefully reviewed and approved for its accurate, complete and reliable, however, no responsibility is assumed for the suitability of any product made by means of this drawing.		Treatment				1	Approved by Date		
Format	Scale	Drawing Standards	American projection	LABORATORY OF FLUID DYNAMICS AND HEAT TRANSFER DEPARTMENT OF PHYSICS WINDENERGY GROUP		Drawing No E8710-00			

2. DESCRIPTION OF THE TEST STAND

The pump test stand used was the so-called CWD 5001 test rig, see fig. 2.1. For this test rig the CWD 5001 windmill was used, in which the rotor was replaced by a DC motor with speed control.

The stroke can be adjusted from 60 to 200 mm with steps of 20 mm. The speed range is from 0 upto 3.3 rps. Depending on the load the maximum rps can be lower than 3.3 rps. The force in the pump rod is measured with a force transducer type E. Brosa + 10 kN. The flow is measured with an inductive flow meter; Disco mag. DMI 6531/H50 Endress + Hauser. The data acquisition was done with an IBM.XT personal computer equipped with a Metrabyte Dash 16 data acquisition board, an Intel 8087 Math co-processor and a Hercules graphics card.

To collect and process data use was made of the scientific software package ASYST.

An analysis of the accuracy of measurement is given in Annex IV.

The well under the test rig has a depth of 33 meter. The CWD 49 D pump was installed at a depth of 15 meters ground level to foot valve. The static head was taken at 23.3 meters. For the rising main 2" GI pipe was used with a $\phi 10$ AISI 316 pump rod inside. From the delivery T to the 1st de-aeration vessel 6 meter 2" plastic hose was used. The stroke was adjusted at 100 mm.

CWD 5001 TEST RIG

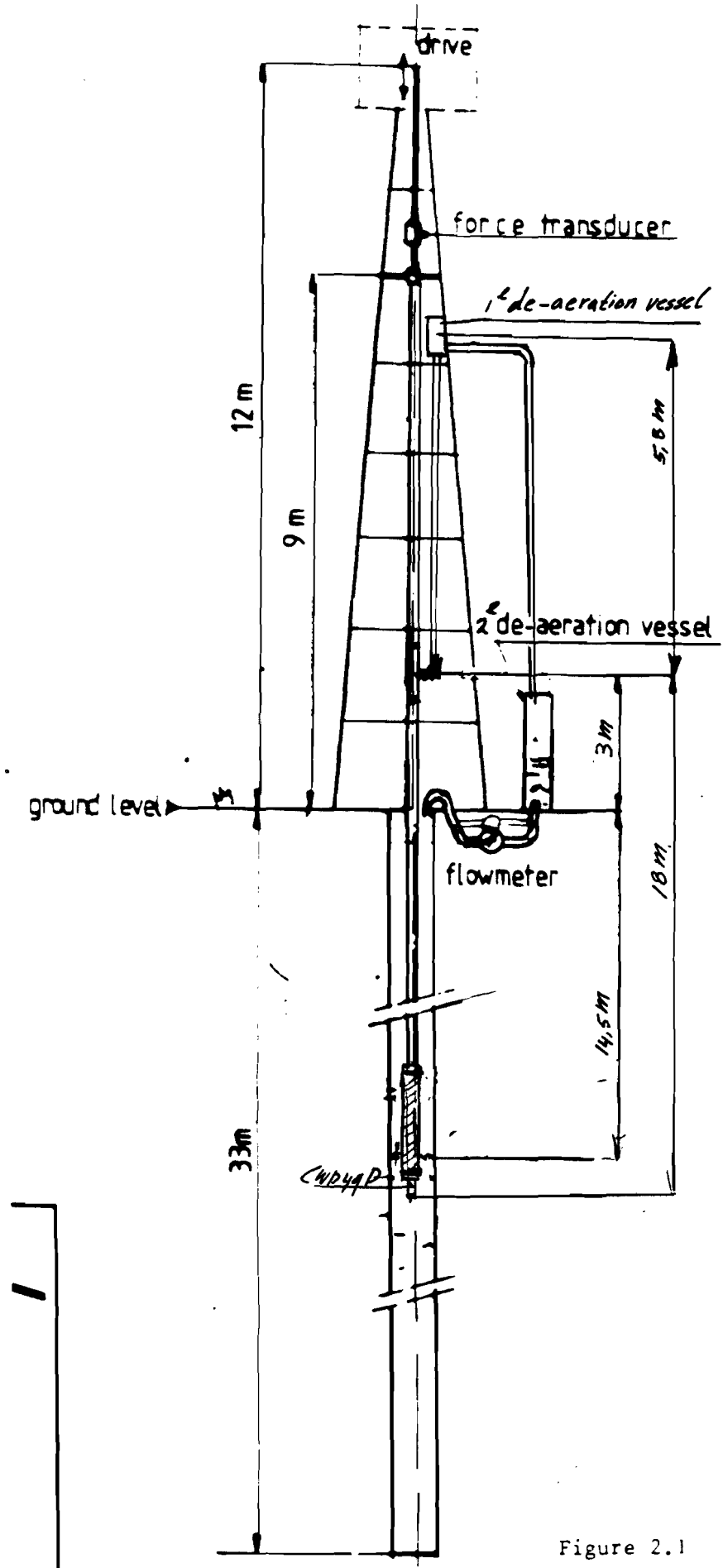


Figure 2.1

If not shown apply		Tolerance	Welds	Roughness	Modification description			
<p>ASME Y14.5M DIMENSIONAL PRACTICES AND TOLERANCES FOR MECHANICAL DESIGN</p>	<p>This drawing is the property of CWD and can only be used, copied or revised to others, wholly or in part, with our prior written permission. The drawing has been carefully reviewed and approved to be accurate, complete and reliable. However, no responsibility is assumed for the operability of any product made by means of this drawing.</p>	<p>Material</p>	<p>Treatment</p>	<p>Subject</p>	Quantity per assembly	Drawn by	Date	
					<p>Formet</p> <p>A4</p>	<p>Scale</p> <p>Drawing Standards ISO</p>	<p>Approved by</p> <p>Date</p>	<p>Drawing No</p>

3. DESCRIPTION OF TESTED CONFIGURATIONS

During the test period of the CWD 49 D, 6 configurations are tested. The pump has made 27.6 cycles in total at 3 rps with the different configurations.

3.1 configurations 37

Pump tested: CWD 49 D

Diameter pump: 49 mm

Stroke: 0,1 m

Static head: 23.3 m

Immersion depth of pump: 0.5 m

Static pump rod force: 413 N

Internal diameter rising main: 53 mm

External diameter pump rod: 10 mm

Soft element: expansion tube 1 meter pvc hose

Length pump rod: 18m ϕ 10 + 6 m 1/2 " GI pipe

Valve lifting height – piston valve: 4 mm

 – foot valve: 4 mm

Valve type – piston valve: normal valve

 – foot valve : normal valve

Type of test: performance and duration test

Rotation speed duration test: 3 rps

Number of cycles: 1,6 x 10⁶

3.2 configuration 38

Pump tested: CWD 49 D

Diameter pump: 49 mm

Stroke: 0.1 m

Static-head: 23.3 m

Immersion depth of pump: 0.5 m

Static pump rod force: 413 N

Internal diameter rising main: 53 mm

External diameter pump rod: 10 mm

Soft element: expansion tube 5 meter PVC hose

Length pump rod: 10 m' ϕ 10 + 6 m 1/2" GI pipe

Valve lifting height — piston valve: 4 mm

— foot valve : 4 mm

Valve type — piston valve: normal valve

— foot valve : normal valve

Type of test: performance test

3.3 Configuration 39

Pump tested: CWD 49 D

Diameter pump: 49 mm

Stroke: 0.1 m

Static-head: 23.3 m

Immersion depth of pump: 0.5 m

Static pump rod force: 413 N

Internal diameter rising main: 53 mm

External diameter pump rod: 10 mm

Soft element: expansion tube 5 meter PVC

Length pump rod: 18 m' ϕ 10 + 6 m 1/2" GI pipe

Valve lifting height — piston valve: 4mm

— foot valve : 4mm

Valve type — piston valve: floating valve epoxy foam

(see fig. 3.1 and 3.2)

— foot valve: normal valve

Type of test: performance and duration

Rotation speed duration test: 3 rps

Number of cycles: 13×10^6

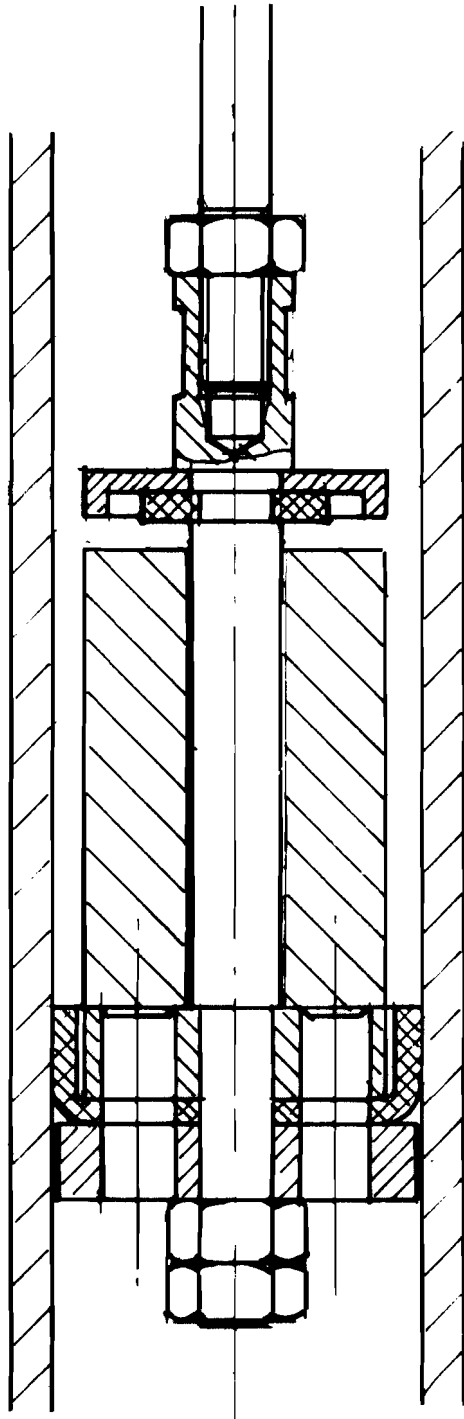


Figure 3.1

1

Figure 3.2

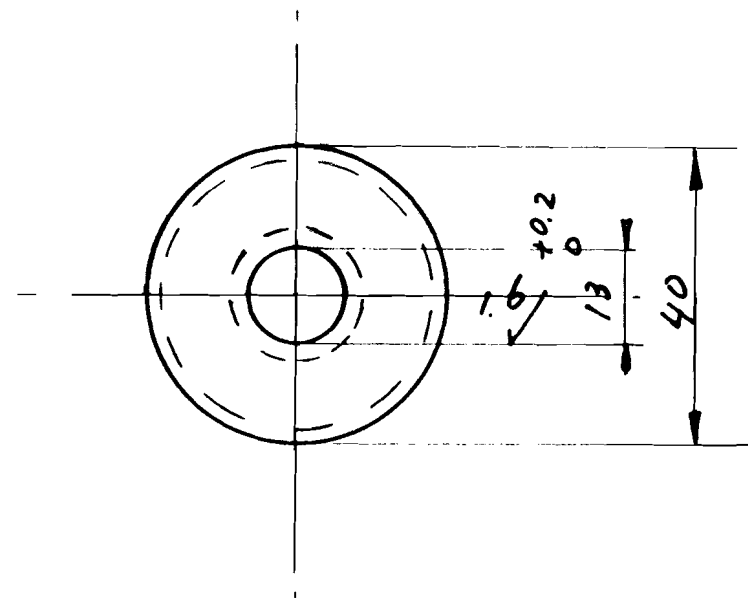
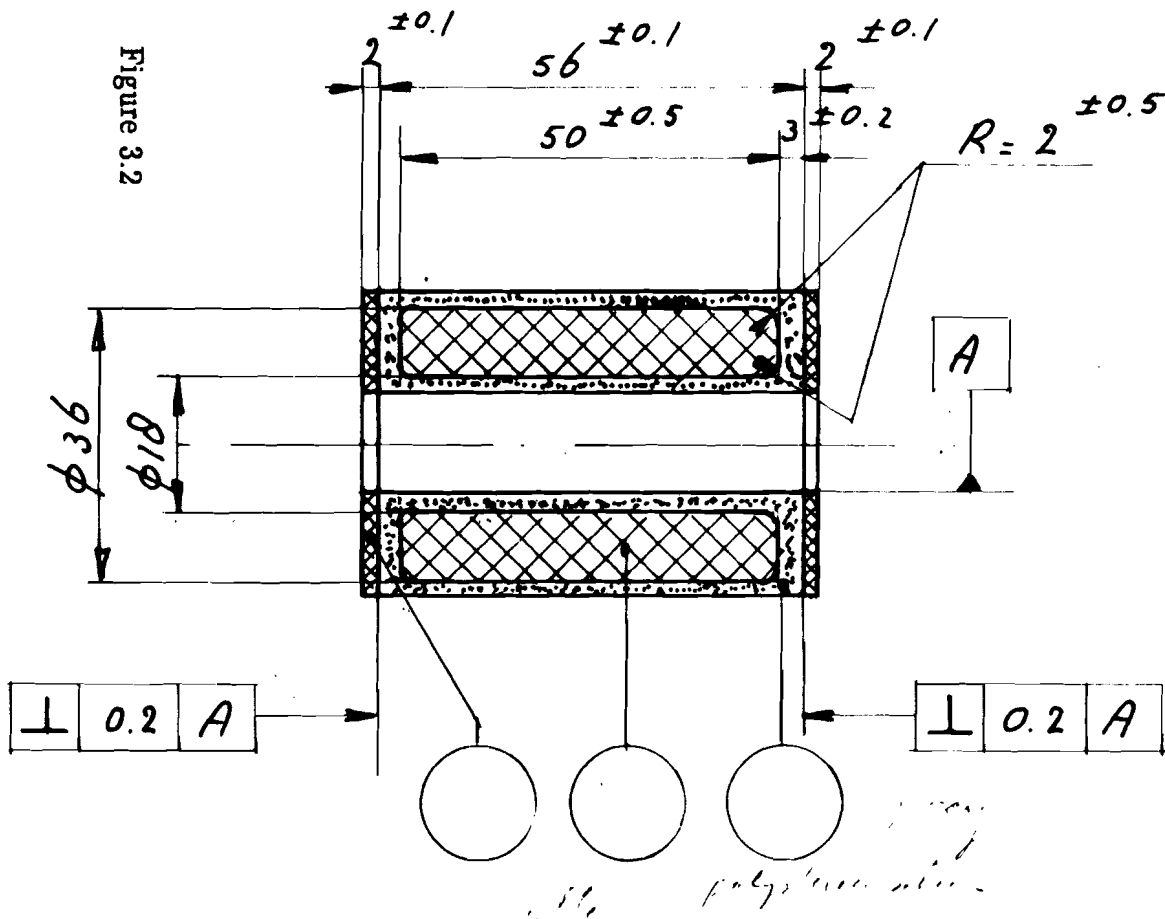


Figure 3.1

not shown apply	Tolerance ± 0.2	Welds	Roughness 3.2	Modification description	Date	Initials	Moet
CONSULTANCY SERVICES WIND ENERGY DEVELOPING COUNTRIES P.O. BOX 96 3800 AB AMERSFOORT THE NETHERLANDS				Material SEE PARTS LIST	Subject CWD 49 D	Quantity per assembly 1	Drawn by A. KRAGTEN
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Format A4	Scale 1:1	Drawing Standards ISO	American projection	FLOATING VALVE			Approved by
							Date
							Drawing No. SCHEETS 1

3.4 Configuration 40

Pump tested: CWD 49 D

Diameter pump: 49 mm

Stroke: 0.1 m

Static-head: 23.3 m

Immersion depth of pump: 0.5 m

Static pump rod force: 413 N

Internal diameter rising main: 53 mm

External diameter pump rod: 10 mm

Soft element: expansion tube 5 meter PVC hose

Length pump rod: 10 m' ϕ 10 + 6 m 1/2" GI pipe

Valve lifting height – piston valve: 4 mm

– foot valve: 4 mm

Valve type – piston valve: floating valve epoxy foam

– foot valve: normal valve

Type of test: performance

Remark: This configuration is equal to configuration 39, but measured after 13×10^6 cycles.

3.5 configuration 41

Pump tested: CWD 49 D

Diameter pump: 49 mm

Stroke: 0.1 m

Static-head: 23.3 m

Immersion depth of pump: 0.5 m

Static pump rod force: 413 N

Internal diameter rising main: 53 mm

External diameter pump rod: 10 mm

Soft element: non

Length pump rod: 10' ϕ 10 + 6 m 1/2" GI pipe

Valve lifting height – piston valve: 4 mm

– foot valve: 4 mm

Valve type – piston valve: floating valve epoxy foam

– foot valve: normal valve

Type of test: performance test

Remark: This test is done to check the influence of the expansion tube. Compare configuration 41 with 40.

3.6 configuration 42

Pump tested: CWD 49 D

Diameter pump: 49 mm

Stroke: 0.1 m

Static-head: 23.3 m

Immersion depth of pump: 0.5 m

Static pump rod force: 413 N

Internal diameter rising main: 53 mm

External diameter pump rod: 10 mm

Soft element: expansion tube 5 meter PVC hose

Length pump rod: 10 m $\phi 10$ + 6 m 1/2" GI pipe

Valve lifting height – piston valve: 4 mm

 – foot valve: 4 mm

Valve type – piston valve: floating valve of polypropen

 – foot valve: normal valve

Type of test: performance and endurance test

Rotation speed during duration test: 3 rps

Number of cycles: 13×10^6

4. RESULTS PERFORMANCE MEASUREMENTS

Each measurement has an index number according the format:

pxxxxyzz

where in :

p = for pump

xxx = diameter pump in mm

yy = configuration

zz = number of measurement

The results of the measurements are given in the annexes.

Configuration 37 annex 1 po4937.....

Configuration 38 annex 2 po4938.....

Configuration 39 annex 3 po4939.....

Configuration 40 annex 4 po4940.....

Configuration 41 annex 5 po4941.....

Configuration 42 annex 6 po4942.....

The results are represented as indicator diagrams for each rotation speed measured. Also the total results, $F_{\max}-F_{\min}$, η_{mech} and η_{vol} are given as function of the rotational speed.

In the force signal vibrations can be seen. The natural frequency of pump rod and the accelerated water mass is:

$$f_0 = \frac{1}{2\pi} \sqrt{\frac{H_{\text{pr}}}{m^*}}$$

$$k = \frac{1}{\sum \frac{1}{k_i}}$$

$$K_i = \frac{E_{\text{pr}_i} A_{\text{pr}_i}}{l_{\text{pr}_i}}$$

$$m^* = m_{wc} + m_p + 1/3 m_{pr} + \frac{A^2}{A_{rm}} * l_{rm} \rho_w$$

f_0	= natural frequency	[Hz]
E_{pr}	= elasticity modulus pump rod	[N/m ²]
A_{pr}	= cross section pump rod	[m ²]
A_{rm}	= cross section rising main	[m ²]
l_{pr}	= length pump rod	[m]
l_{rm}	= length rising main	[m]
m_{wc}	= mass water in cilinder	[kg]
m_p	= mass piston	[kg]
m_{pr}	= mass pump rod	[kg]
m^*	= seeming mass	[kg]
ρ_w	= density water	[kg/m ³]

For the configurations 37 to 42 the data is:

l_{pr_1}	= 6 m 1/2 " GI pipe
A_{pr_1}	= $1.53 \times 10^{-4} \text{ m}^2$
l_{pr_2}	= 18 m $\phi 10$ AISI 316
A_{pr_2}	= $0.7854 \times 10^{-5} \text{ m}^2$
$E_{pr_{1,2}}$	= $2.1 \times 10^{11} \text{ N/m}^2$
$m_{pr_{1,2}}$	= 18.8 kg
m_{wc}	= 0.33 kg
m_p	= 0,6 kg
A_{rm}	= $2.12 \times 10^{-3} \text{ m}^2$
l_{rm}	= 24 m
A_p	= $1.8 \times 10^{-3} \text{ m}^2$

$$K_1 = \frac{2.1 \times 10^{11} \cdot 1.53 \times 10^{-4}}{6} = 5.355 \times 10^6 \text{ N/m}$$

$$K_2 = \frac{2.1 \times 10^{11} \cdot 0.785 \times 10^{-5}}{18} = 9.1583 \times 10^4 \text{ N/m}$$

$$\frac{1}{K} = \frac{1}{5.355 \times 10^6} + \frac{1}{9.1583 \times 10^4} \rightarrow K = 9.0043 \times 10^4 \text{ N/m}$$

up stroke

$$m^* = 0.33 + 0.6 + \frac{1}{3} \times 18.8 + \frac{(1.8 \times 10^{-3})^2}{2.12 \times 10^{-3}} * 24 \times 1000 = 44 \text{ kg}$$

down stroke

$$m^* = 0.6 + \frac{1}{3} \times 18.8 = 6.9 \text{ kg}$$

The natural frequency of the pump system is in:

upward stroke

$$f_{0\text{up}} = \frac{1}{2\pi} \sqrt{\frac{9.0043 \times 10^4}{44}} = 7.19 \text{ Hz}$$

downward stroke

$$f_{0\text{down}} = \frac{1}{2\pi} \sqrt{\frac{9.0043 \times 10^4}{6.9}} = 18 \text{ Hz}$$

In the configurations with expansion tube (37, 38, 39, 40, 42) frequencies of 33 up to 54 Hz are measured. In the configuration without expansion tube (41) frequencies of 11.6 to 14.4 Hz are measured. The difference in the frequencies between pump with and without expansion tube indicate that the expansion tube reduces the seeming mass and with this the pump rod forces. In figure 4.1 the effect of the expansion tube on the maximum force step as function of the rotation speed is given of configuration 37, 38, 39 and 41. A reduction of $\pm 30\%$ is possible in the force-step, important for the fatigue-lifetime of pump rod, with an expansion tube.

In fig. 4.2 and 4.3 the volumetric and mechanical efficiency are given of the same configurations 37, 38, 39, and 41. The volumetric efficiency of the pump with normal valves (37, 38) is somewhat lower at the low rotation speeds due to the leakhole, pumps with floating valve don't have a leakhole. The effect of the expansion tube on the volumetric efficiency is almost zero compare 39 and 41. The mechanical efficiency reduces considerable at 3 rps about 20% and in the working area (1 rps to 2) 5 to 12%. For rotation speeds higher than 3 rps the mechanical efficiency decreases fast. The behavior of the two different types of floating valves is somewhat different. The rotation speed at which the valves closes are different. The epoxy foam valve closes at ≈ 0.31 rps and the polypropylene closes at 0,2 rps. The optimal valve close rotation speed, for the CWD 2000, is ≈ 0.4 rps.

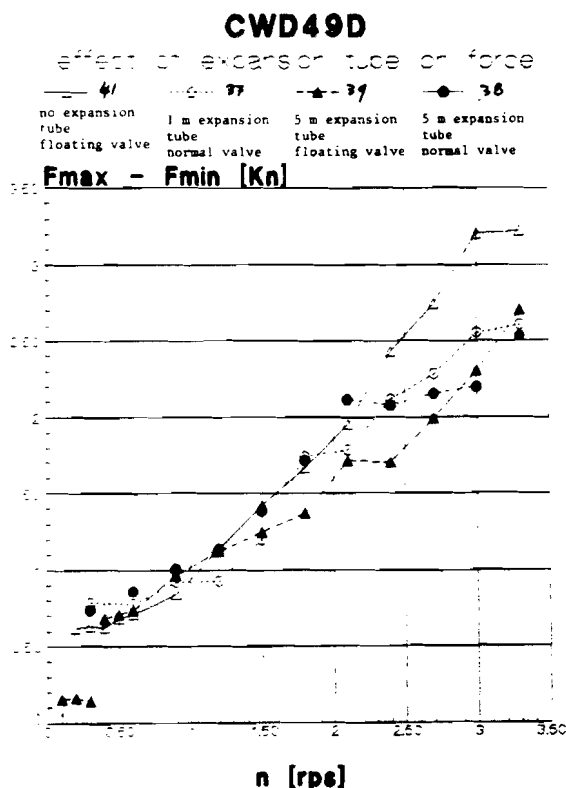


Figure 4.1

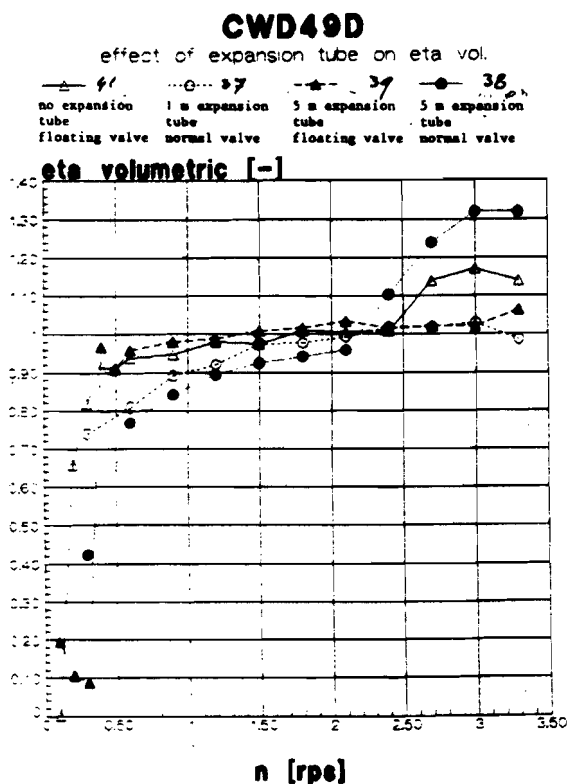


Figure 4.2

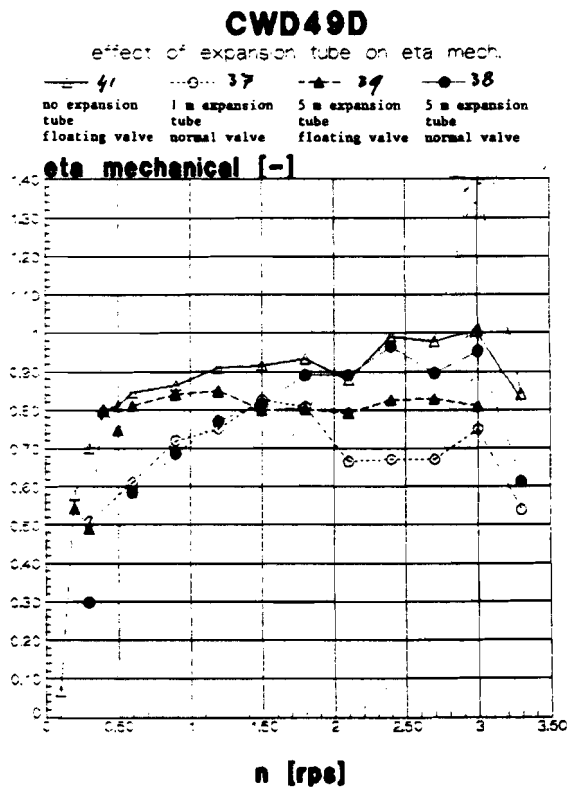


Figure 4.3

5. RESULTS ENDURANCE TEST

The endurance test started with configuration 37 (1 meter expansion tube and normal valve). The rotation speed was adjusted at 3 rps. After $1,6 \times 10^6$ cycles the reinforced PVC tube was bursted (see fig. 5.1).

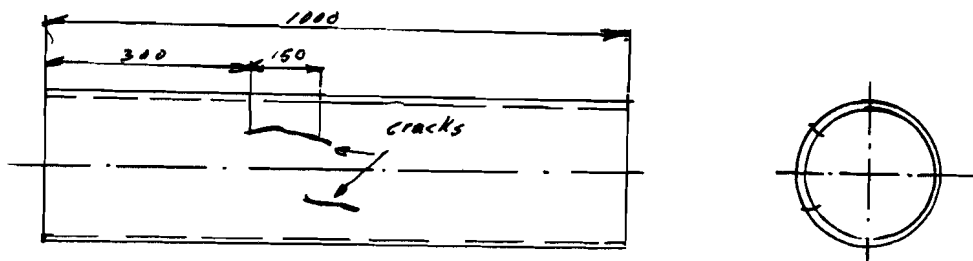


Fig. 5.1 Cracks in pvc expansion tube of 1 meter after 1.6×10^6 cycles.

The 1 meter reinforced PVC was replaced by the same type of tube with a length of 5 meter. Also the normal valve was replaced by a floating valve made of epoxy and foam configuration 39. The rotation speed was adjusted at 3 rps and the endurance test continued starting at 0 cycles and stopping at 26×10^6 cycles.

Problems and breakdowns during the endurance test where:

- 1) at $\approx 12 \times 10^6$ cycles pump rod broken, at the end of the thread (see fig. 5.2).

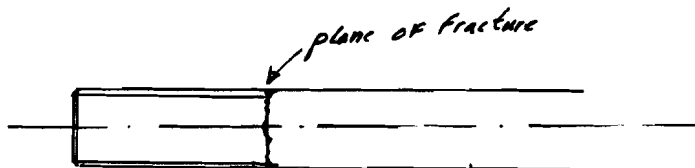


Fig. 5.2

It must be noticed that this pump rod was bended, at the place of the crack, during installation and bended back, which caused the initial cracks for the failure.

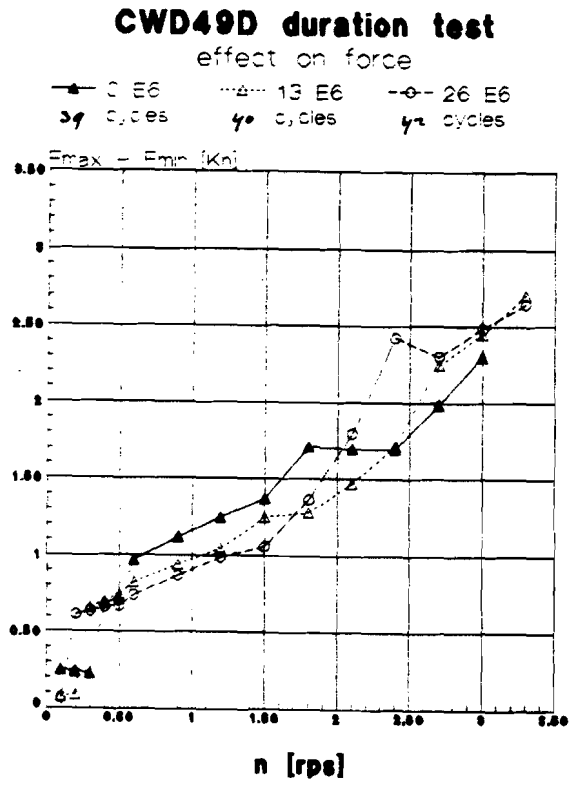


Figure 5.3

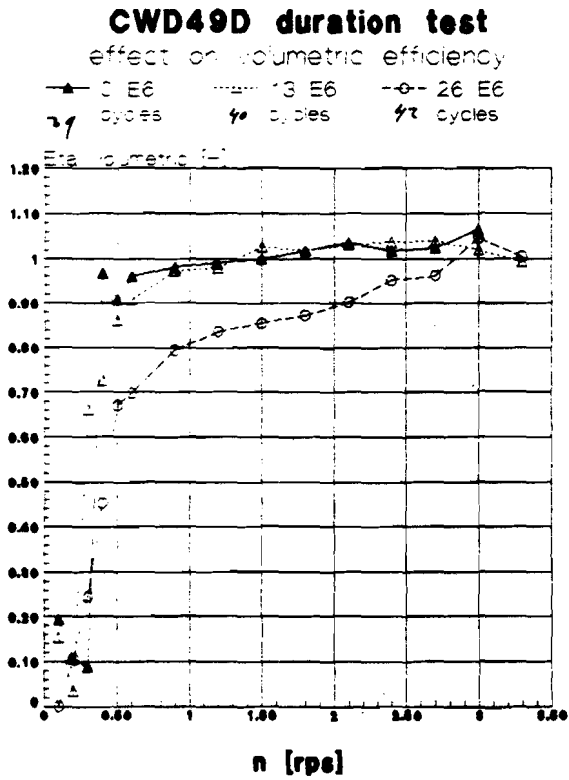


Figure 5.4

CWD49D duration test

effect on mechanical efficiency

—▲— 0 E6 -△- 13 E6 -○- 26 E6
 37 cycles 40 cycles 42 cycles

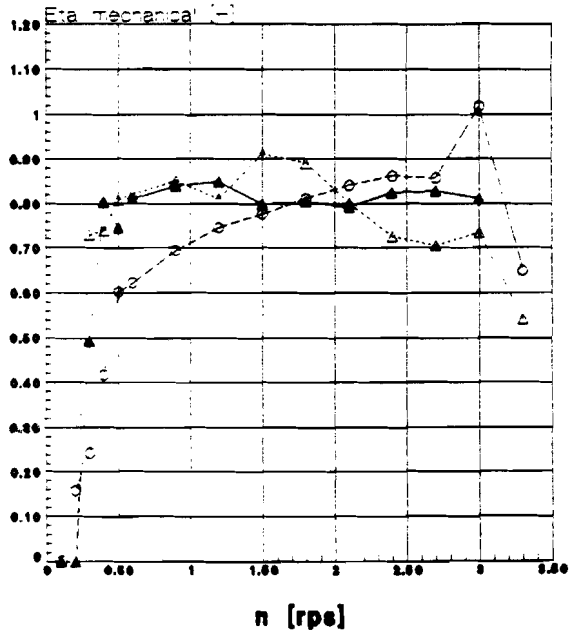


Figure 5.5

- 2) at 12.6×10^6 cycles the floating valve showed cracks and one rubber, at valve seatside, had come loose. The epoxy foam valve was replaced by a polypropylene valve.
- 3) at 26×10^6 cycles the 4th pump rod seen from pump side failed due to fatigue.

Performance

During the duration test the performance of the pump was measured at:

0×10^6 (po4939.—), 13×10^6 (po4940).. and 26×10^6 (po4942..) cycles.

The results are given in figures 5.3, 5.4 and 5.5. The force step $F_{\max}-F_{\min}$ doesn't change very much at 3 rps at 2.4 rps the difference is ± 0.7 KN probably the difference is due to the different valves (epoxy foam, polypropylene).

The volumetric efficiency doesn't change up to 13×10^6 cycles. Between 13×10^6 cycles it decreases slowly but is still good in the working area of 1 to 2 rps (see fig. 5.5).

The mechanical efficiency decreased for the lower rotation speeds $n \geq 1.7 \leq 3.3$ it increased during duration test (see fig. 5.6).

Wear

No abnormal wear is found after 27.6×10^6 cycles. Corrosion or cavitation damage is not found. The foot valve (bronze on bronze) still closes very well and hardly leaks. The floating valve of polypropylene didn't show any wear after 13×10^6 cycles while the epoxy foam valve failed somewhere between the 10×10^6 and 13×10^6 cycles.

6. CONCLUSIONS AND RECOMMENDATIONS

- The expansion tube made of 5 meter reinforced PVC suction hose functions well, forces are reduced with $\pm 30\%$ at higher rotation speeds.
- The fatigue lifetime of the 1 meter expansion tube is too short, a length of 5 meter survived 26×10^6 cycles at maximum load.
It is expected that the lifetime, of the 5 meter expansion tube, is longer than 5 years. Probably shorter expansion tubes will have a sufficiently long lifetime but duration tests are necessary to verify this.
- The fatigue lifetime of the pump rods is good. The failure of pump rod after 27.6×10^6 cycles (total of cycles during duration test included configuration 37) is equal to ≈ 106 days running at maximum speed of 3 rps. In practice the CWD 2000 runs only with a frequency of ± 1 cycle per minute at 3 rps average a year (Almere testfield). With this the real lifetime of the pump rod in practice becomes:

$$K = \frac{27,6 \times 10^6}{1.60 \cdot 24 \cdot 365} = 52.5 \text{ years in fresh water}$$

- Pump rods which are bended during transport or assembly must not be used because the negative effect on the lifetime. Also much attention has to be paid to cut the thread straight on the pump rods to avoid an introduction of a bending moment.
- The volumetric efficiency did not decrease a lot and the cup is still in a good condition. This cup was made according the latest method, impregnation during 2 minutes in candlewax of 80°C and pressing it in a mold with a diameter 3% less than the pump diameter.
- The floating valve made of epoxy and foam failed in a short time, cracks appeared in the epoxy layer, hence more research has to be done on material choice and production of the floating valve.

- The floating valve made out of polypropylene did not show any wear and seems a good alternative for the epoxy foam valve. However, the closing behavior is not optimal, it closes too fast.
- More research has to be done on the optimal design of the valve (dimensions and valve lifting height) to reach the optimal valve closure rotation speed of 0.4 rps for the CWD 2000.
- No corrosion or cavitation is noticed on the pump parts. All parts are in a very good condition and no extensive wear was found.

Annex I

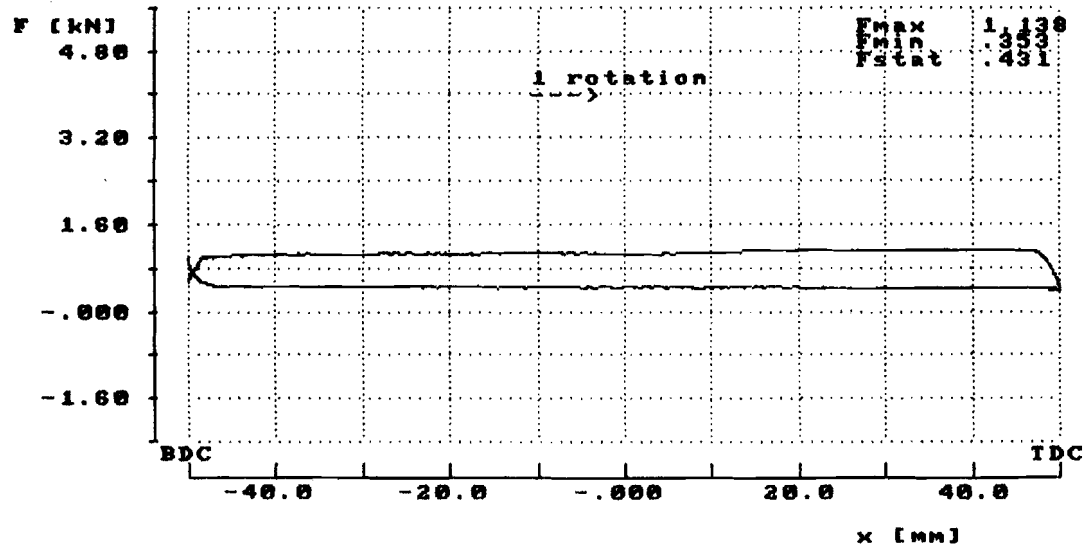
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19.089
Pout[W]:
9.716

Evol :
.740
Emech :
.509

head [m] :
23.3
pump [mm] :
49.0
stroke [mm]:
100.0



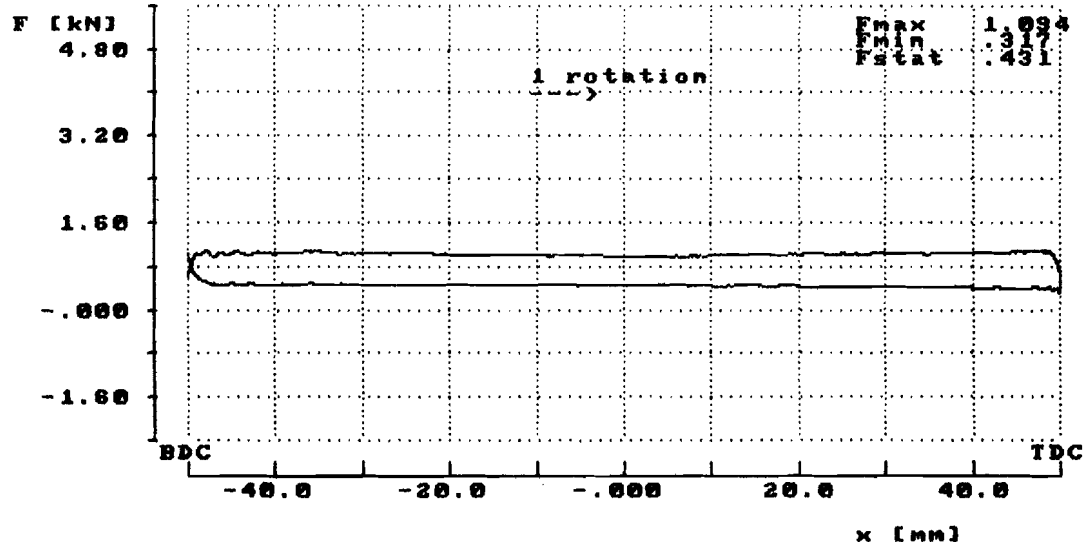
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Emech :
.611

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23.3
pump [mm] :
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stroke [mm]:
100.0



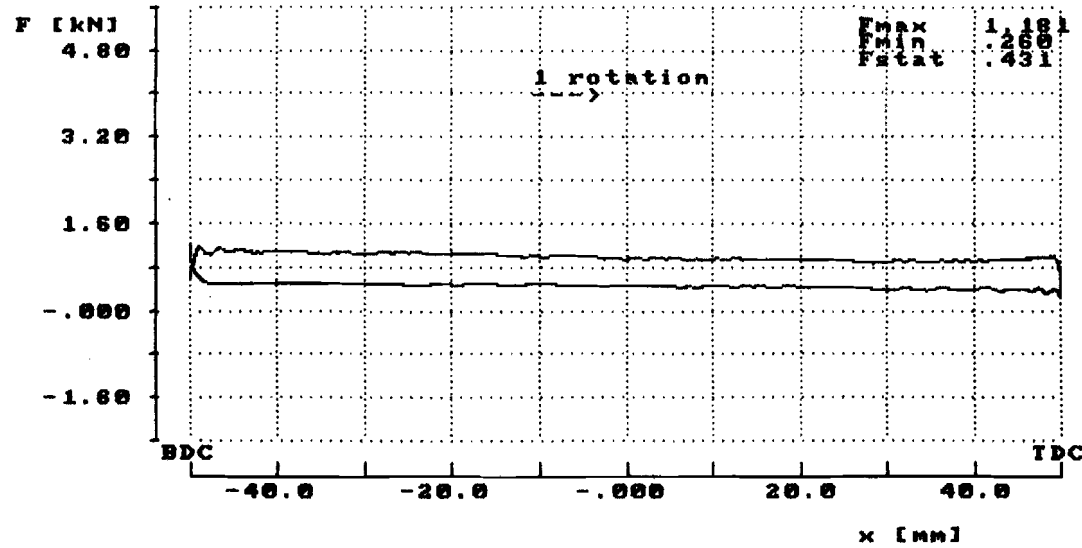
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47.899
Pout[W]:
34.327

Evol :
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Emech :
.720

head [m] :
23.3
pump [mm] :
49.0
stroke [mm]:
100.0



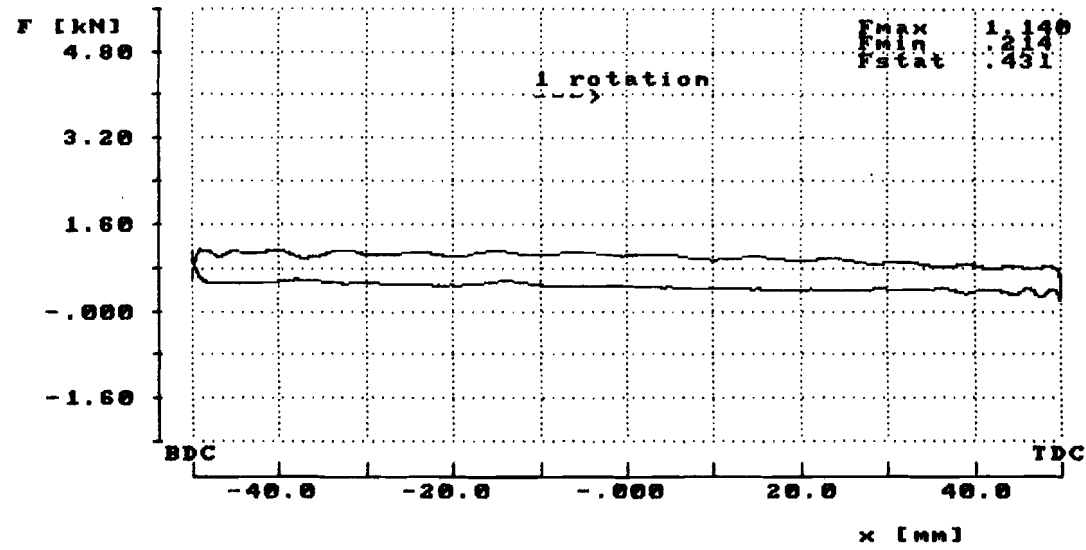
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meanflow (dm3/s) : .150 sample frequency (Hz): 1830.812

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Pin [W]:
63.947
Pout[W]:
47.979

Evol :
.929
Emech :
.750

head [m] :
23.3
pump [mm] :
49.0
stroke [mm]:
100.0



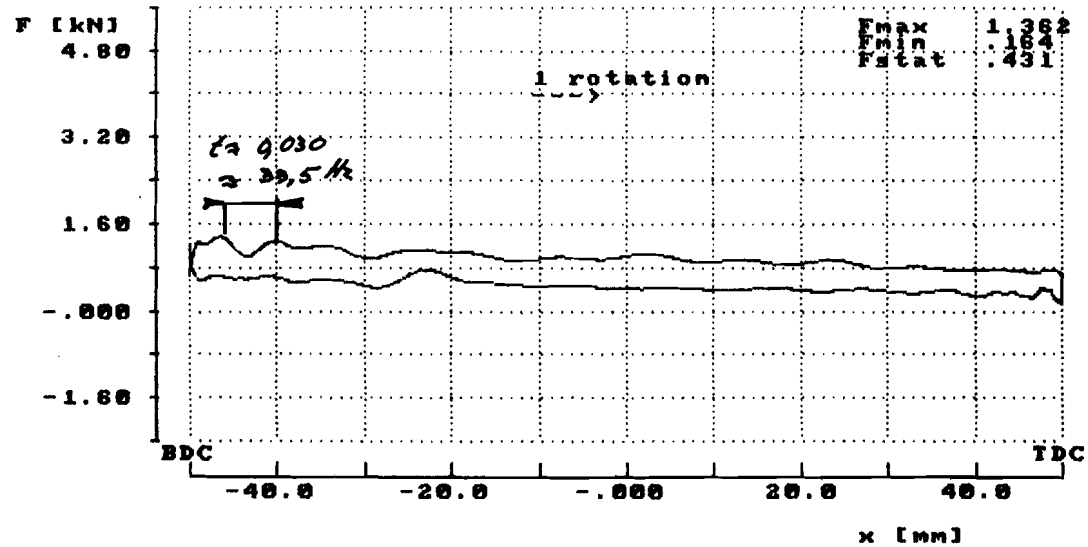
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meanflow (dm3/s) : .210 sample frequency (Hz): 2453.736

filename --> B:P0493705_

Pin [W]:
75.835
Pout[W]:
62.832

Evol :
.978
Enech :
.829

head [m] :
23.3
pump [mm] :
49.0
stroke [mm]:
100.0



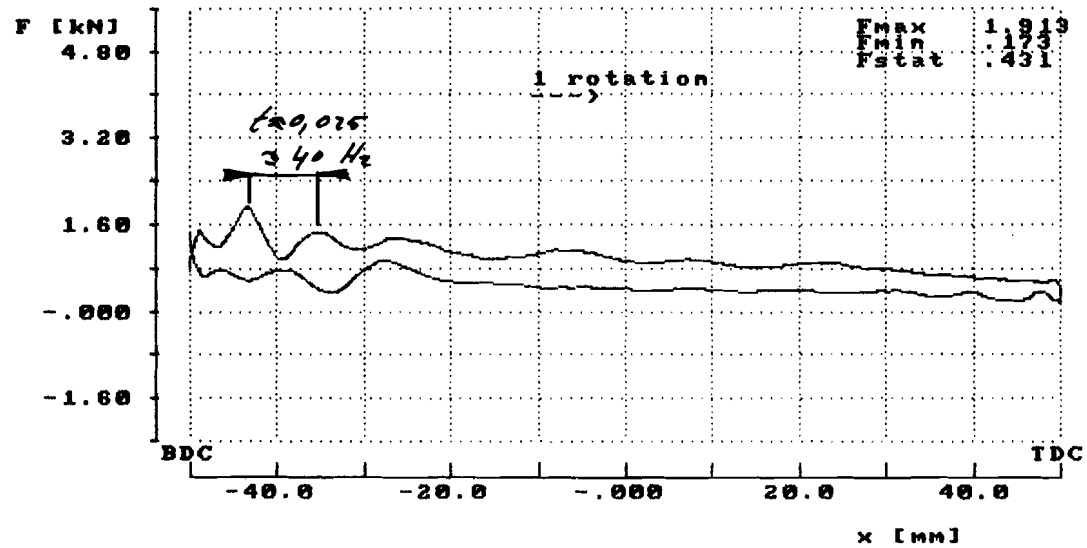
rotationspeed (rps): 1.493
meanflow (dm3/s) : .275 sample frequency (Hz): 3057.756

filename --> P0493706_

Pin [W]:
94.444
Pout[W]:
76.234

Evol :
.978
Emech :
.887

head [m] :
23.3
PUMP [mm] :
49.8
stroke [mm]:
100.0



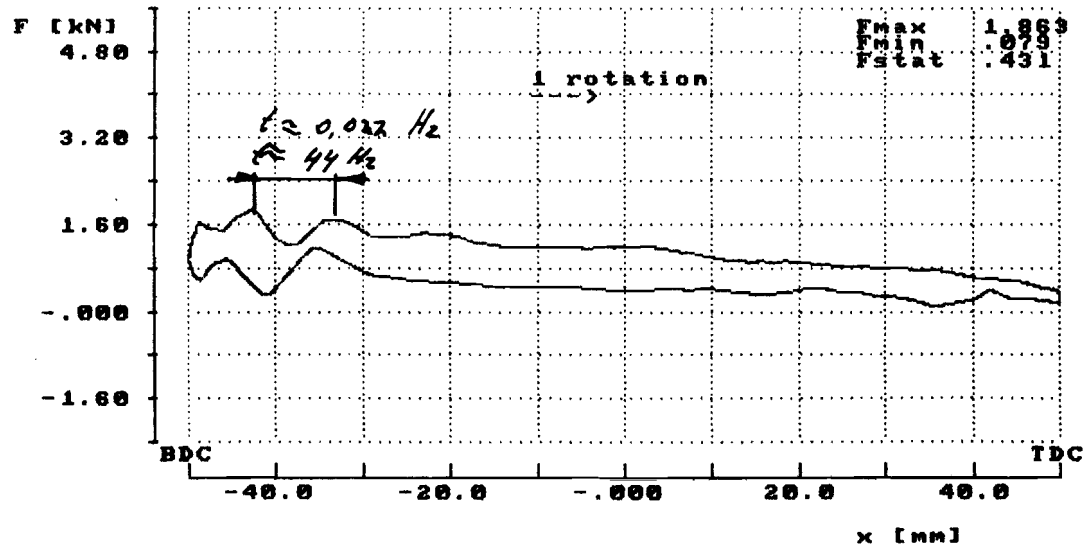
rotationspeed (rps): 1.809
meanflow (dm3/s) : .334 sample frequency (Hz): 3705.458

filename --> P0493707_

Pin [W]:
135.361
Pout[W]:
90.047

Evol :
.994
Emech :
.665

head [m] :
23.3
pump [mm] :
48.0
stroke [mm]:
100.0



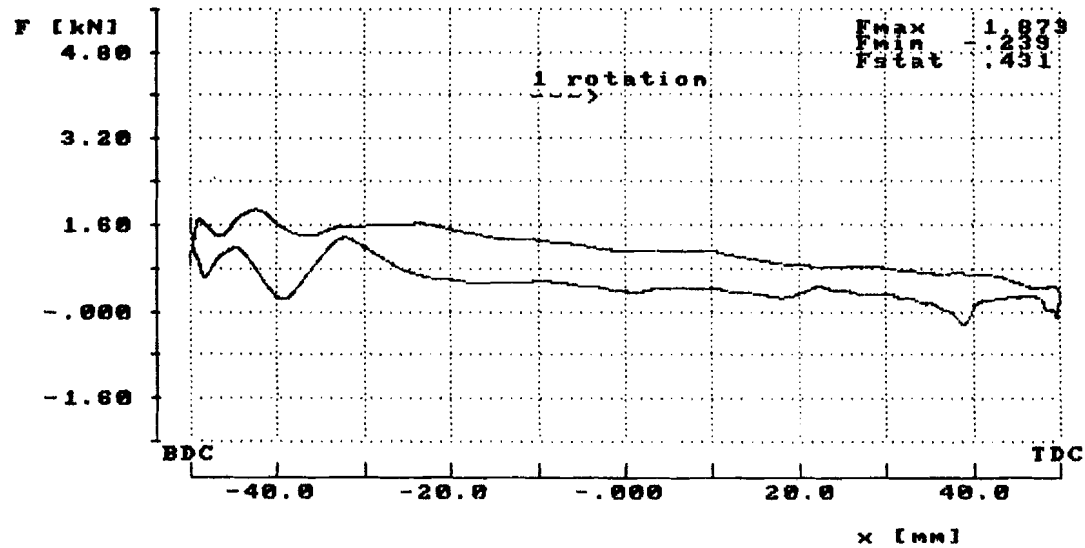
rotationspeed (rps): 2.102
meanflow (dm3/s) : .394 sample frequency (Hz): 4304.206

filename --> P0493708_

Pin [W]:
156.895
Pout[W]:
105.325

Evol :
1.018
Emech :
.671

head [m] :
23.3
pump [mm] :
49.0
stroke [mm]:
100.0



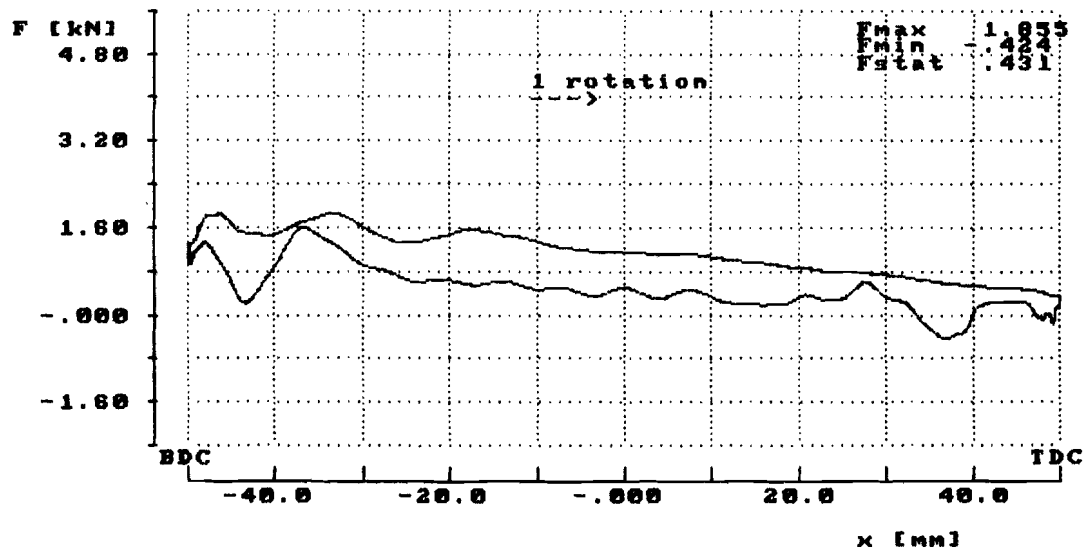
rotationspeed (rps): 2.400
meanflow (dm3/s) : .461 sample frequency (Hz): 4915.305

filename --> P0493709_

Pin [W]:
176.104
Pout[W]:
118.239

Evol :
1.019
Emech :
.671

head [m] :
23.3
pump [mm] :
49.0
stroke [mm]:
100.0



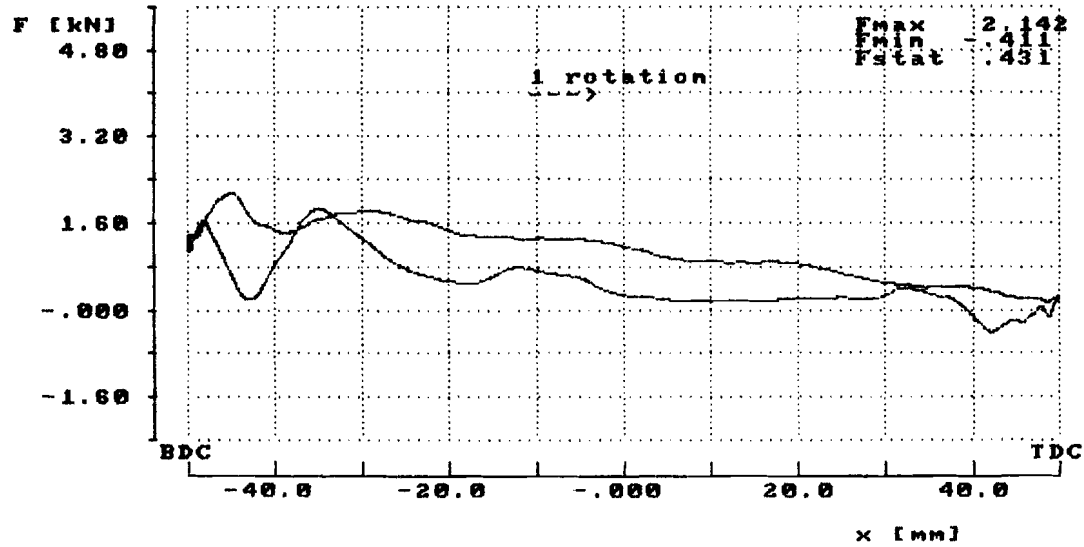
rotationspeed (rps): 2.691
meanflow (dm3/s) : .517 sample frequency (Hz): 5510.738

filename --> P0493710_

Pin [W]:
177.434
Pout[W]:
133.345

Evol :
1.031
Emech :
.752

head [m] :
23.3
pump [mm] :
49.0
stroke [mm]:
100.0



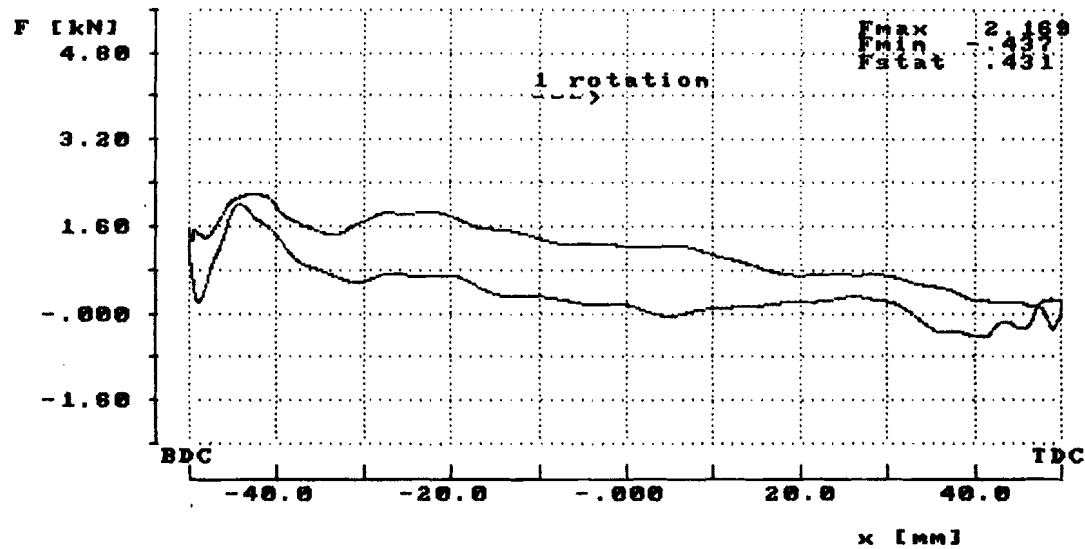
rotationspeed (rps): 3.000
meanflow (dm3/s) : .583 sample frequency (Hz): 6144.131

filename --> P0493711_

Pin [W]:
259.171
Pout[W]:
140.141

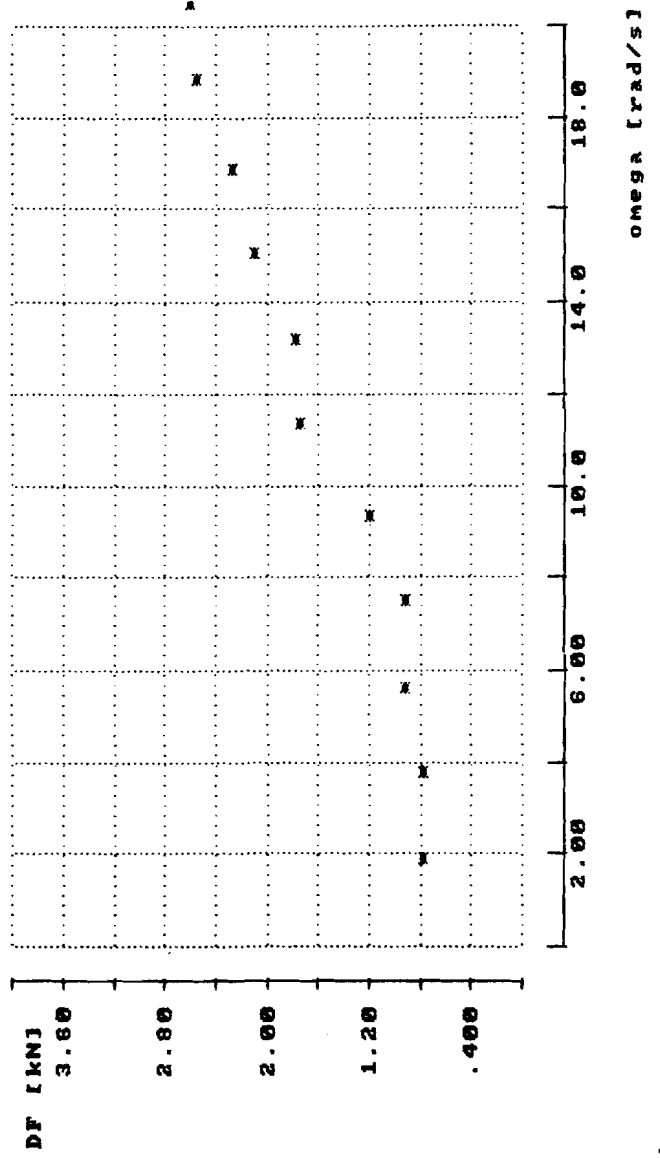
Evol :
.988
Emech :
.541

head [m] :
23.3
pump [mm] :
49.0
stroke [mm]:
100.0

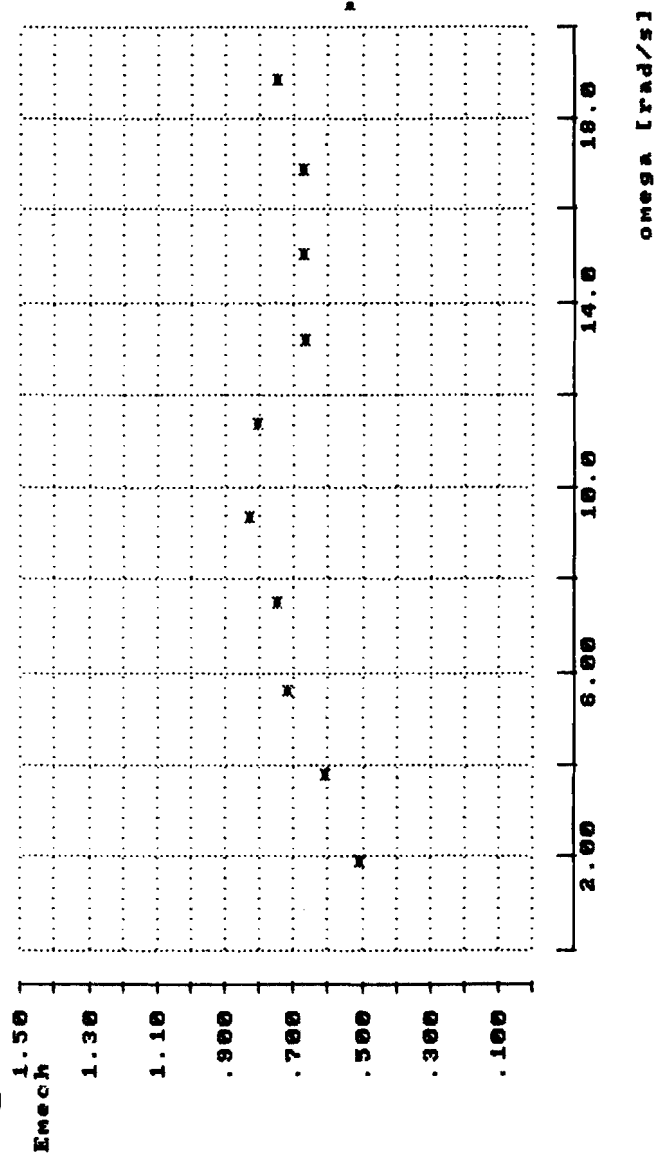


rotationspeed (rps): 3.296
meanflow (dm3/s) : .613 sample frequency (Hz): 6751.163

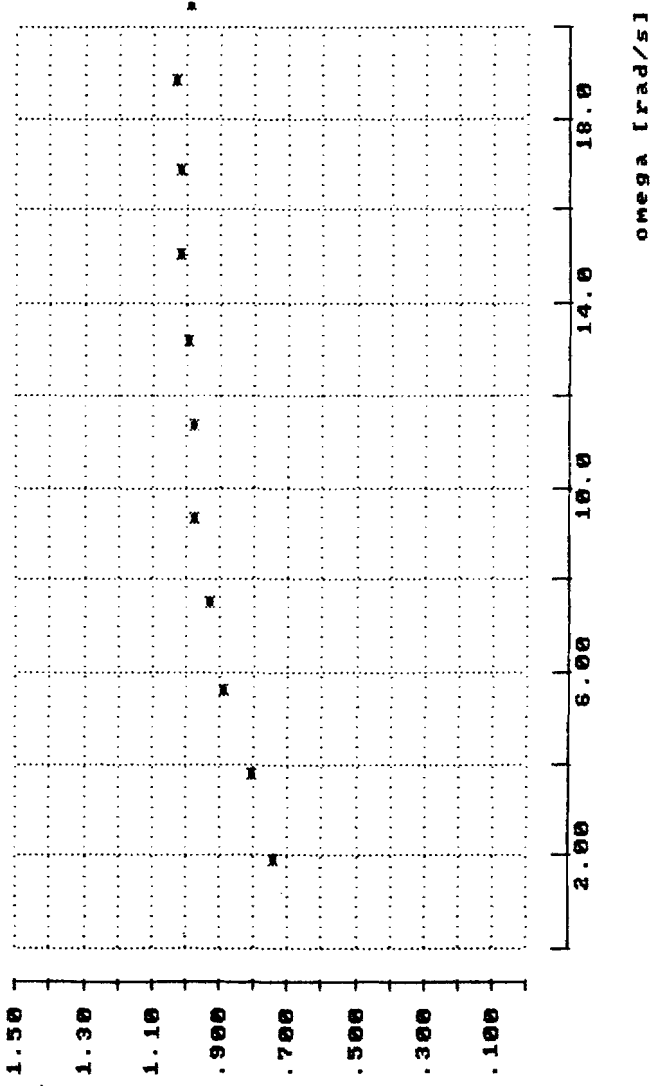
filename --> P04937



filename --> P0493711_



filename --> P0493711



Annex II

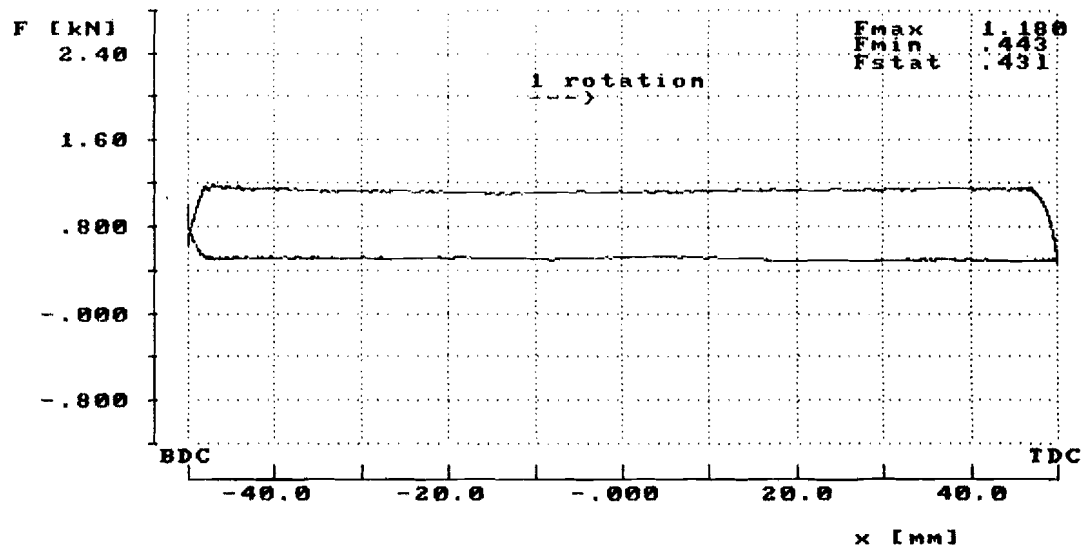
Configuration 38

filename --> P0493801_

Pin [W]:
18.323
Pout[W]:
5.469

Evol :
.423
Emech :
.298

head [m] :
23.3
pump [mm] :
49.0
stroke [mm]:
100.0



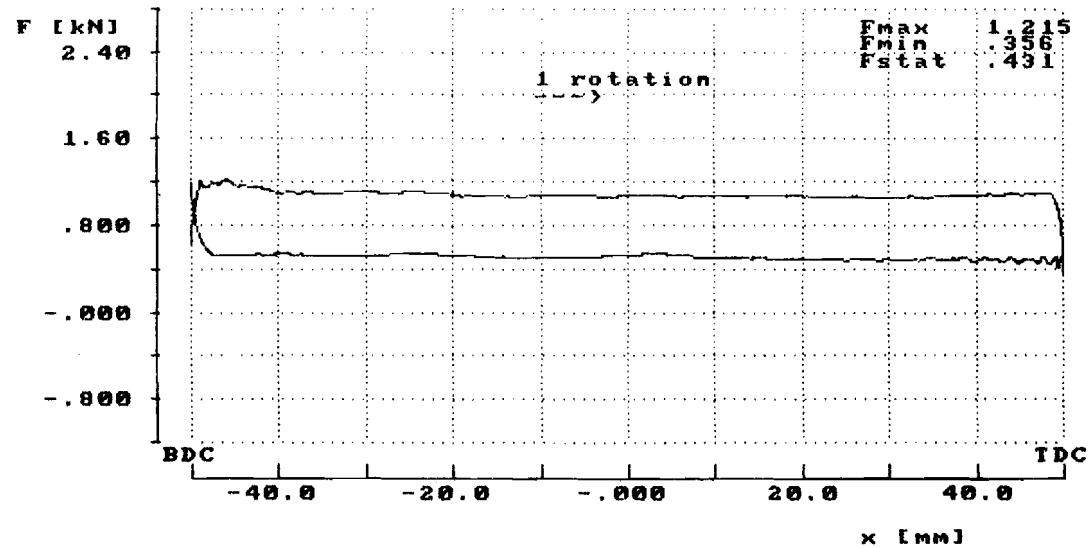
rotationspeed (rps): .300
meanflow (dm3/s) : .024 sample frequency (Hz): 614.262

filename --> P0493802_

Pin [W]:
33.380
Pout[W]:
19.499

Evol :
.768
Emech :
.584

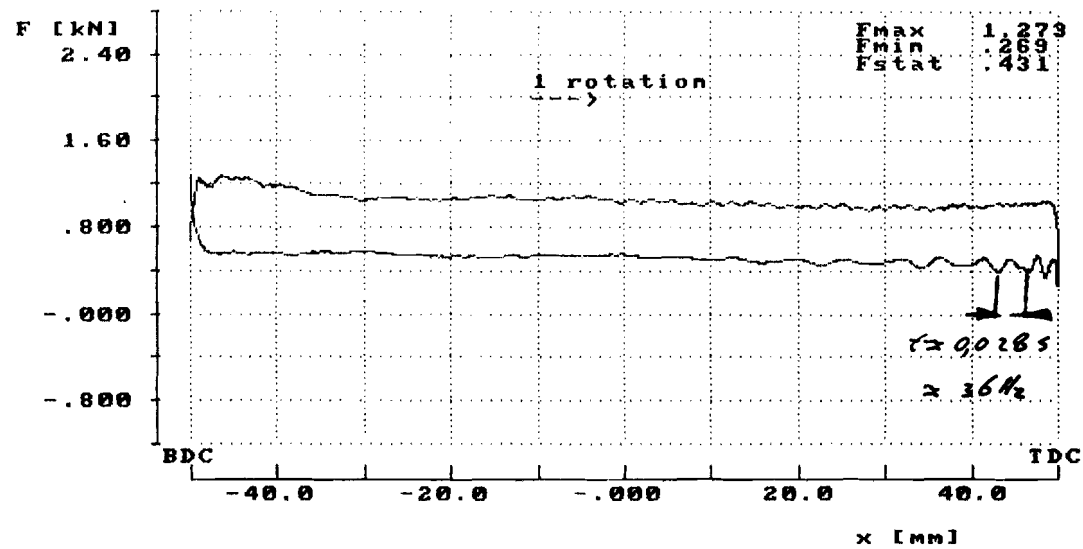
head [m] :
23.3
pump [mm] :
49.0
stroke [mm]:
100.0



rotationspeed (rps): .589
meanflow (dm3/s) : .085 sample frequency (Hz): 1206.533

filename --> P0493803_

Pin [W]:
47.425
Pout[W]:
32.472
Evol :
.841
Emech :
.685
head [m] :
23.3
pump [mm] :
49.0
stroke [mm]:
100.0



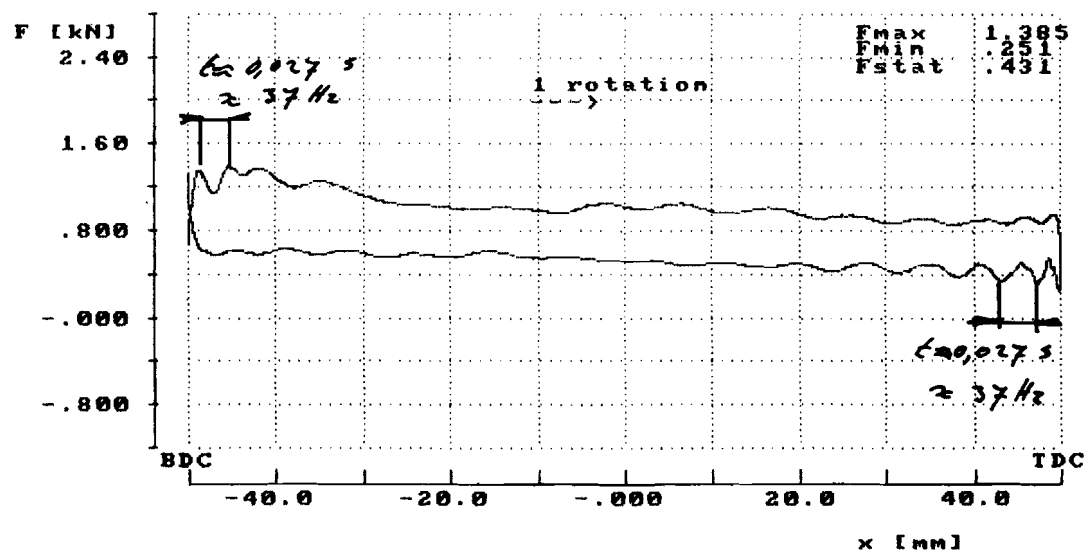
rotationspeed (rps): .896
meanflow (dm3/s) : .142 sample frequency (Hz): 1835.557

filename --> P0493804_

Pin [W]:
59.730
Pout[W]:
46.001

Evol :
.893
Emech :
.770

head [m] :
23.3
pump [mm] :
49.0
stroke [mm]:
100.0



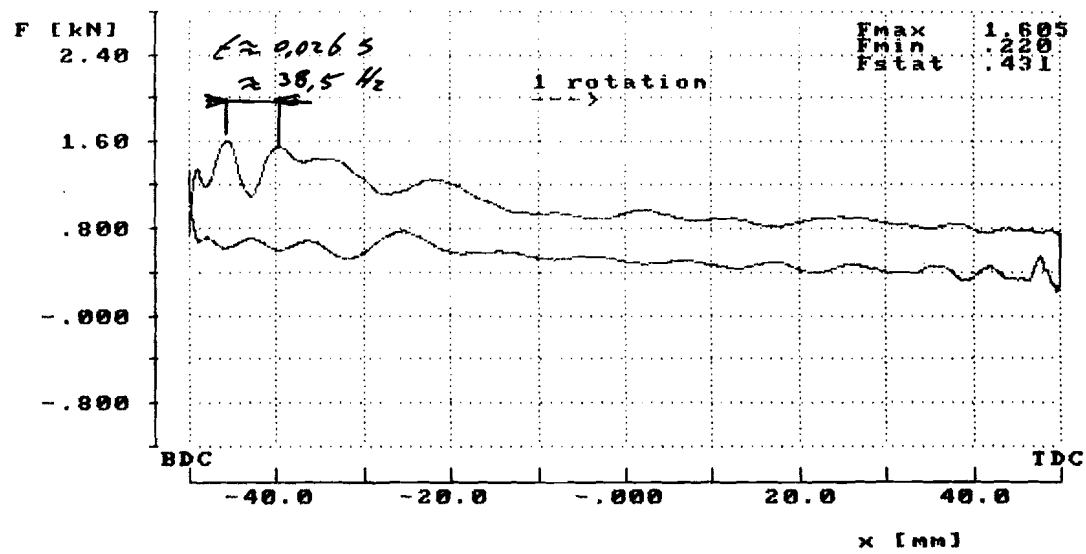
rotationspeed (rps): 1.195
meanflow (dm3/s) : .201 sample frequency (Hz): 2447.711

filename --> P0493805_

Pin [W]:
73.252
Pout[W]:
59.675

Evol :
.924
Emech :
.815

head [m] :
23.3
pump [mm] :
49.0
stroke [mm]:
100.0



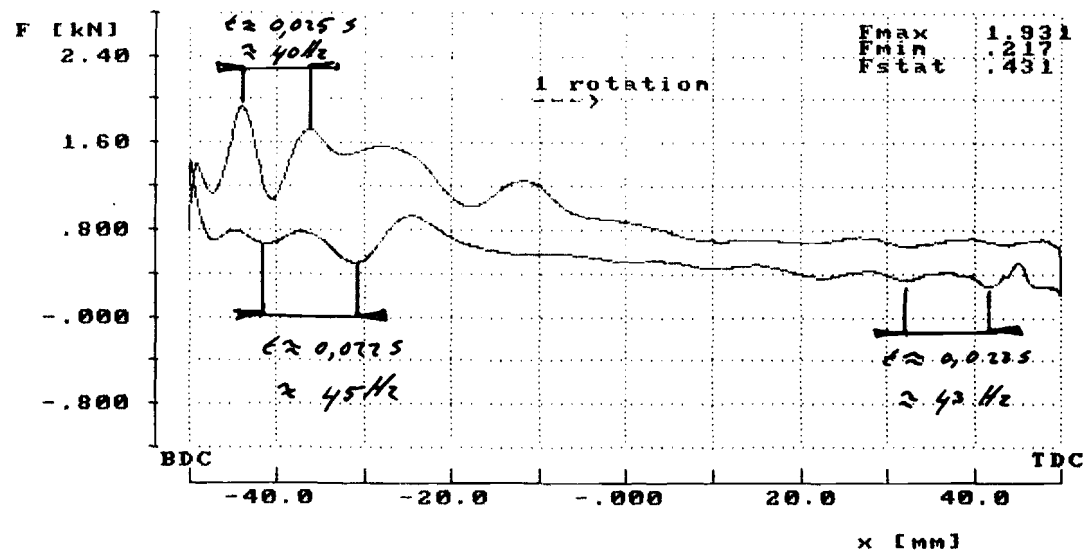
rotationspeed (rps): 1.499
meanflow (dm3/s) : .261 sample frequency (Hz): 3069.806

filename --> P0493806_

Pin [W]:
81.614
Pout[W]:
72.628

Evol :
.941
Emech :
.890

head [m] :
23.3
pump [mm] :
49.0
stroke [mm]:
100.0



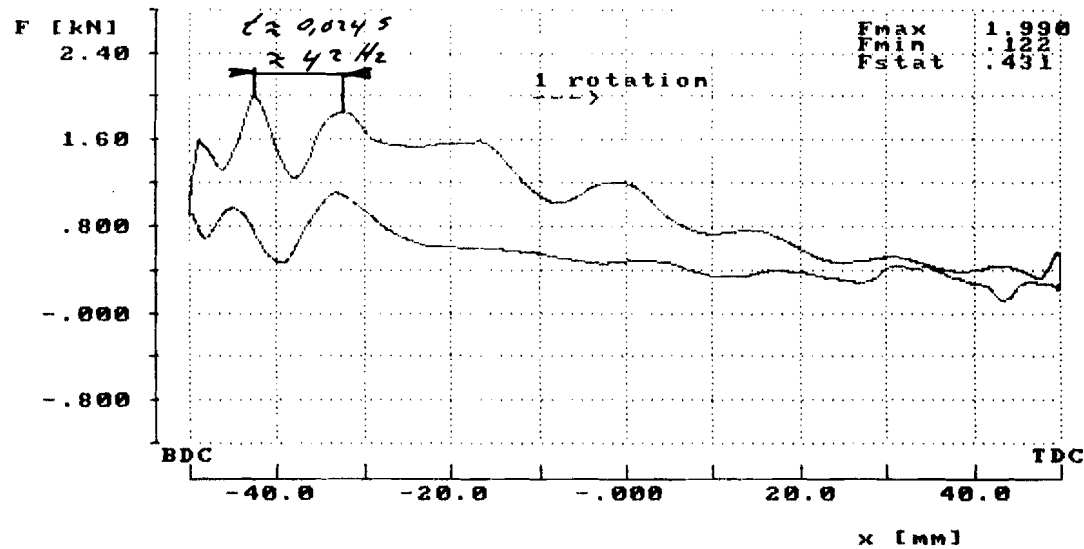
rotationspeed (rps): 1.791
meanflow (dm3/s) : .318 sample frequency (Hz): 3667.047

filename --> P0493807_

Pin [W]:
107.373
Pout[W]:
86.881

Evol :
.959
Emech :
.809

head [m] :
23.3
pump [mm] :
49.0
stroke [mm]:
100.0



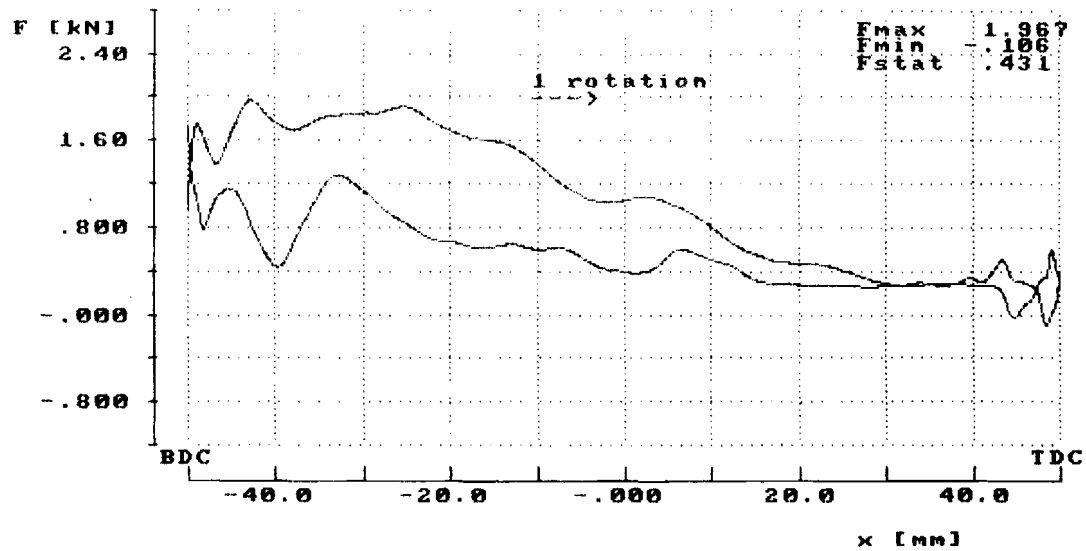
rotationspeed (rps): 2.102
meanflow (dm3/s) : .380 sample frequency (Hz): 4304.958

filename --> P0493808_

Pin [W]:
118.365
Pout[W]:
114.171

Evol :
1.104
Emech :
.965

head [m] :
23.3
pump [mm] :
49.0
stroke [mm]:
100.0



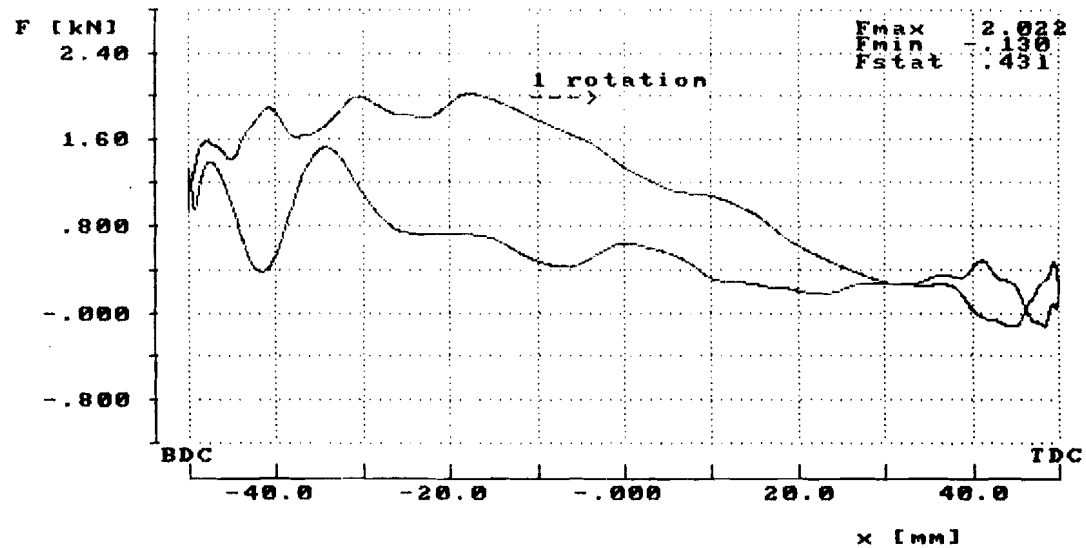
rotationspeed (rps): 2.399
meanflow (dm3/s) : .499 sample frequency (Hz): 4913.497

filename --> P0493809_

Pin [W]:
161.506
Pout[W]:
144.621

Evol :
1.239
Emech :
.895

head [m] :
23.3
pump [mm] :
49.0
stroke [mm]:
100.0



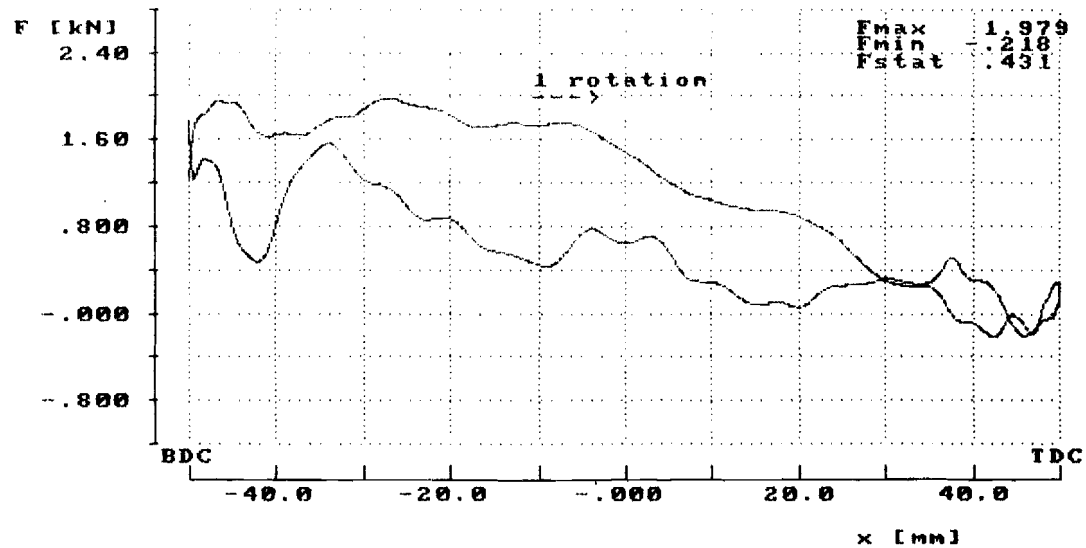
rotationspeed (rps): 2.707
meanflow (dm3/s) : .633 sample frequency (Hz): 5544.630

filename --> P0493810_

Pin [W]:
179.366
Pout[W]:
170.760

Evol :
1.320
Erech :
.952

head [m] :
23.3
pump [mm] :
49.0
stroke [mm]:
100.0



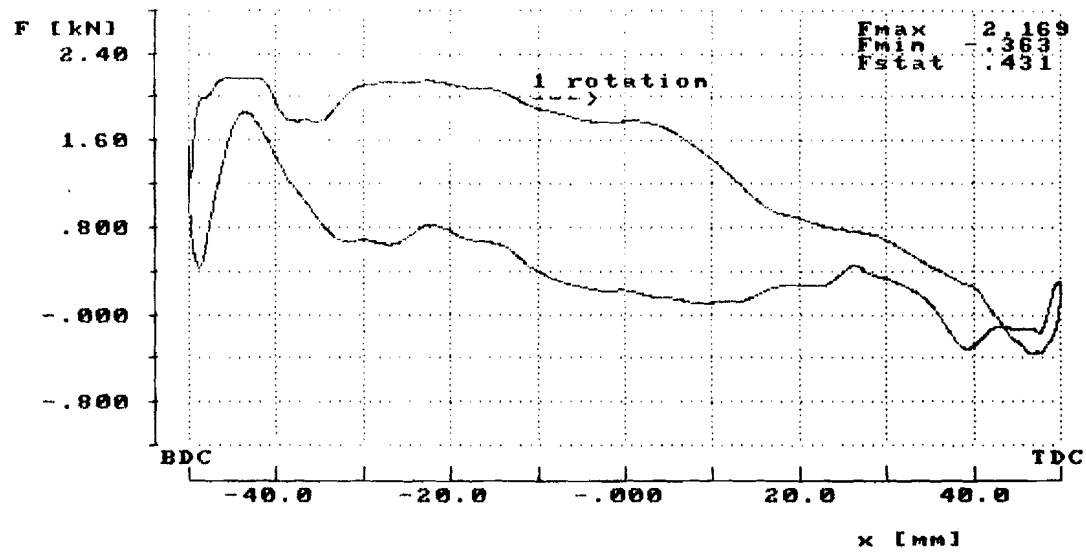
rotationspeed (rps): 3.002
meanflow (dm3/s) : .747 sample frequency (Hz): 6148.649

filename --> P0493811_

Pin [W]:
306.938
Pout[W]:
188.138

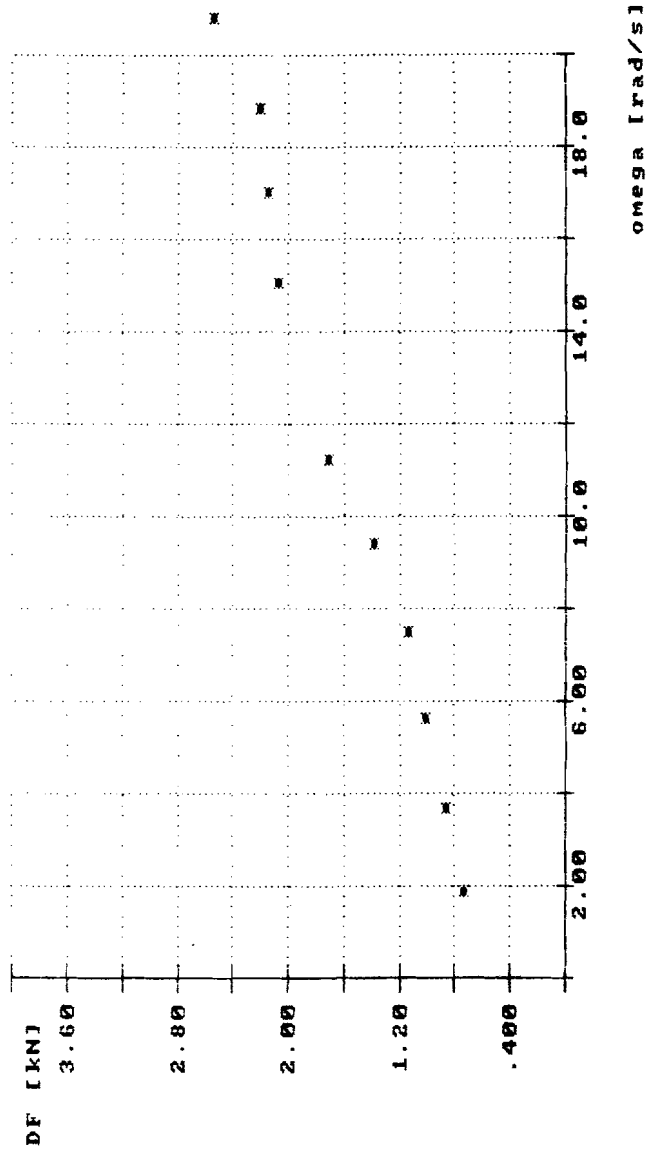
Evol :
1.319
Emech :
.613

head [m] :
23.3
pump [mm] :
49.0
stroke [mm]:
100.0

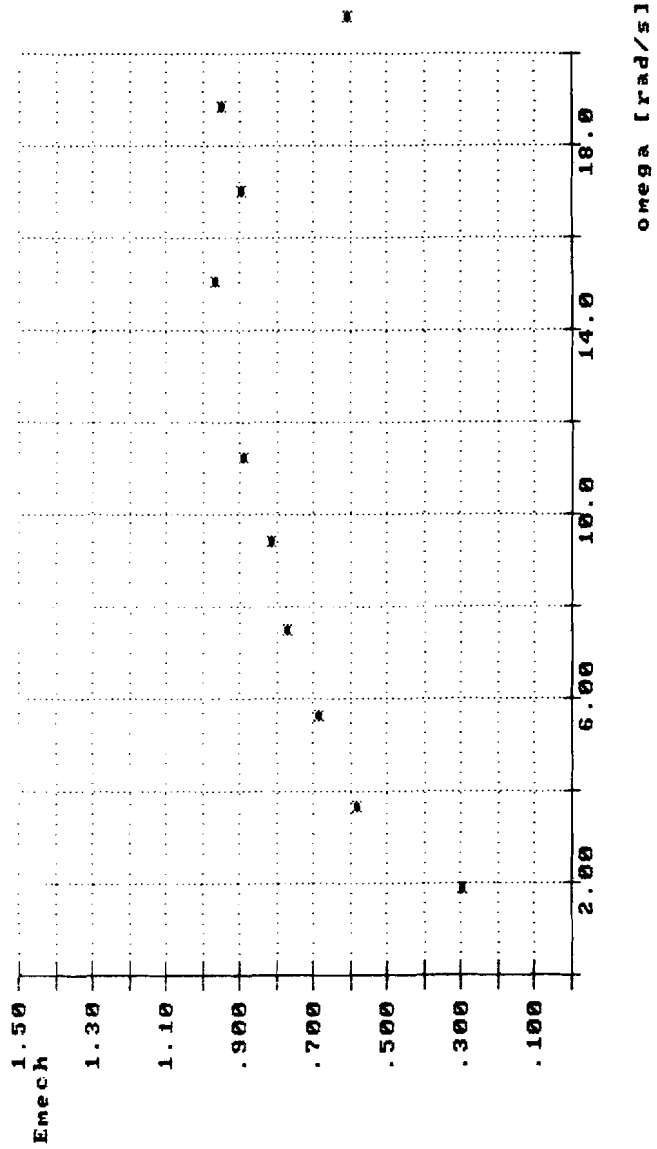


rotationspeed (rps): 3.310
meanflow (dm3/s) : .823 sample frequency (Hz): 6778.276

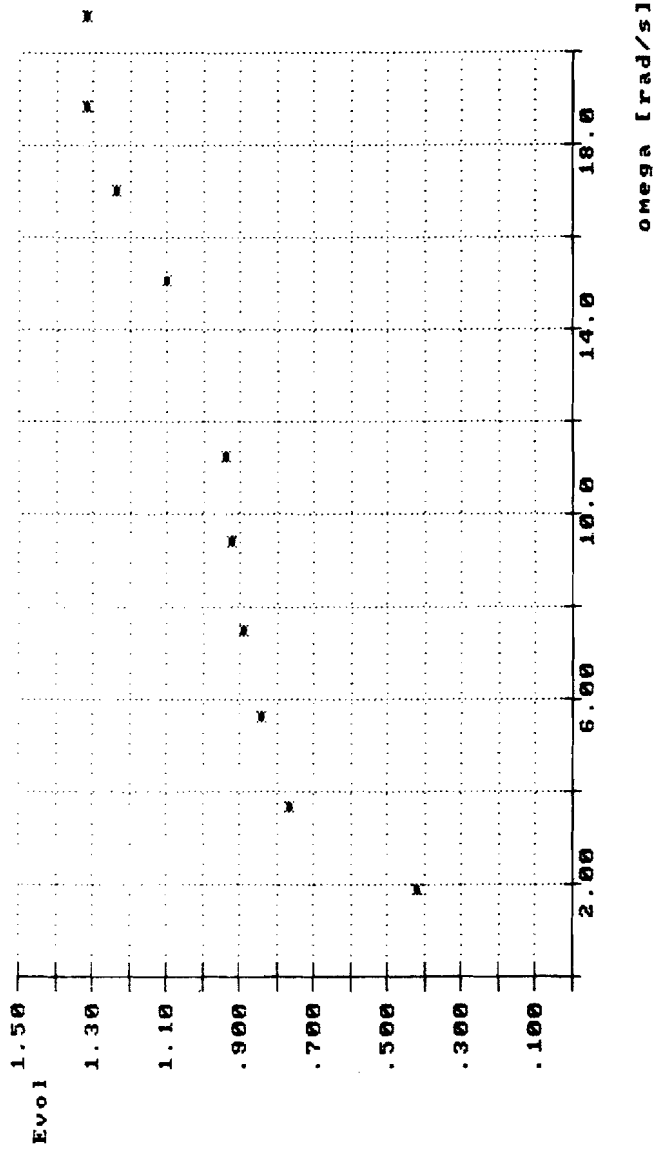
filename --> -



filename --> --



filename --> -



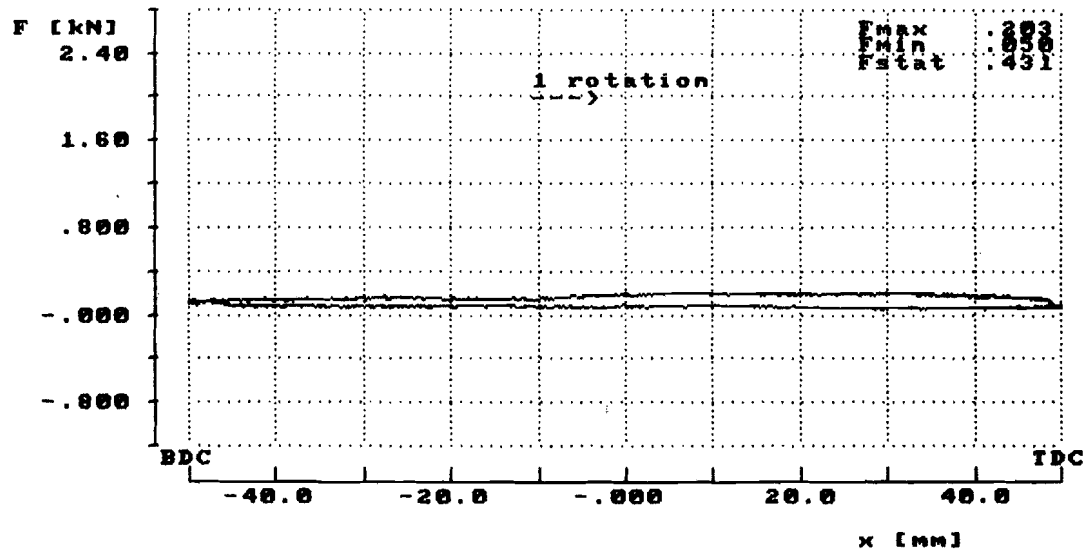
L

Annex III

Configuration 39

filename --> P0493901_

Pin [W]:
.872
Pout[W]:
.832
Evol :
.195
Enech :
.954
head [m] :
23.3
pump [mm] :
49.0
stroke [mm]:
100.0



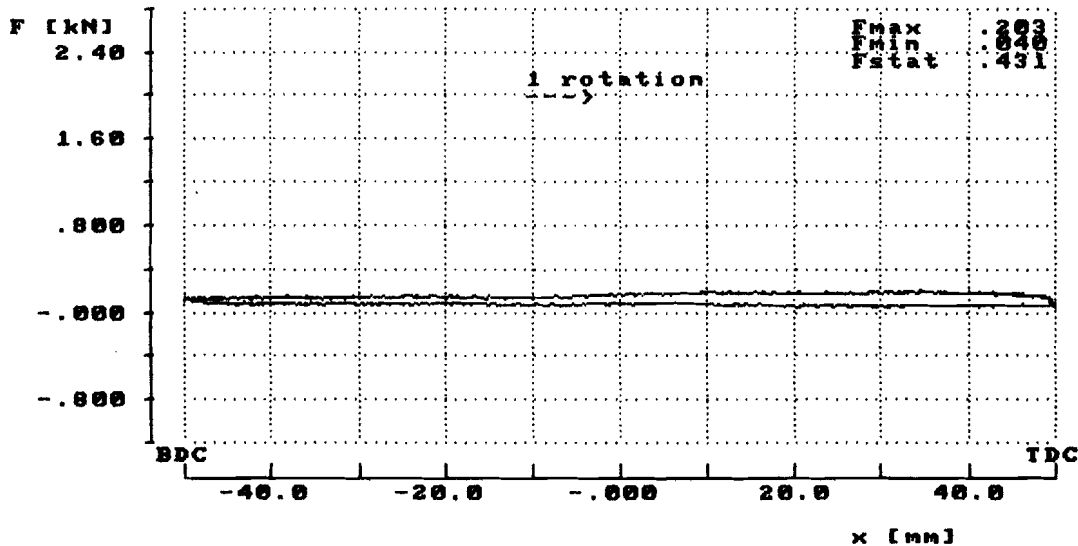
rotationspeed (rps): .099
meanflow (dm3/s) : .004 sample frequency (Hz): 202.748

filename --> P0493902_

Pin [W]:
1.705
Pout[W]:
.926

Evol :
.107
Emech :
.543

head [m] :
23.3
pump [mm] :
49.0
stroke [mm]:
100.0



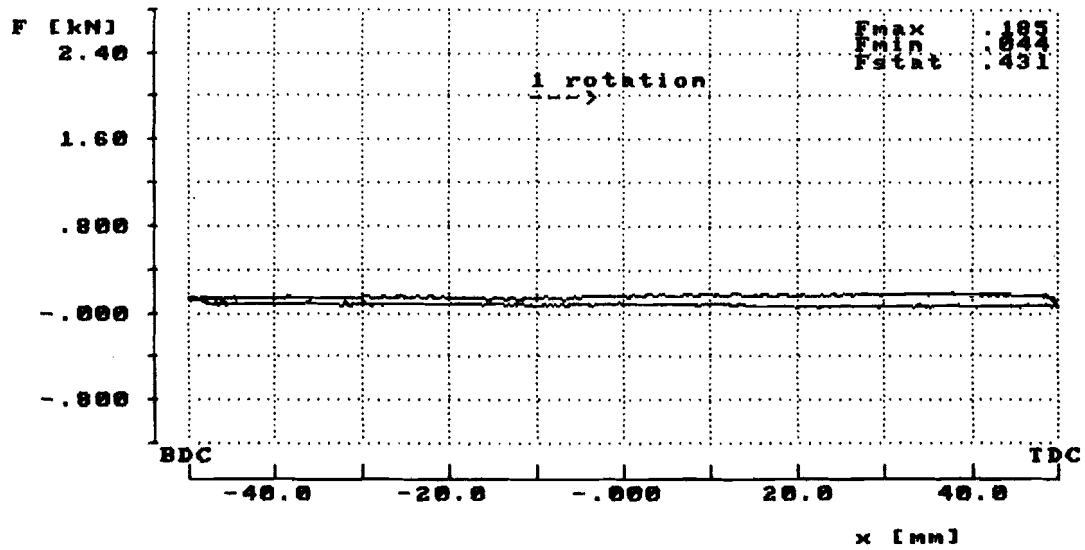
rotationspeed (rps): .200
meanflow (dm3/s) : .004 sample frequency (Hz): 409.709

filename --> P0493903_

Pin [W]:
2.284
Pout[W]:
1.124

Evol :
.008
Emech :
.492

head [m] :
23.3
pump [mm] :
49.0
stroke [mm]:
100.0



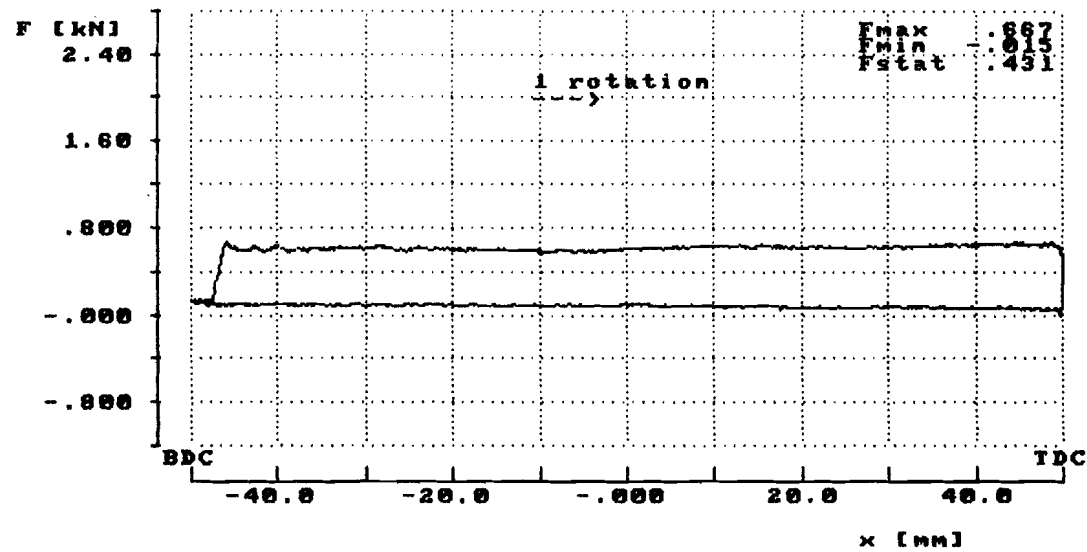
rotationspeed (rps): .296
meanflow (dm3/s) : .005 sample frequency (Hz): 605.300

filename --> P0493904_

Pin [W]:
21.135
Pout[W]:
16.976

Evol :
.967
Emech :
.883

head [m] :
23.3
pump [mm] :
49.0
stroke [mm]:
100.0



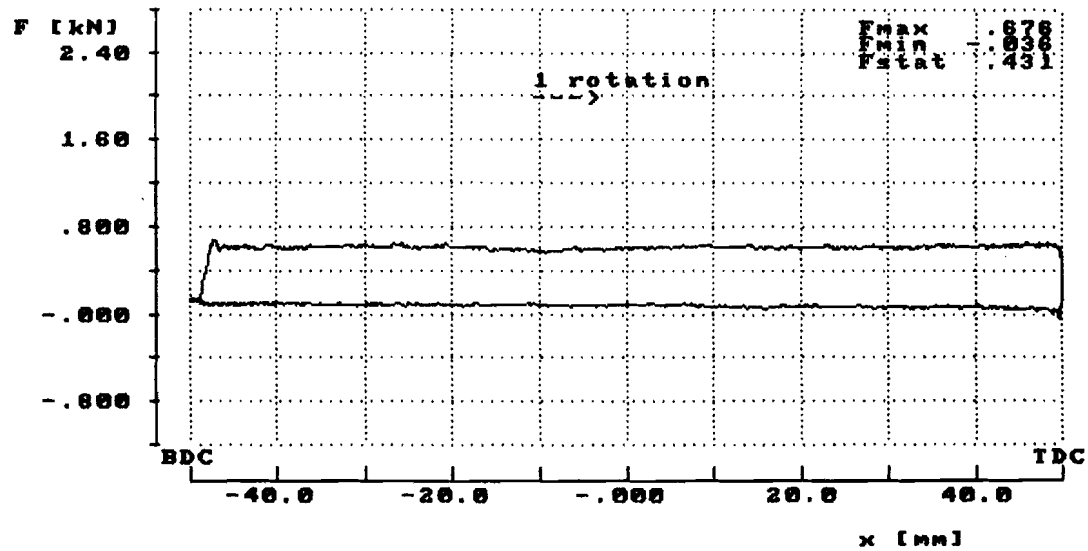
rotationspeed (rps): .487
meanflow (dm3/s) : .074 sample frequency (Hz): 834.486

filename --> P0493905_

Pin [W]:
25.916
Pout[W]:
19.327

Evol :
.910
Ewech :
.746

head [m] :
23.3
pump [mm] :
49.0
stroke [mm]:
100.0



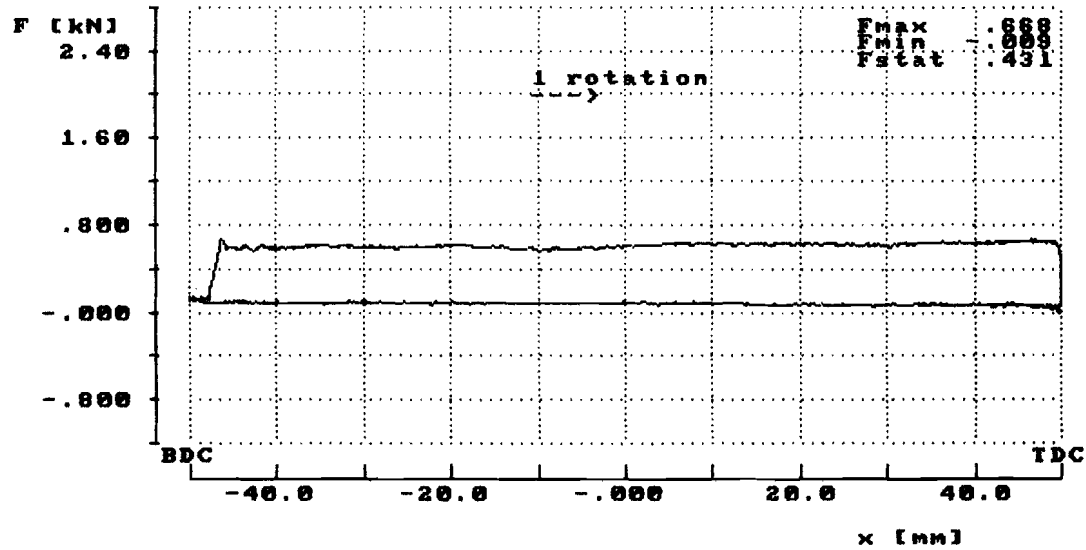
rotationspeed (rps): .493
meanflow (dm3/s) : .085 sample frequency (Hz): 1009.210

filename --> P0493906_

Pin [W]:
18.472
Pout[W]:
13.671

Evol :
.893
Erech :
.740

head [m] :
23.3
pump [mm] :
49.0
stroke [mm]:
100.0



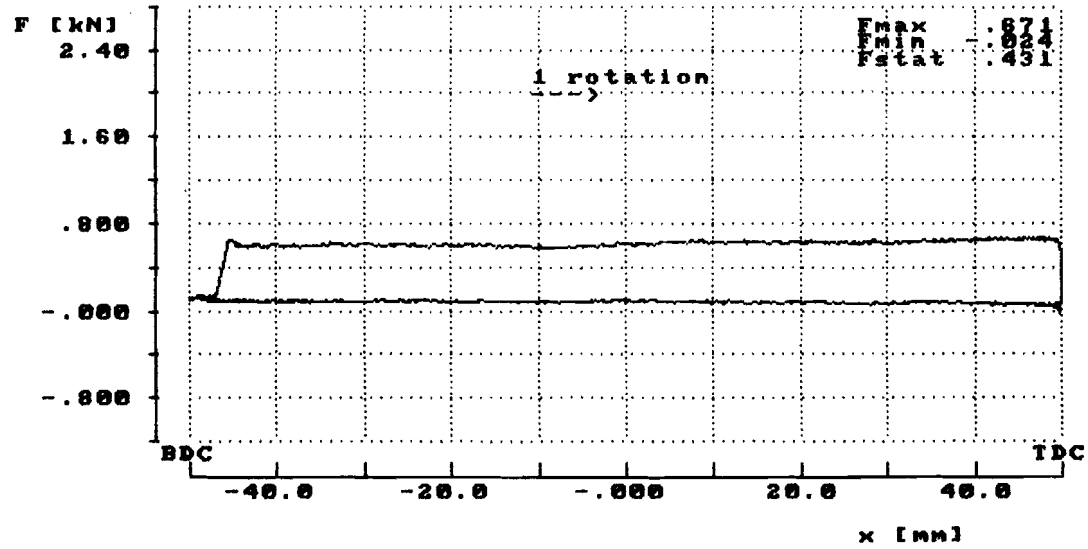
rotationspeed (rps): .355
meanflow (dm3/s) : .060 sample frequency (Hz): 727.309

filename --> P0493907_

Pin [W]:
18.370
Pout[W]:
15.127

Evol :
.988
Emech :
.823

head [m] :
23.3
pump [mm] :
49.0
stroke [mm]:
100.0



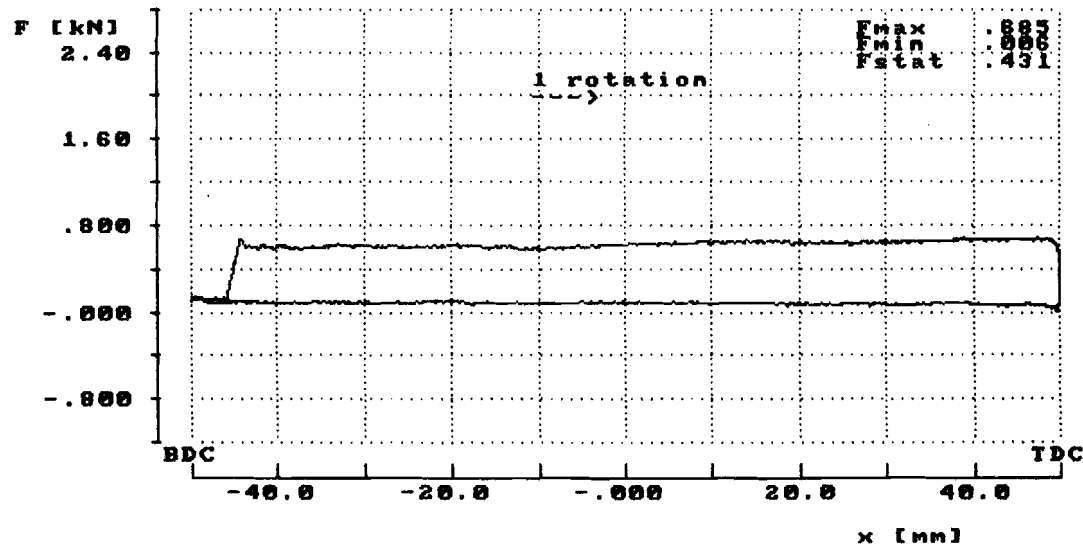
rotationspeed (rps): .355
meanflow (dm3/s) : .066 sample frequency (Hz): 727.309

filename --> P0493908_

Pin [W]:
16.586
Pout[W]:
14.555

Evol :
1.055
Erech :
.878

head [m] :
23.3
pump [mm] :
49.0
stroke [mm]:
100.0



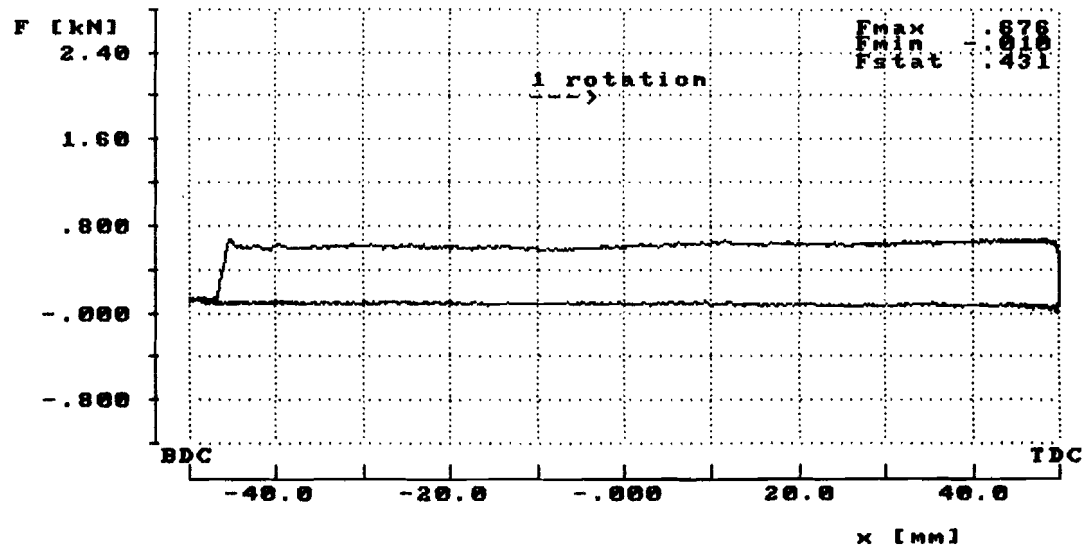
rotationspeed (rps): .320
meanflow (dm3/s) : .064 sample frequency (Hz): 655.459

filename --> P0493909_

Pin [W]:
19.466
Pout[W]:
15.634

Evol :
.967
Emech :
.803

head [m] :
23.3
pump [mm] :
49.0
stroke [mm]:
100.0



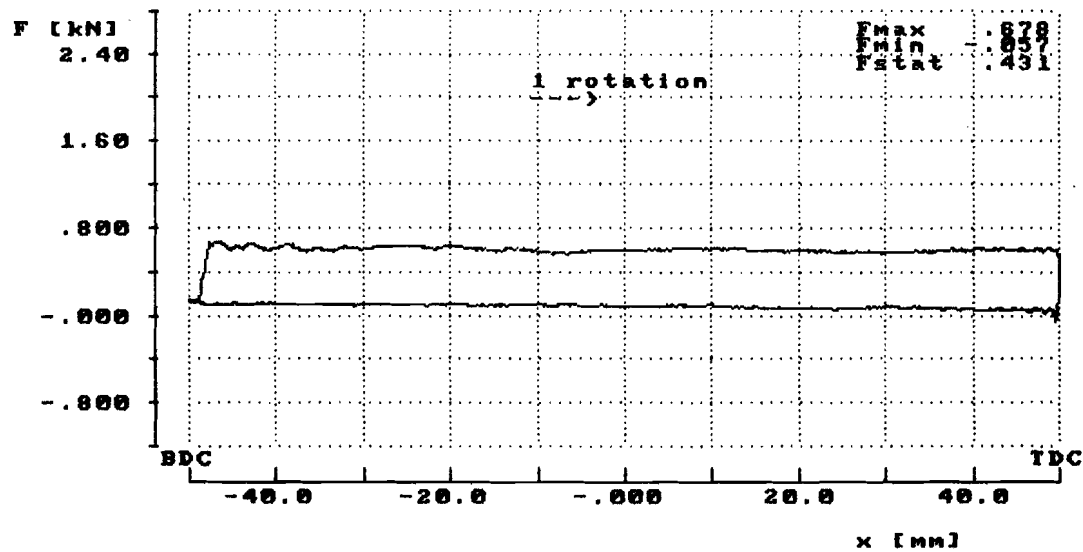
rotationspeed (rps): .375
meanflow (dm3/s) : .068 sample frequency (Hz): 767.903

filename --> P0493911_

Pin [W]:
30.668
Pout[W]:
24.839

Evol :
.960
Enech :
.810

head [m] :
23.3
pump [mm] :
49.0
stroke [mm]:
100.0



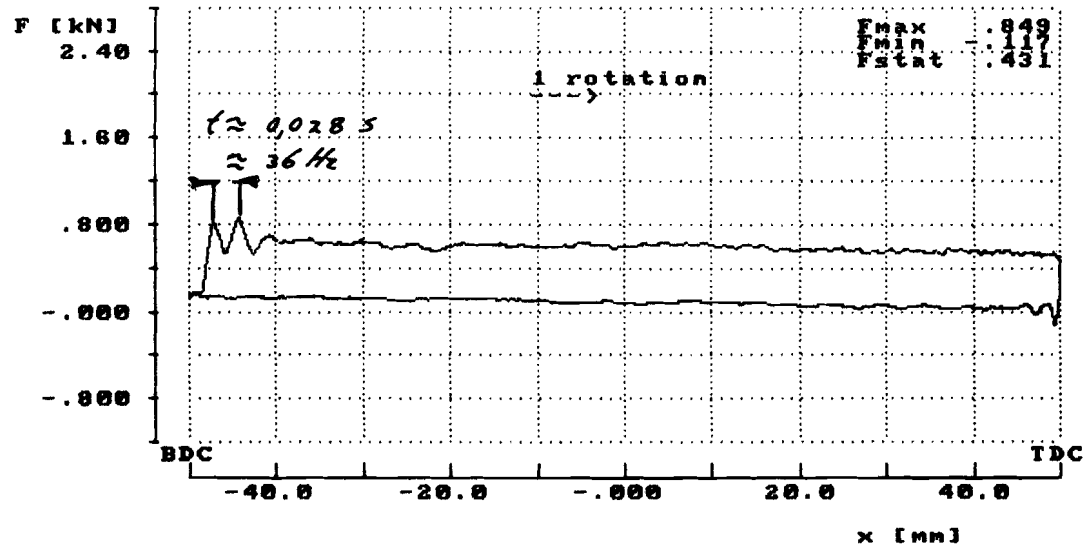
rotationspeed (rps): .600
meanflow (dm3/s) : .109 sample frequency (Hz): 1228.826

filename --> P0493912_

Pin [W]:
44.935
Pout[W]:
37.735

Evol :
.980
Emech :
.840

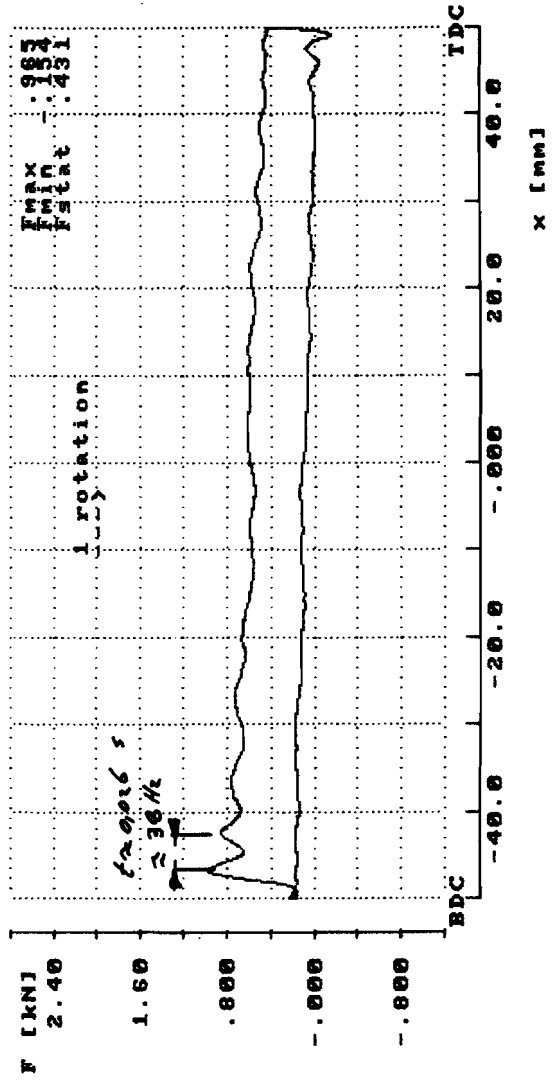
head [m] :
23.3
PUMP [mm] :
49.0
stroke [mm]:
100.0



rotationspeed (rps): .894
meanflow (dm3/s) : .165 sample frequency (Hz): 1630.135

filename --> P0493913_

Pin [W]:
58.890
Pout[W]:
50.779
Evol :
.989
Emech :
.848
head [m] :
23.3
pump [mm] :
48.0
stroke [mm]:
100.0



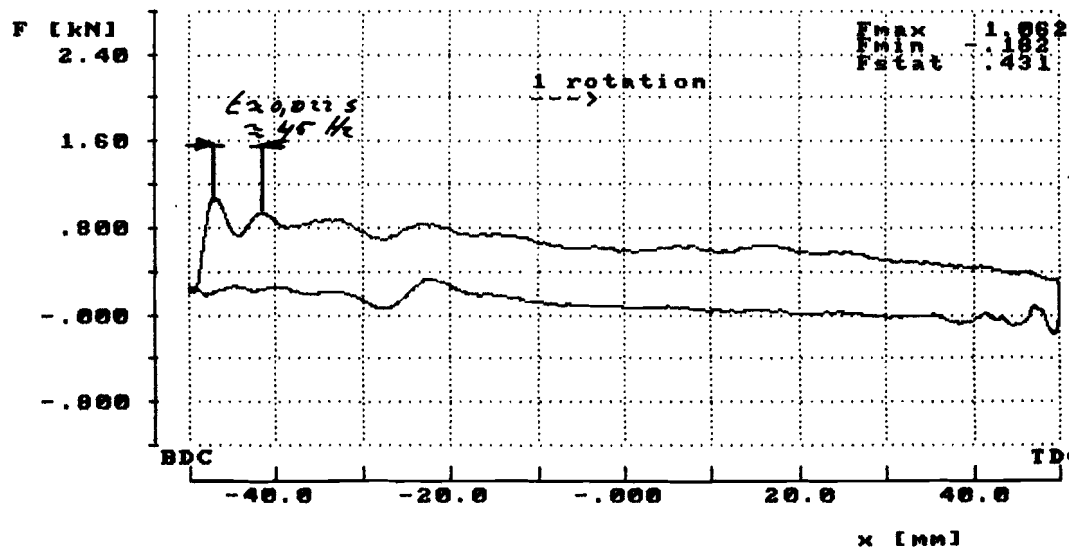
rotationspeed (rps): 1.191
meanflow (dm3/s) : .222 sample frequency (Hz): 2440.179

filename --> P0493914_

Pin [W]:
82.156
Pout[W]:
65.691

Evol :
1.000
Emech :
.800

head [m] :
23.3
pump [mm] :
49.0
stroke [mm]:
100.0



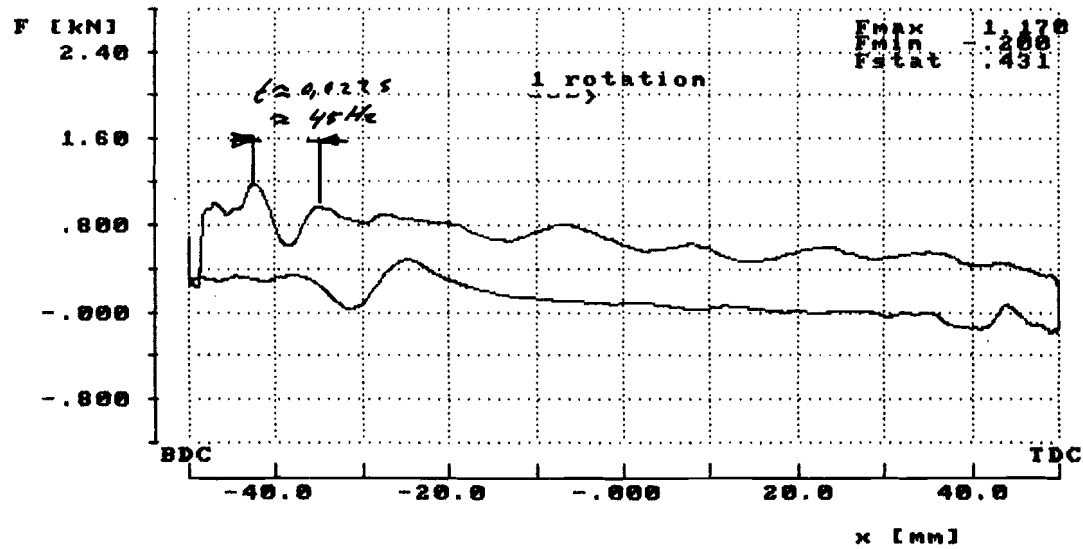
rotationspeed (rps): 1.513
meanflow (dm3/s) : .287 sample frequency (Hz): 3097.672

filename --> P0493915_

Pin [W]:
97.840
Pout[W]:
78.586

Evol :
1.016
Emech :
.803

head [m] :
23.3
pump [mm] :
48.0
stroke [mm]:
100.0



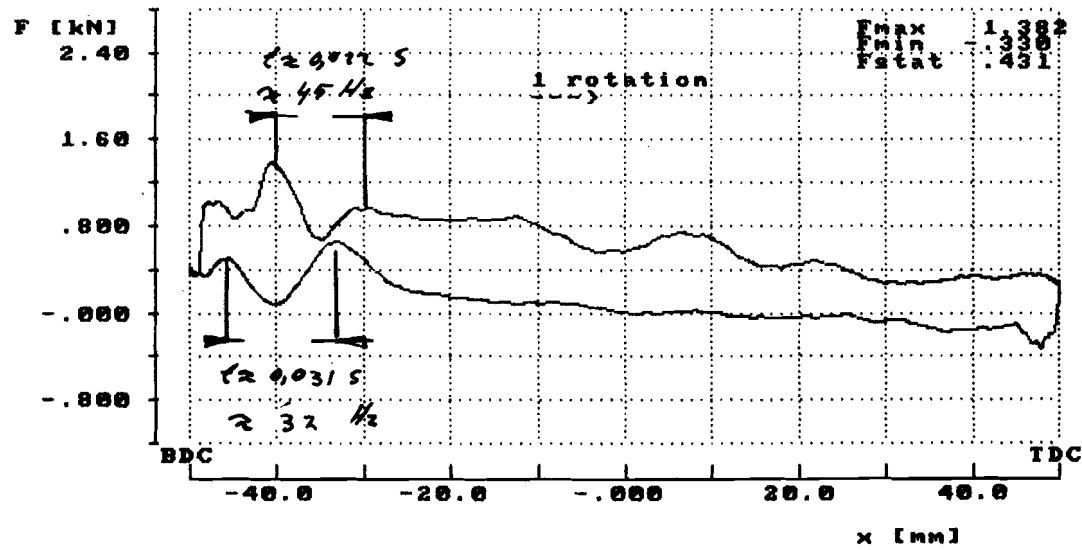
rotationspeed (rps): 1.794
meanflow (dm3/s) : .344 sample frequency (Hz): 3673.825

filename --> P0493916_

Pin [W]:
118.801
Pout[W]:
94.233

Evol :
1.034
Emech :
.793

head [m] :
23.3
pump [mm] :
49.0
stroke [mm]:
100.0



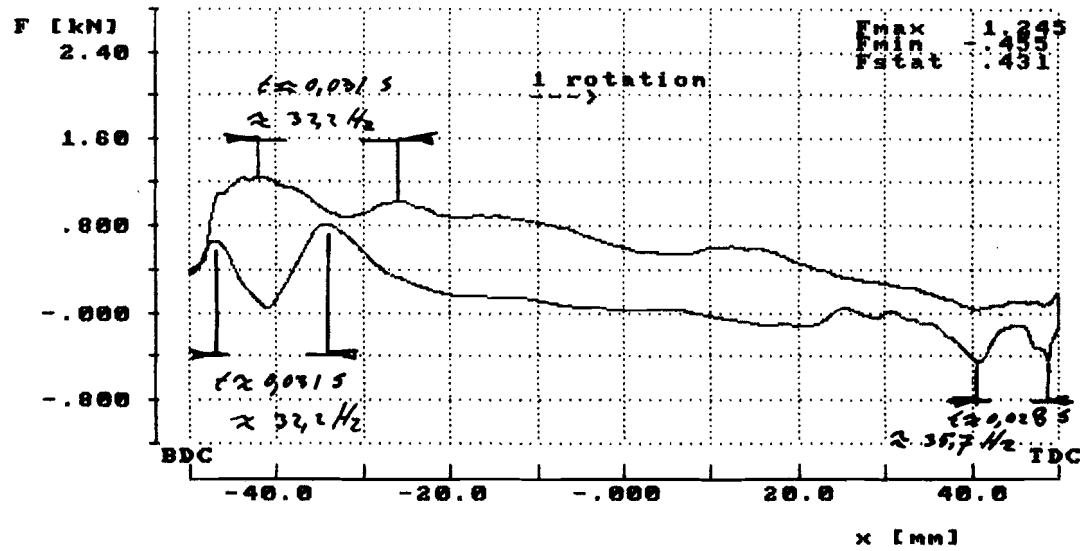
rotationspeed (rps): 2.115
meanflow (dm3/s) : .412 sample frequency (Hz): 4331.318

filename --> P0493917_

Pin [W]:
126.906
Pout[W]:
104.676

Evol :
1.018
Emech :
.825

head [m] :
23.3
pump [mm] :
49.0
stroke [mm]:
100.0



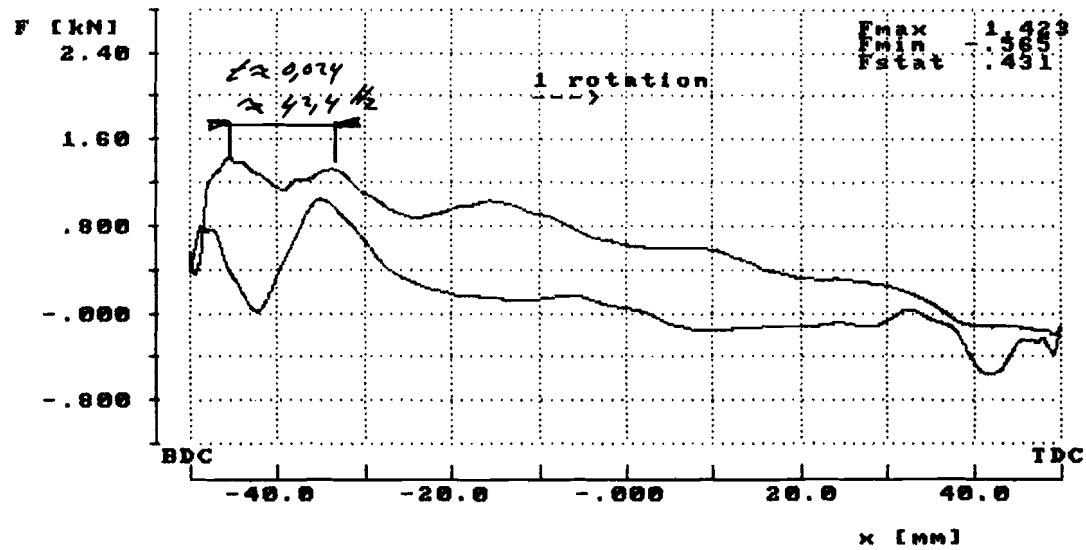
rotation speed (rps): 2.388
mean flow (dm³/s) : .458 sample frequency (Hz): 4887.137

filename --> P0493918_

Pin [W]:
144.128
Pout[W]:
118.374

Evol :
1.023
Emech :
.828

head [m] :
23.3
pump [mm] :
48.0
stroke [mm]:
100.0



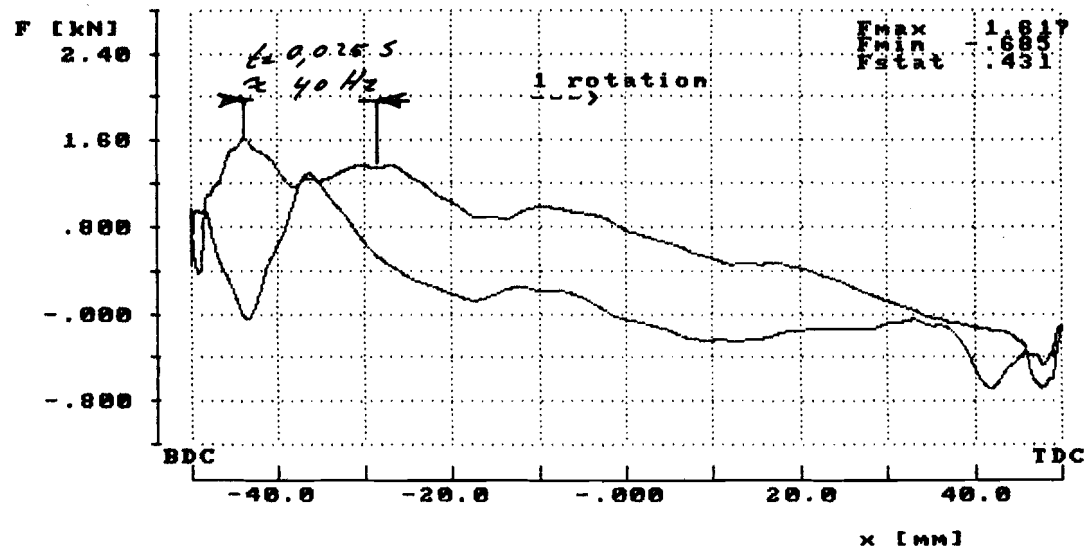
rotationspeed (rps): 2.707
meanflow (dm3/s) : .522 sample frequency (Hz): 5544.630

filename --> P0493919_

Pin [W]:
169.666
Pout[W]:
137.502

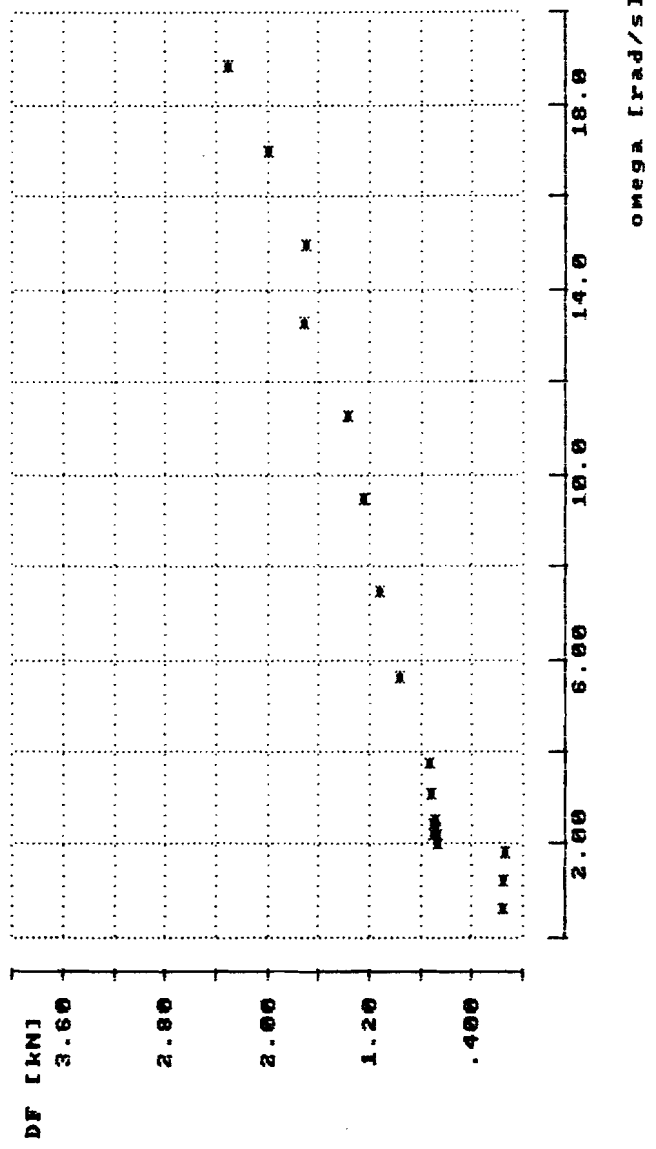
Evol :
1.063
Emech :
.810

head [m] :
23.3
pump [mm] :
49.0
stroke [mm]:
100.0

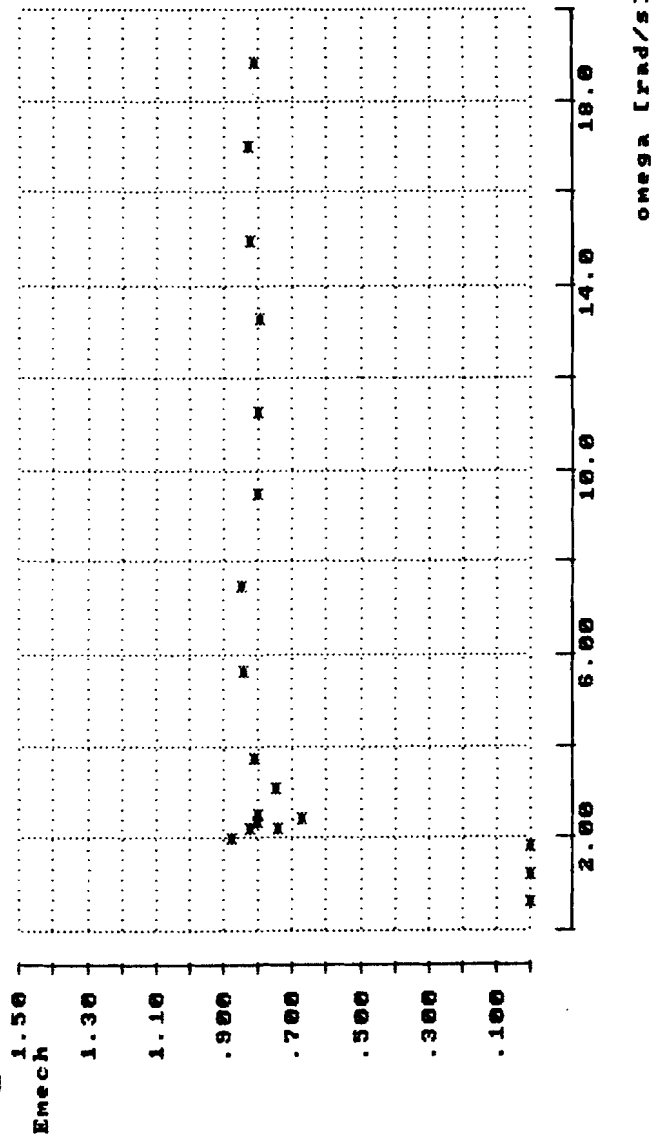


rotationspeed (rps): 3.002
meanflow (dm3/s) : .602 sample frequency (Hz): 6147.896

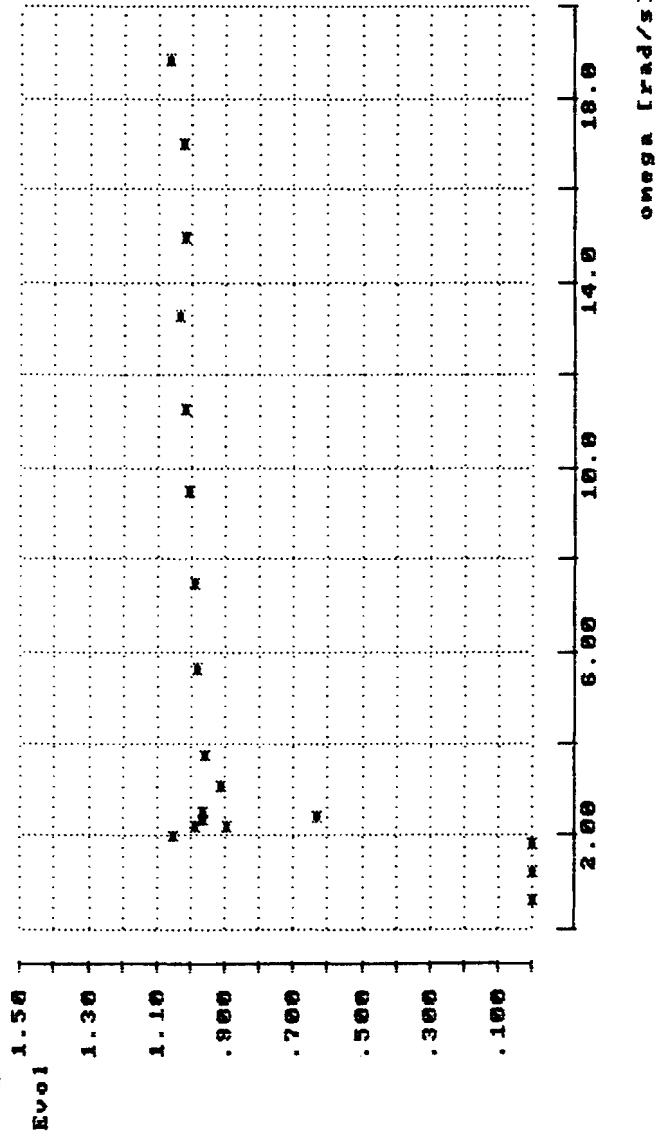
filename --> P0493919_



filename --> P0493919_



filename --> P0493919_

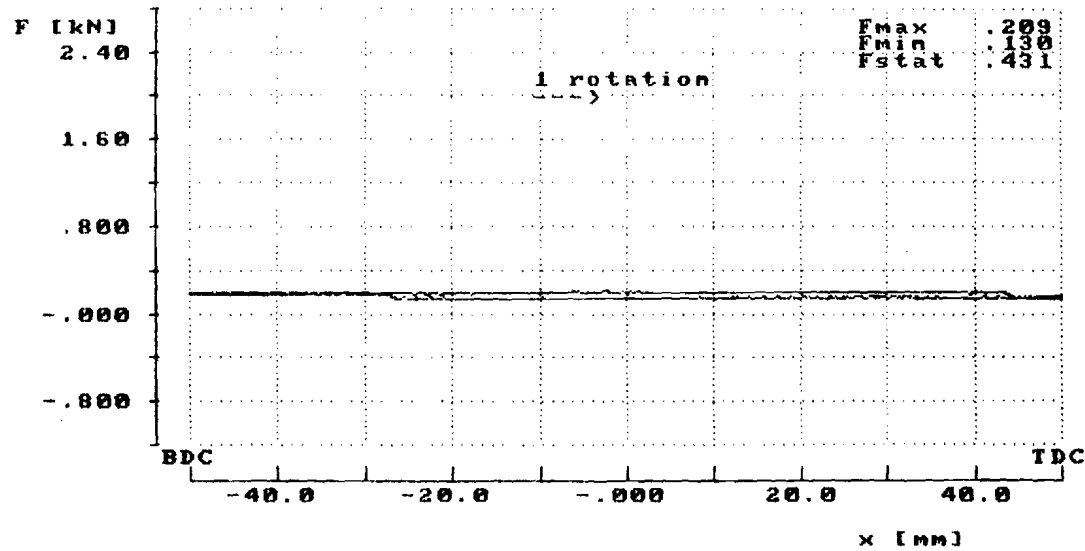


Annex IV

Configuration 40

filename --> P0494001_

Pin [W]:
.312
Pout[W]:
.590
Evol :
.153
Emech :
1.894
head [m] :
23.3
pump [mm] :
49.0
stroke [mm]:
100.0



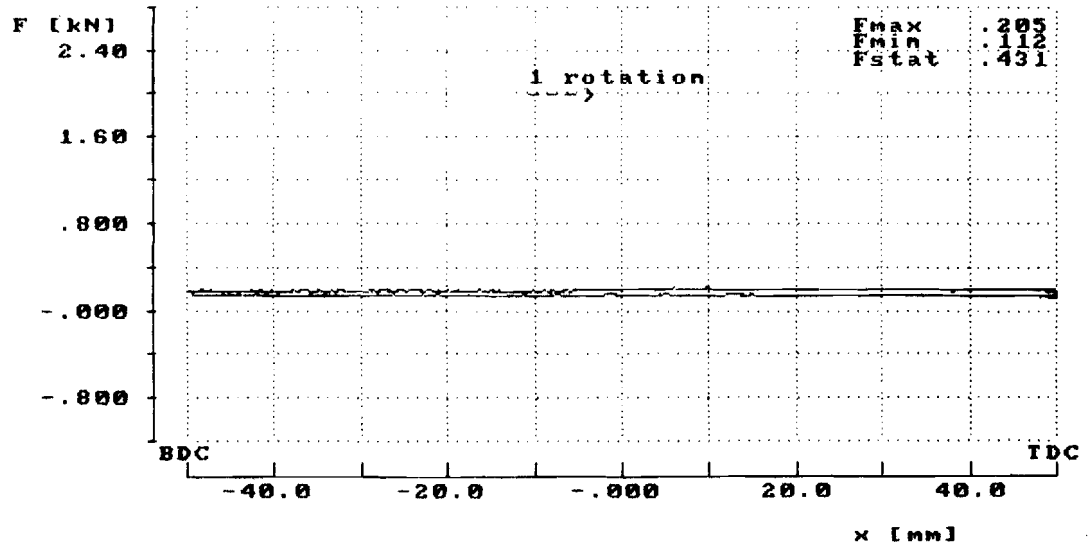
rotationspeed (rps): .089
meanflow (dm3/s) : .003 sample frequency (Hz): 183.164

filename --> P0494002_

Pin [W]:
.919
Pout[W]:
.301

Evol :
.035
Enech :
.327

head [m] :
23.3
pump [mm] :
49.0
stroke [mm]:
100.0



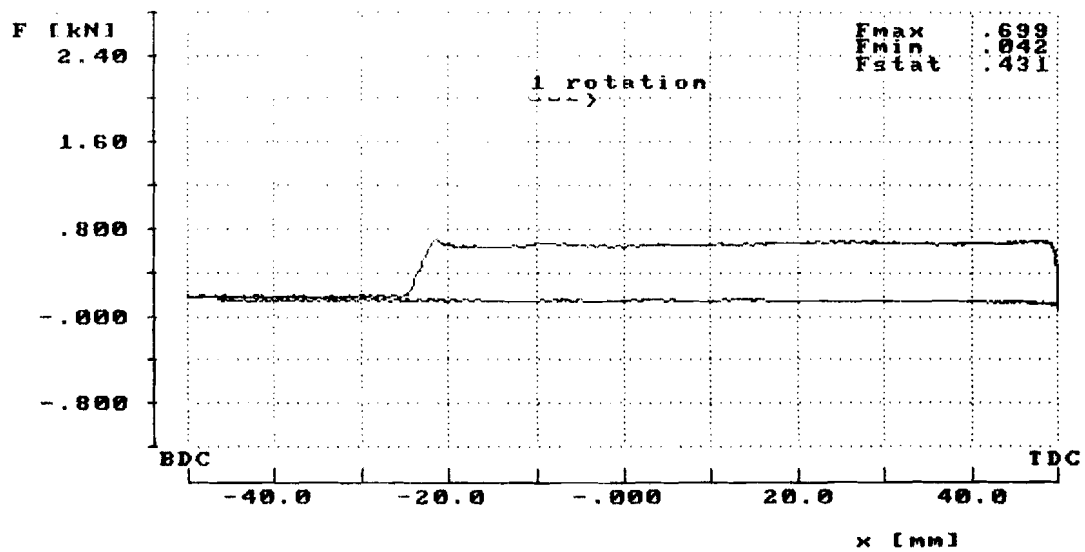
rotationspeed (rps): .200
meanflow (dm3/s) : .001 sample frequency (Hz): 409.709

filename --> P0494003_

Pin [W]:
11.663
Pout[W]:
8.541

Evol :
.661
Emech :
.732

head [m] :
23.3
pump [mm] :
49.0
stroke [mm]:
100.0



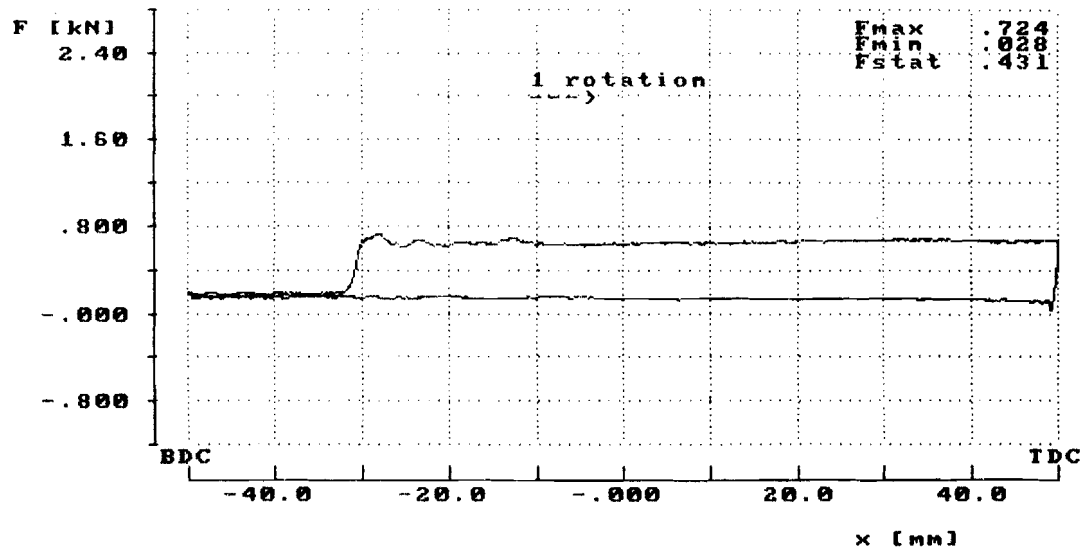
rotationspeed (rps): .300
meanflow (dm3/s) : .037 sample frequency (Hz): 614.262

filename --> P0494004_

Pin [W]:
16.908
Pout[W]:
12.497

Evol :
.725
Emech :
.739

head [m] :
23.3
pump [mm] :
49.0
stroke [mm]:
100.0



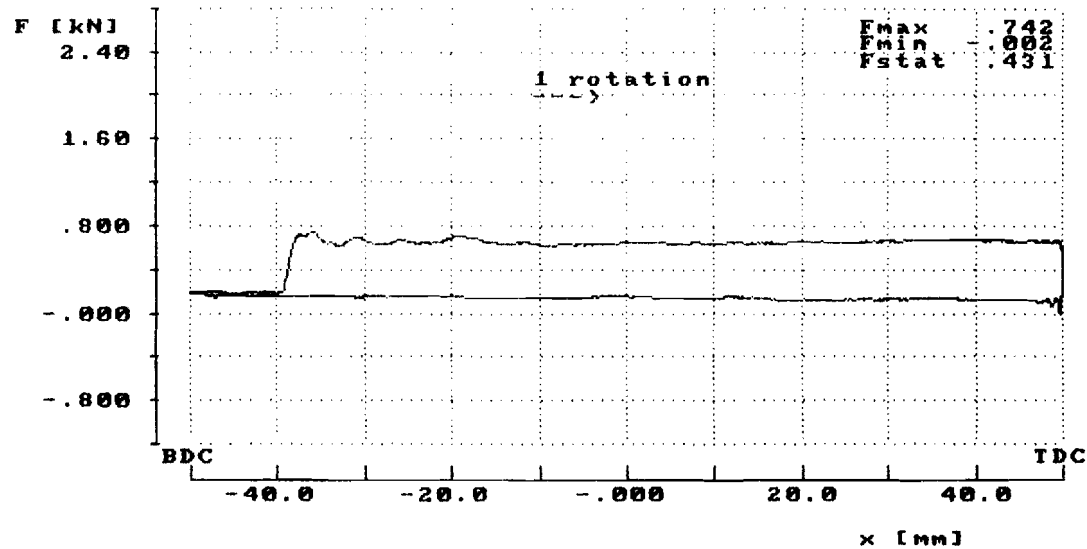
rotationspeed (rps): .400
meanflow (dm3/s) : .055 sample frequency (Hz): 818.816

filename --> P0494005_

Pin [W]:
22.954
Pout[W]:
18.582

Evol :
.862
Enech :
.810

head [m] :
23.3
pump [mm] :
49.0
stroke [mm]:
100.0



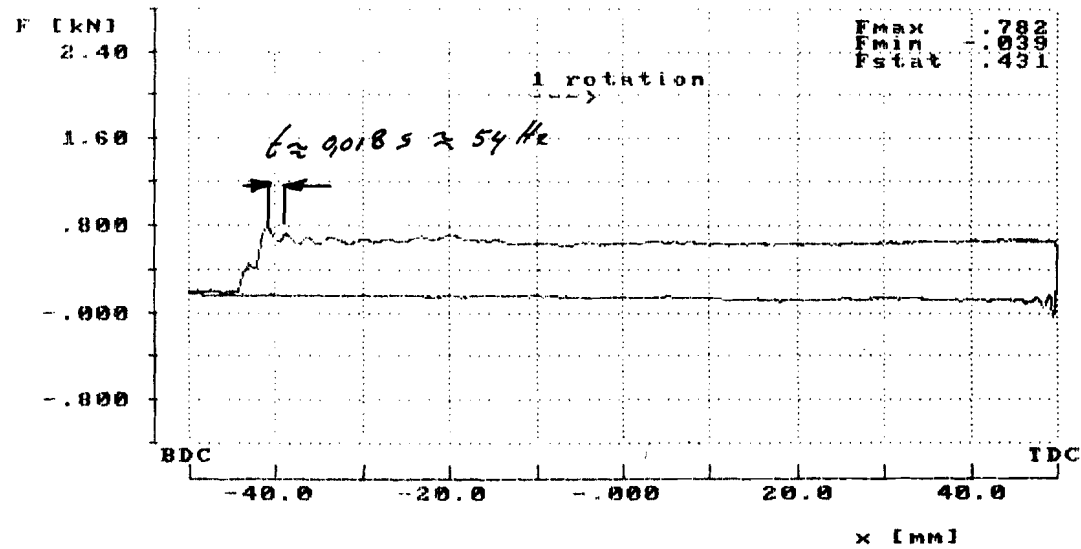
rotationspeed (rps): .500
meanflow (dm3/s) : .081 sample frequency (Hz): 1023.972

filename --> B:P0494006...

Pin [W]:
28.588
Pout[W]:
23.529

Evol :
.910
Emech :
.823

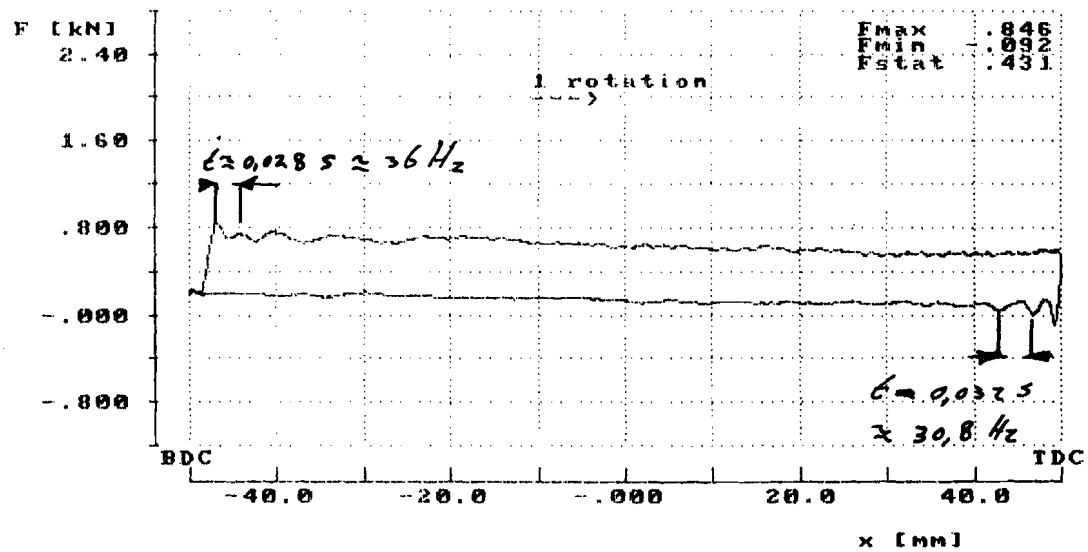
head [m] :
23.3
pump [mm] :
49.0
stroke [mm]:
100.0



rotationspeed (rps): .600
meanflow (dm3/s) : .103 sample frequency (Hz): 1228.826

filename --> P0494007_

Pin [W]:
44.300
Pout[W]:
37.741
Evol :
.973
Emech :
.852
head [m] :
23.3
pump [mm] :
49.0
stroke [mm]:
100.0



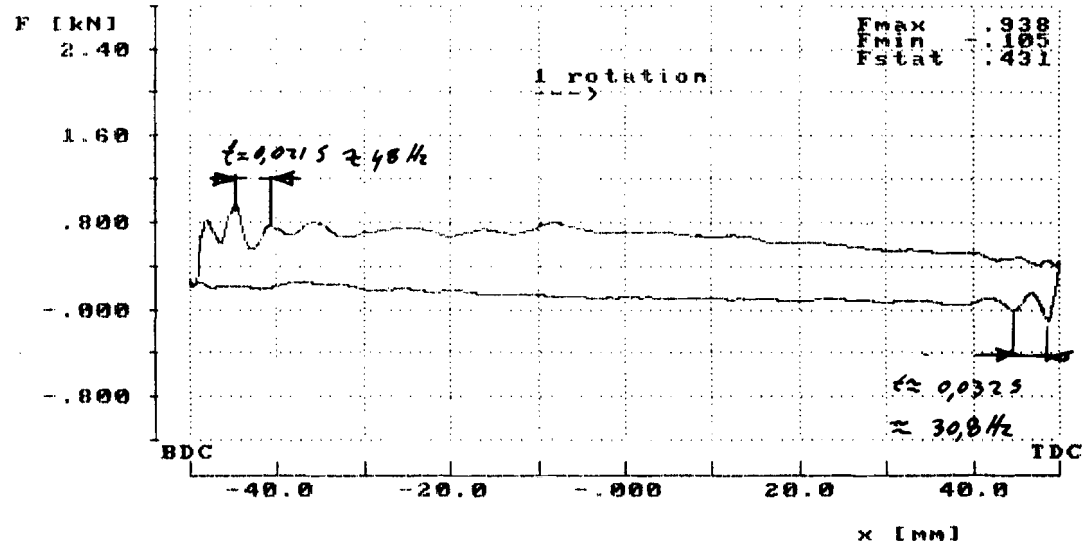
rotationspeed (rps): .900
meanflow (dm³/s) : .165 sample frequency (Hz): 1843.089

filename --> P0494008_

Pin [W]:
62.361
Pout[W]:
50.604

Evol :
.978
Emech :
.811

head [m] :
23.3
pump [mm] :
49.0
stroke [mm]:
100.0



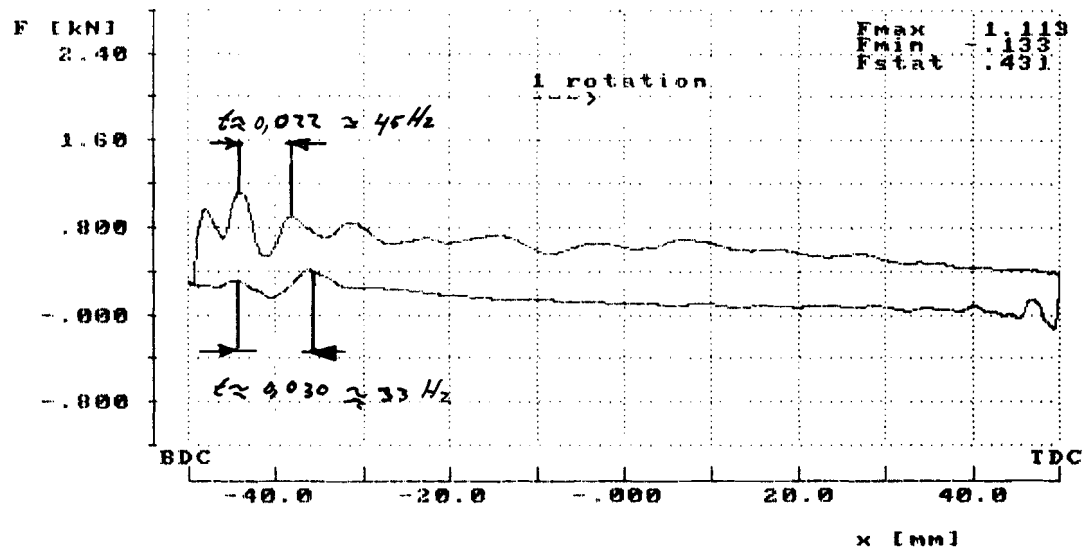
rotationspeed (rps): 1.200
meanflow (dm3/s) : .221 sample frequency (Hz): 2457.652

filename --> P0494009_

Pin [W]:
72.752
Pout[W]:
66.350

Evol :
1.026
Emech :
.912

head [m] :
23.3
pump [mm] :
49.0
stroke [mm]:
100.0



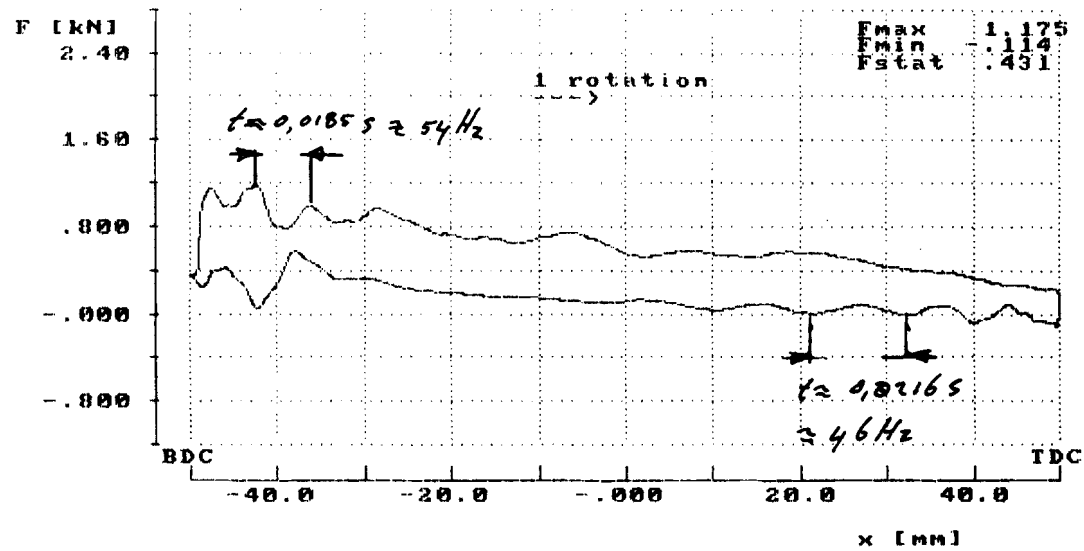
rotationspeed (rps): 1.500
meanflow (dm3/s) : .290 sample frequency (Hz): 3071.915

filename --> P0494010_

Pin [W]:
88.757
Pout[W]:
79.031

Evol :
1.019
Emech :
.890

head [m] :
23.3
pump [mm] :
49.0
stroke [mm]:
100.0



rotationspeed (rps): 1.800
meanflow (dm3/s) : .346 sample frequency (Hz): 3686.479

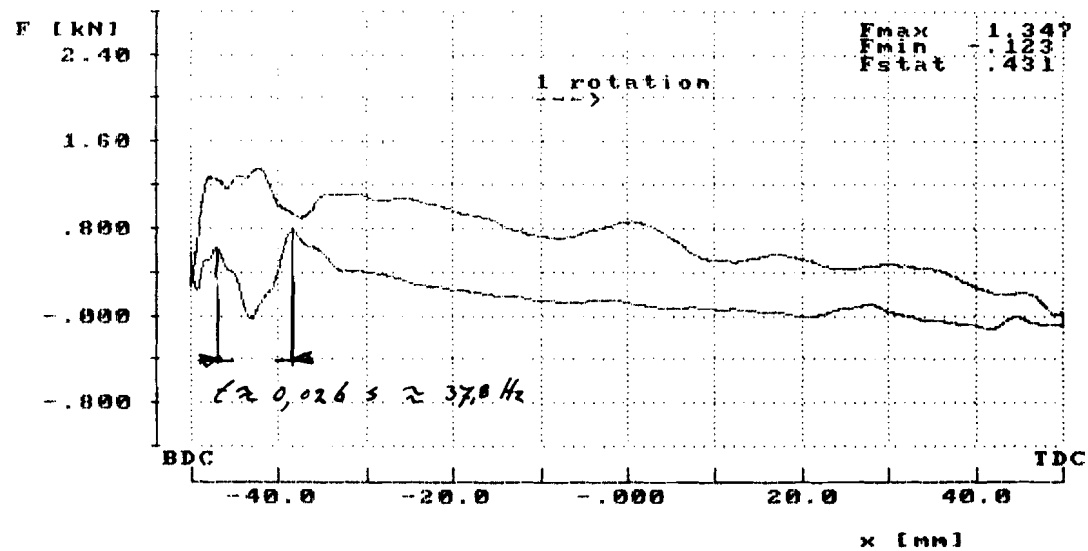
filename --> P0494011_

Pin [W]:
116.323
Pout[W]:
93.342

Evol :
1.031
Emech :
.802

head [m] :
23.3
pump [mm] :
49.0
stroke [mm]:
100.0

rotationspeed (rps): 2.100
meanflow (dm3/s) : .408 sample frequency (Hz): 4300.741



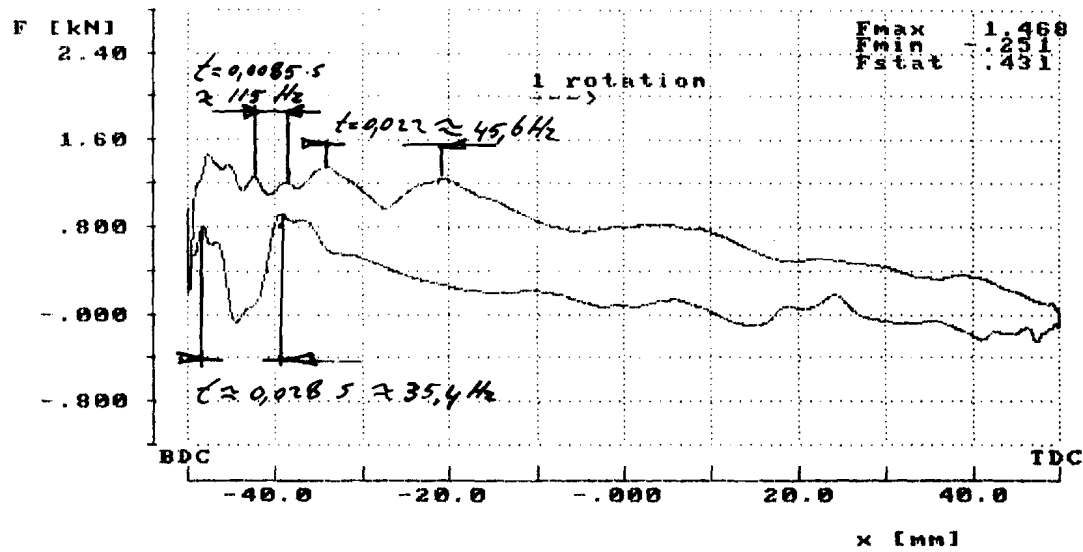
filename --> P0494012_

Pin [W]:
148.217
Pout[W]:
107.522

Evol :
1.037
Emech :
.725

head [m] :
23.3
pump [mm] :
49.0
stroke [mm]:
100.0

rotationspeed (rps): 2.406
meanflow (dm3/s) : .470 sample frequency (Hz): 4927.807



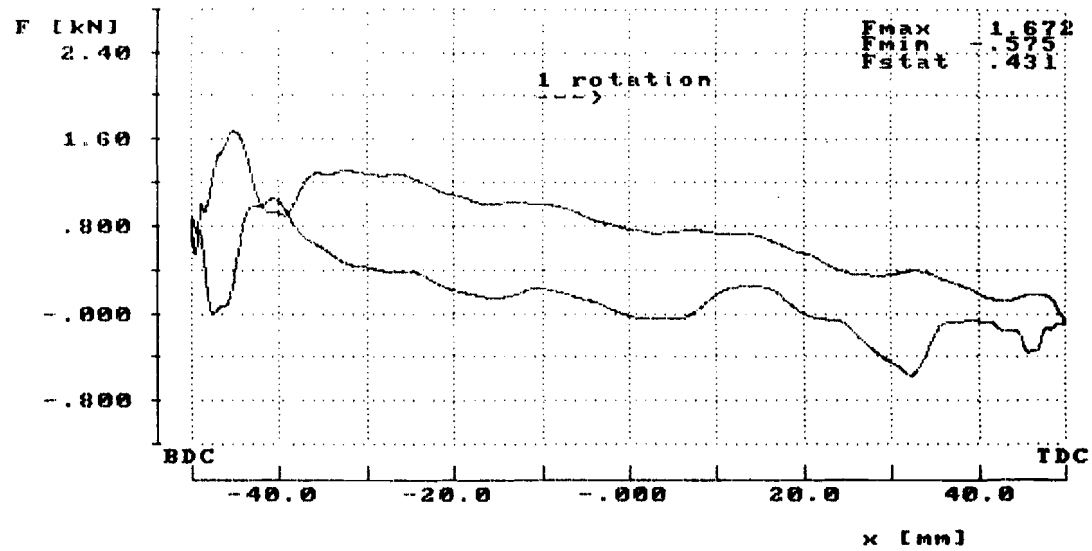
L

filename --> P0494013_

Pin [W]:
172.137
Pout[W]:
121.387

Evol :
1.043
Emech :
.705

head [m] :
23.3
pump [mm] :
49.0
stroke [mm]:
100.0



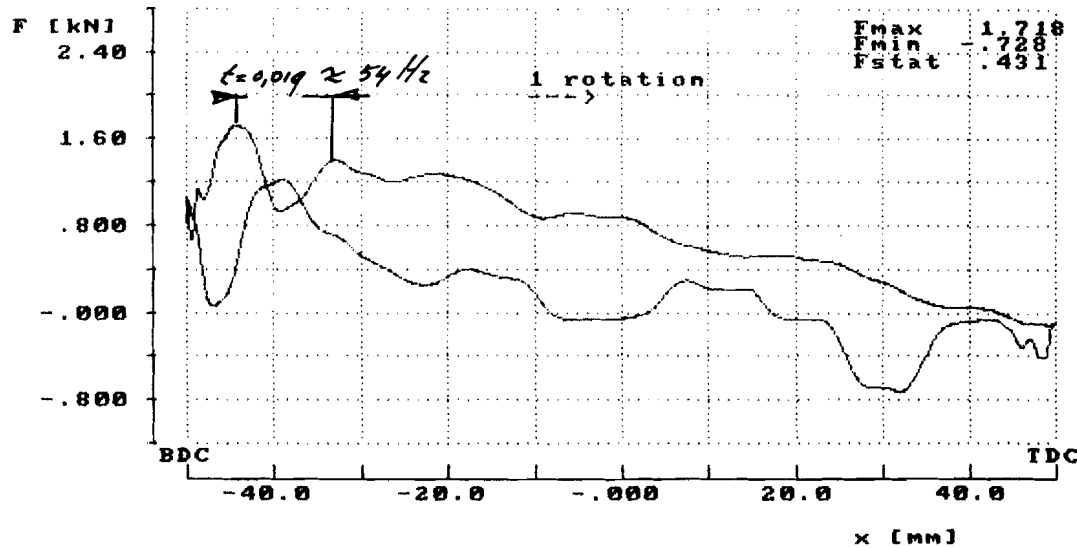
rotationspeed (rps): 2.700
meanflow (dm³/s) : .531 sample frequency (Hz): 5529.567

filename --> P0494014_

Pin [W]:
181.216
Pout[W]:
132.971

Evol :
1.027
Emech :
.734

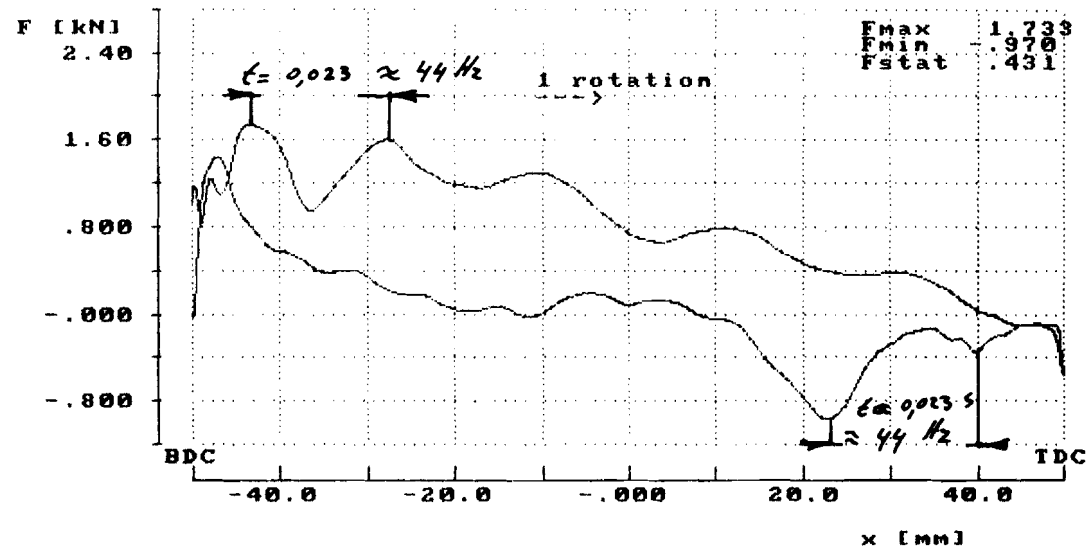
head [m] :
23.3
pump [mm] :
49.0
stroke [mm]:
100.0



rotationspeed (rps): 3.005
meanflow (dm3/s) : .582 sample frequency (Hz): 6154.675

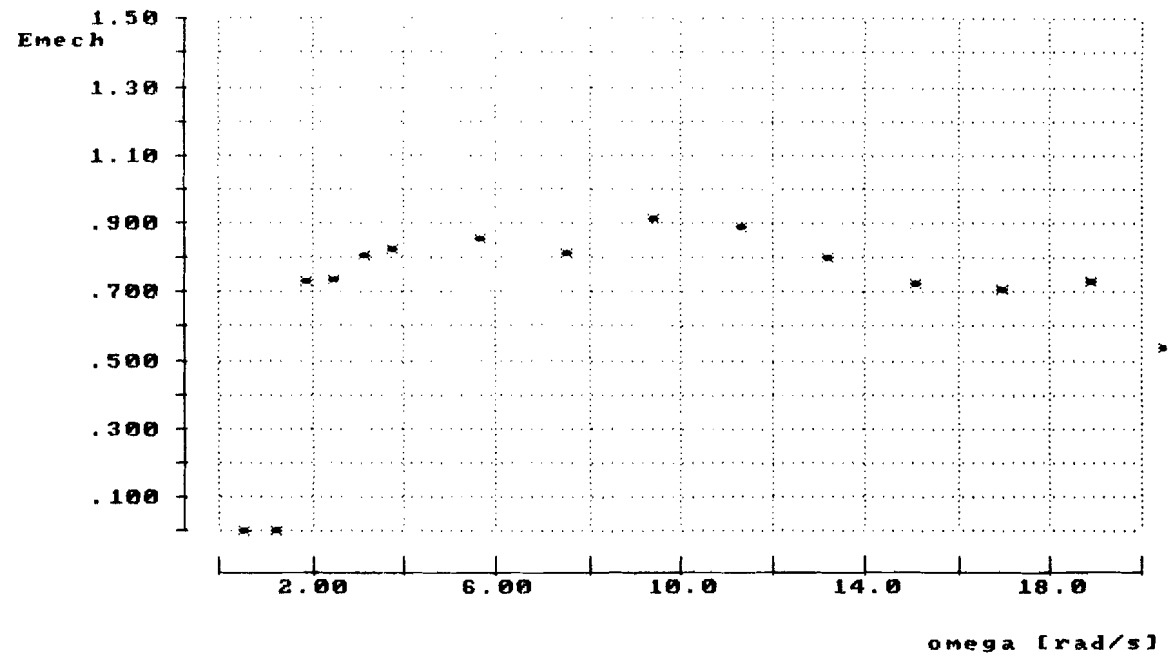
filename --> P0494015_

Pin [W]:
260.978
Pout[W]:
141.110
Evol :
.992
Emech :
.541
head [m] :
23.3
pump [mm] :
49.0
stroke [mm]:
100.0

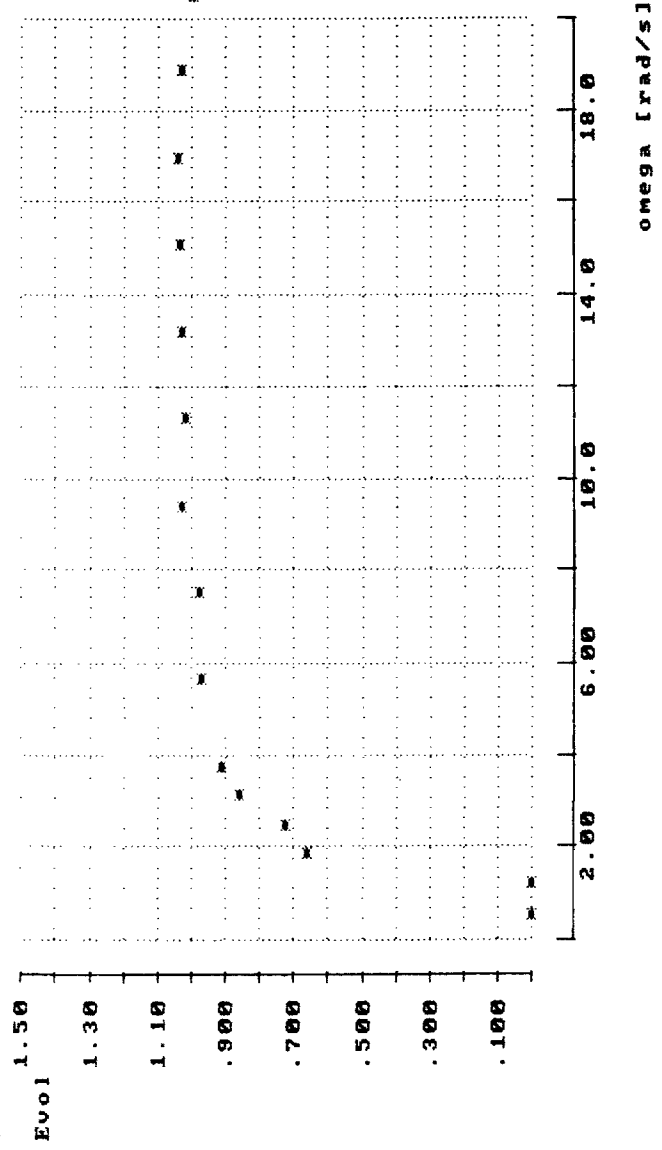


rotationspeed (rps): 3.300
meanflow (dm3/s) : .617 sample frequency (Hz): 6758.393

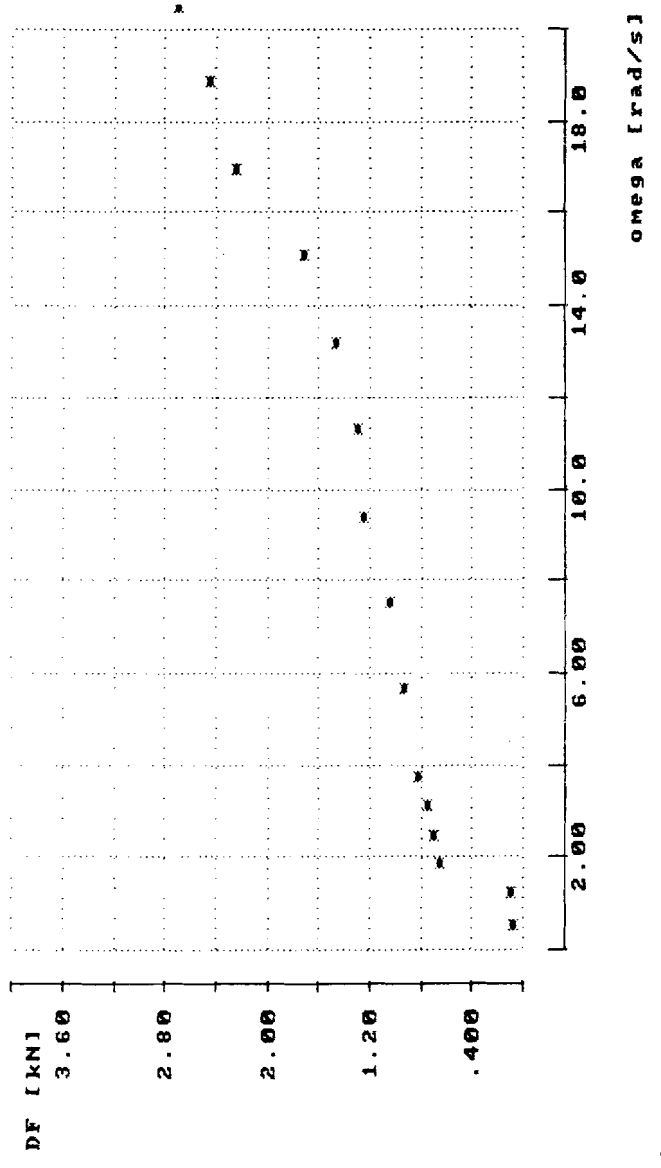
filename --> P04940 T_



filename --> P04940 T



filename --> P04940 T

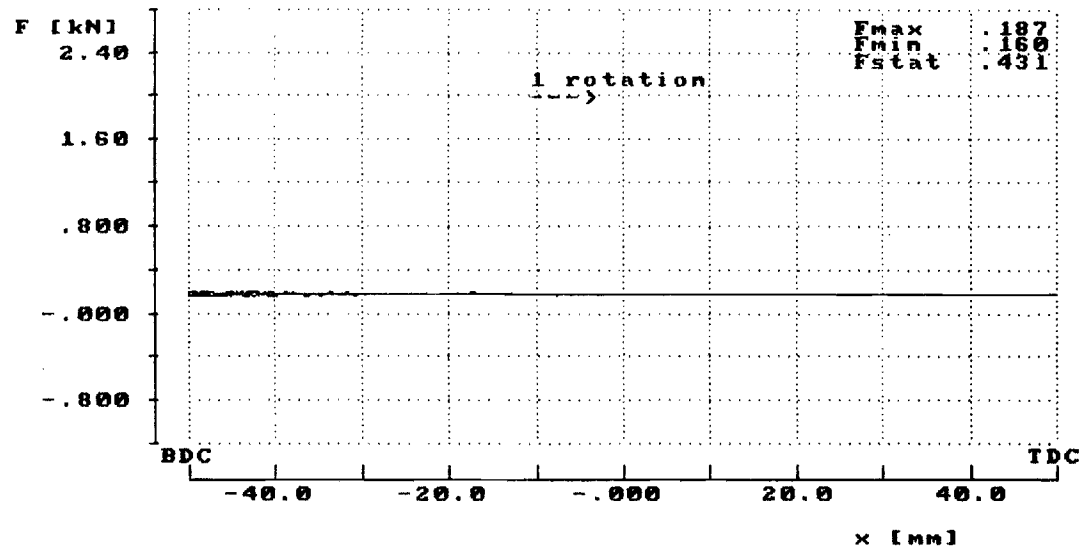


Annex V

Configuration 41

filename --> P0494101

Pin [W]:
-1.012
Pout[W]:
.069
Evol :
.002
Erech :
-.068
head [m] :
23.3
pump [mm] :
49.0
stroke [mm]:
100.0



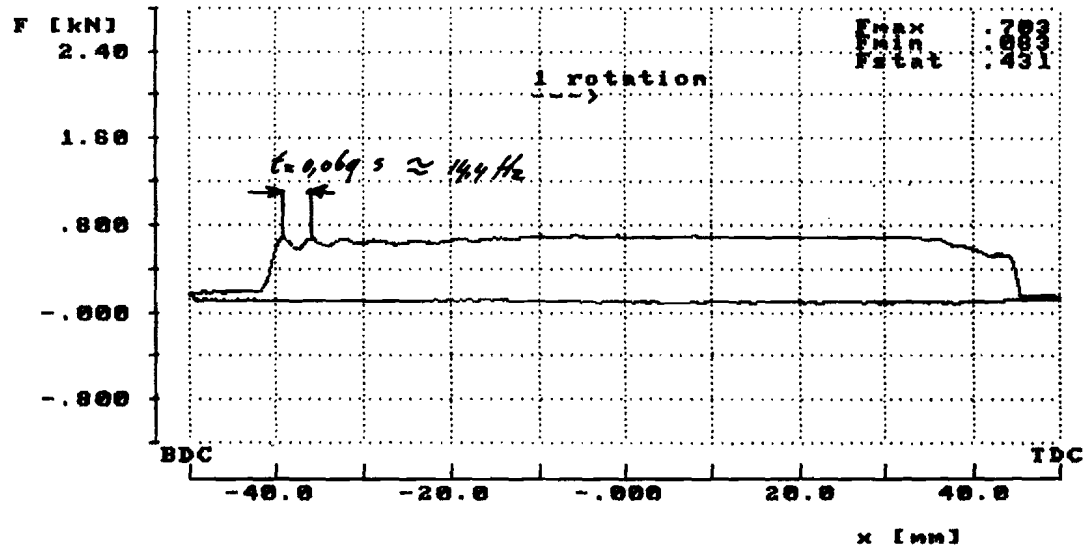
rotationspeed (rps): 1.015
meanflow (dm3/s) : .000 sample frequency (Hz): 2078.671

filename --> P0494102_

Pin [W]:
9.820
Pout[W]:
5.667

Evol :
.637
Emech :
.577

head [m] :
23.3
pump [mm] :
49.0
stroke [mm]:
100.0



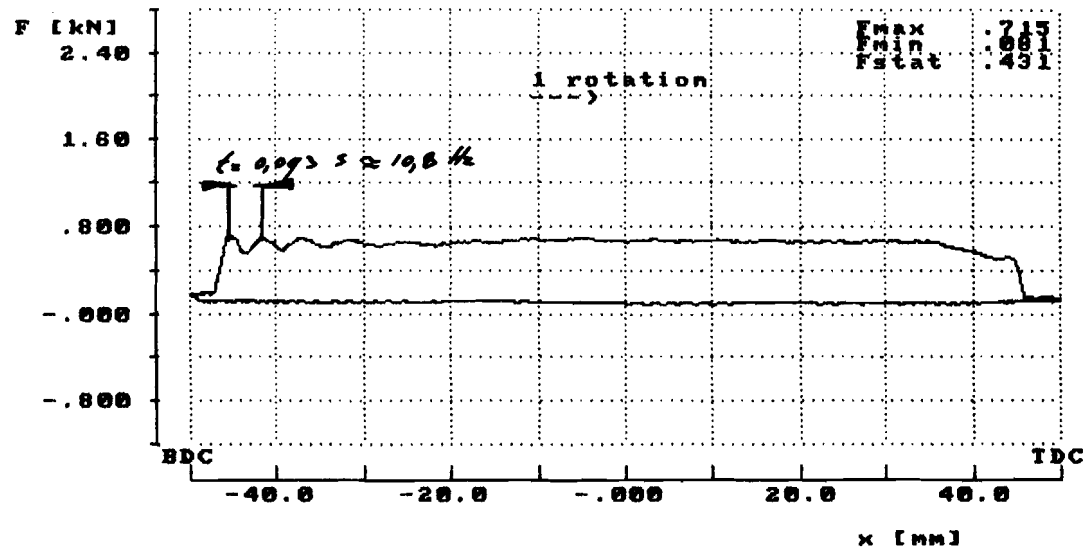
rotationspeed (rps): .200
meanflow (dm3/s) : .025 sample frequency (Hz): 409.709

filename --> P0494103_

Pin [W]:
15.070
Pout[W]:
10.566

Evol :
.817
Emech :
.701

head [m] :
23.3
pump [mm] :
49.0
stroke [mm]:
100.0



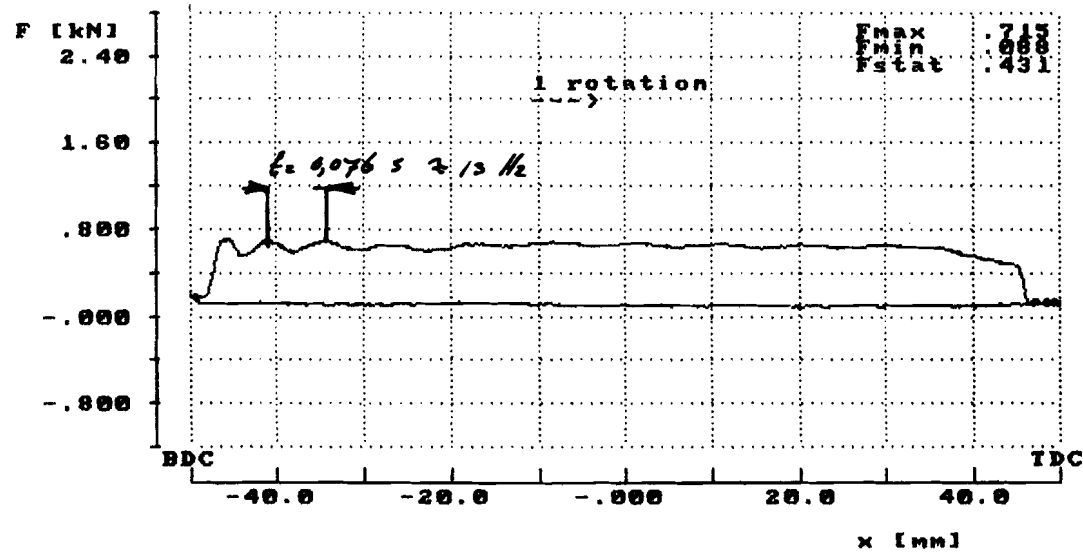
rotationspeed (rps): .300
meanflow (dm3/s) : .046 sample frequency (Hz): 614.262

filename --> P0494104_

Pin [W]:
19.747
Pout[W]:
15.715

Evol :
.912
Enech :
.796

head [m] :
23.3
pump [mm] :
49.0
stroke [mm]:
100.0



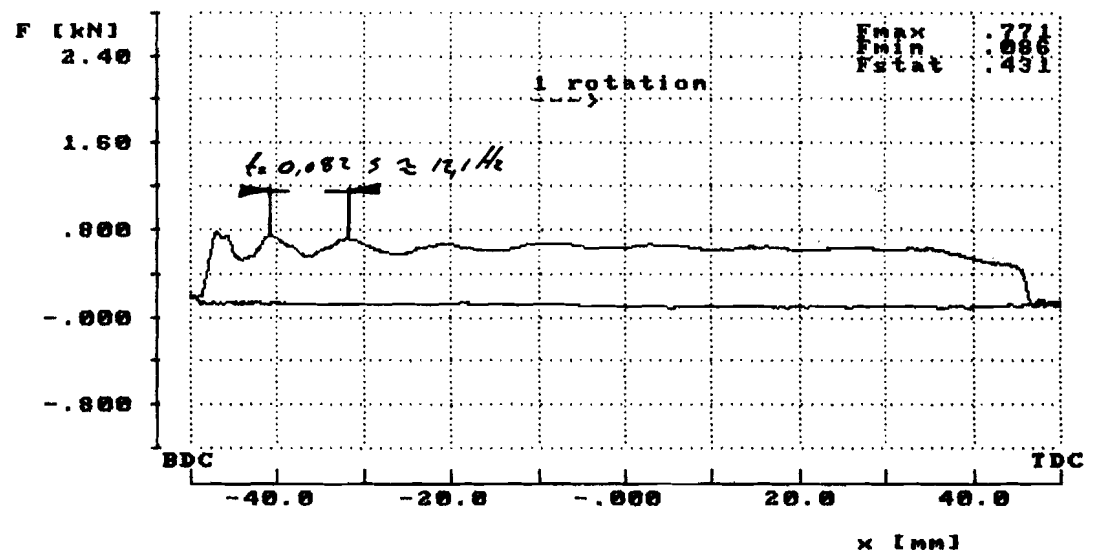
rotationspeed (rps): .400
meanflow (dm3/s) : .069 sample frequency (Hz): 819.117

filename --> P0494105_

Pin [W]:
24.586
Pout[W]:
19.905

Evol :
.913
Emech :
.810

head [m] :
23.3
pump [mm] :
49.0
stroke [mm]:
100.0



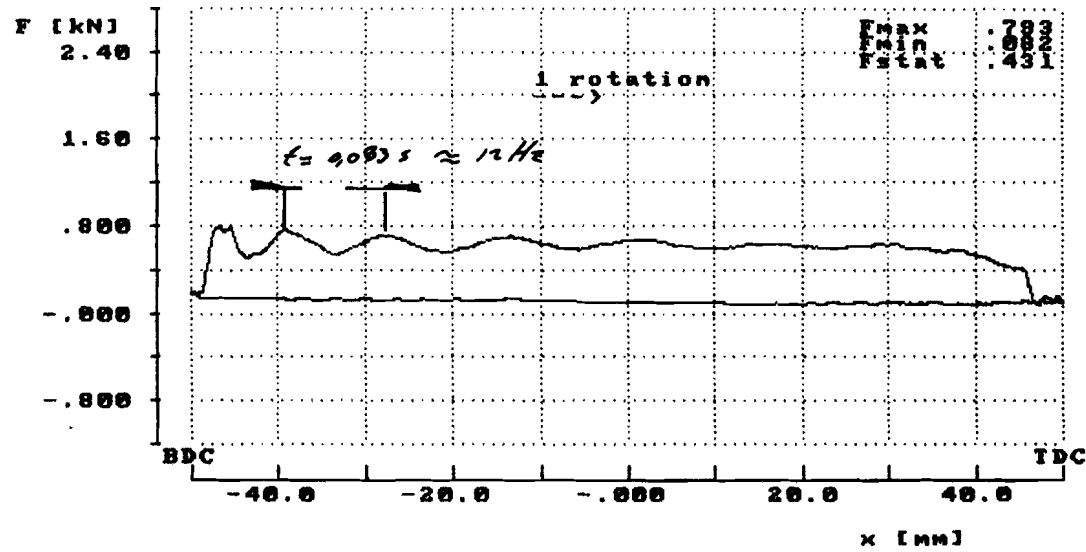
rotationspeed (rps): .506
meanflow (dm3/s) : .087 sample frequency (Hz): 1036.323

filename --> P0494106_

Pin [W]:
28.784
Pout[W]:
24.341

Evol :
.938
Emech :
.846

head [m] :
23.3
pump [mm] :
49.0
stroke [mm]:
100.0



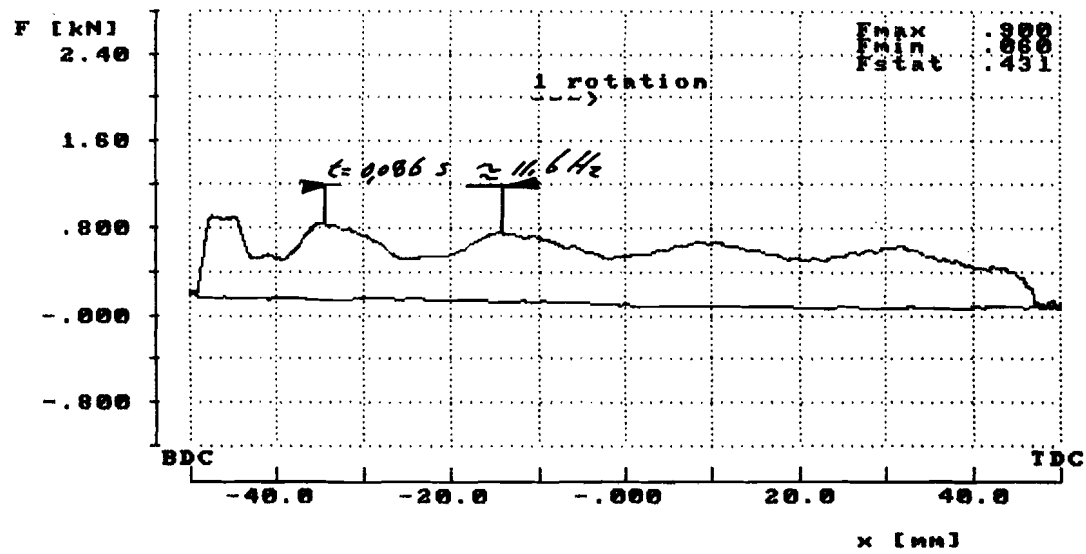
rotationspeed (rps): .602
meanflow (dm3/s) : .106 sample frequency (Hz): 1233.646

filename --> P0494107_

Pin [W]:
42.778
Pout[W]:
36.878

Evol :
.947
Emech :
.862

head [m] :
23.3
pump [mm] :
48.0
stroke [mm]:
100.0



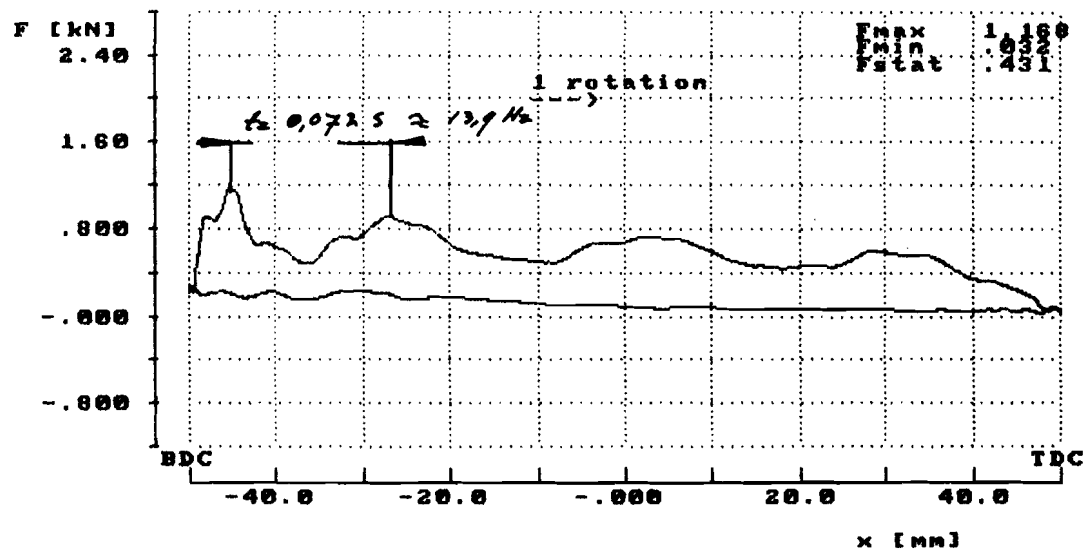
rotationspeed (rps): .904
meanflow (dm3/s) : .161 sample frequency (Hz): 1050.469

filename --> P0494108_

Pin [W]:
55.818
Pout[W]:
50.798

Evol :
.981
Emech :
.910

head [m] :
23.3
pump [mm] :
49.0
stroke [mm]:
100.0



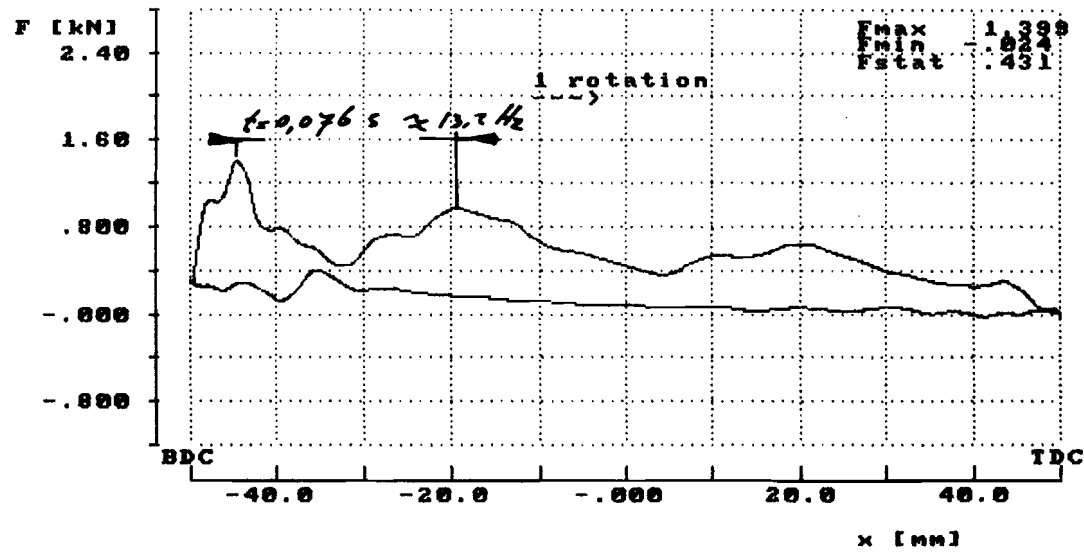
rotationspeed (rps): 1.201
meanflow (dm3/s) : .222 sample frequency (Hz): 2460.514

filename --> P0494109_

Pin [W]:
68.936
Pout[W]:
63.111

Evol :
.978
Emech :
.915

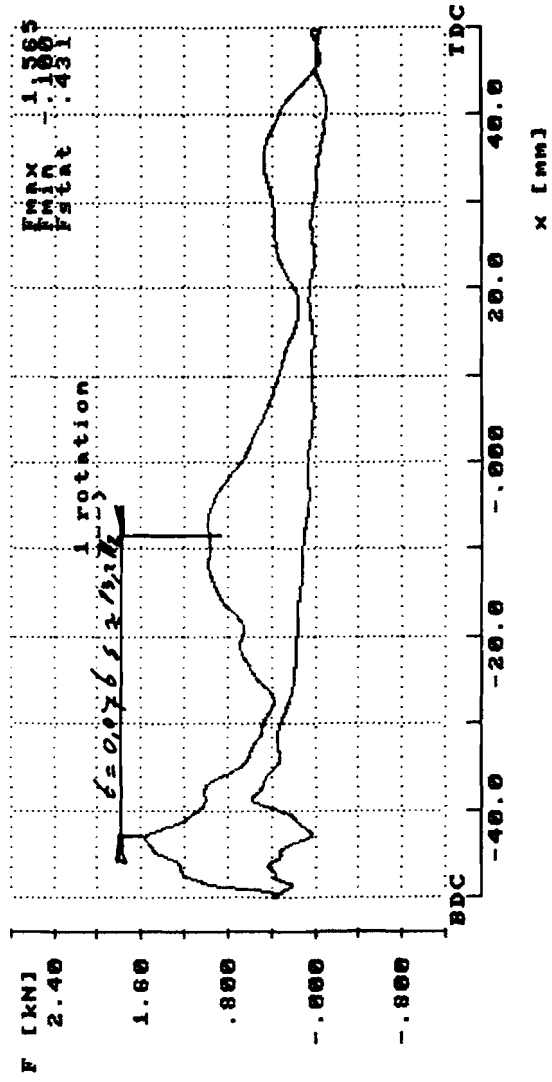
head [m] :
23.3
pump [mm] :
48.0
stroke [mm]:
100.0



rotationspeed (rps): 1.500
meanflow (dm3/s) : .276 sample frequency (Hz): 3071.915

filename --> P0494110_

Pin [W]:
64.412
Pout[W]:
78.718
Evol :
1.014
Emech :
.932
head [m] :
23.3
pump [mm] :
49.0
stroke [mm]:
100.0



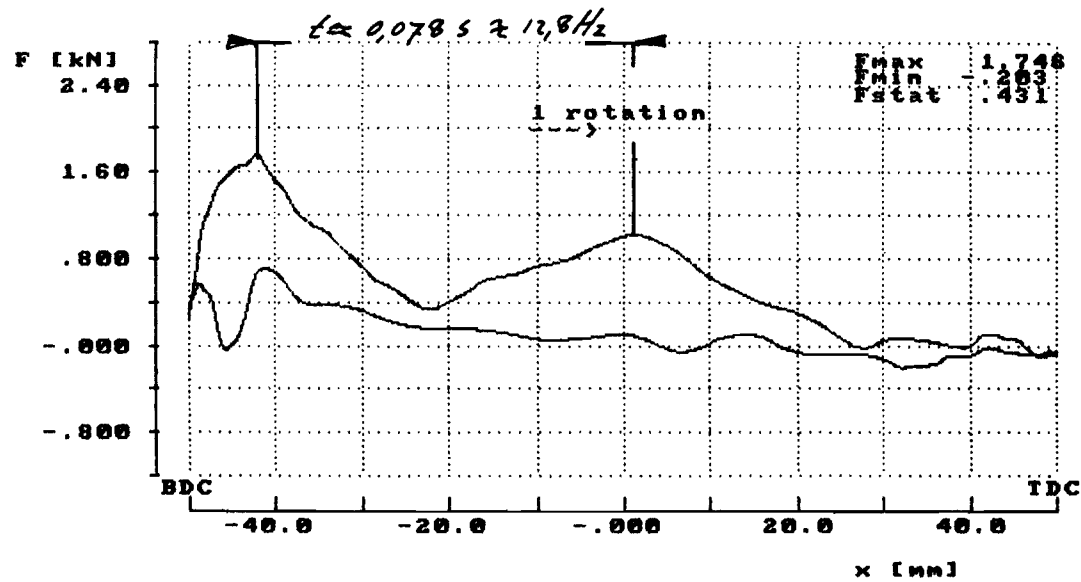
rotation speed (rps): 1.800
mean flow (dm³/s) : .344 sample frequency (Hz): 3687.382

filename --> P0494111

Pin [W]:
103.769
Pout[W]:
91.100

Evol :
1.006
Emech :
.878

head [m] :
23.3
pump [mm] :
49.0
stroke [mm]:
100.0



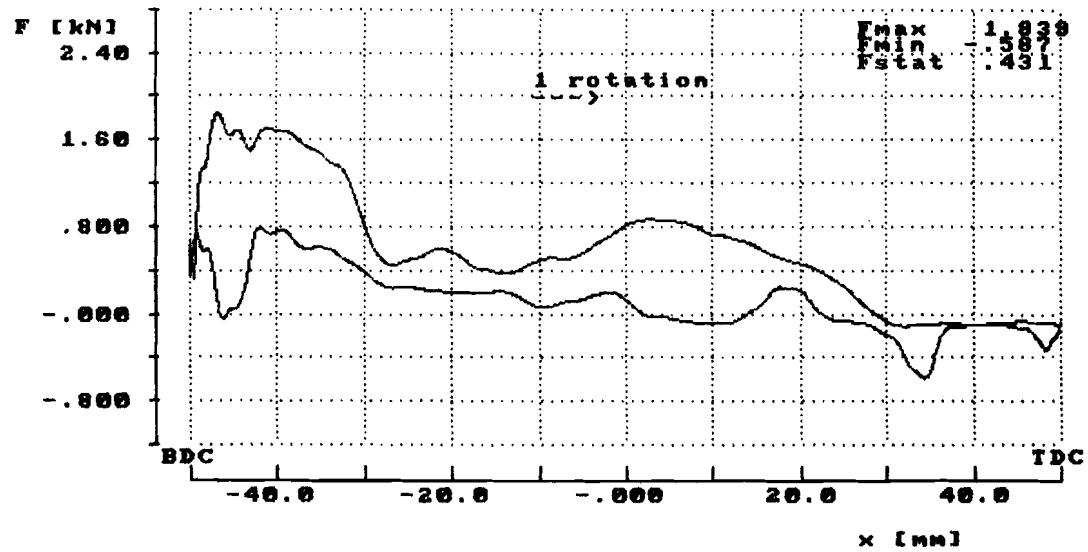
rotationspeed (rps): 2.102
meanflow (dm3/s) : .399 sample frequency (Hz): 4304.206

filename --> P0494112_

Pin [W]:
113.188
Pout[W]:
112.887

Evol :
1.085
Emech :
.980

head [m] :
23.3
pump [mm] :
49.0
stroke [mm]:
100.0



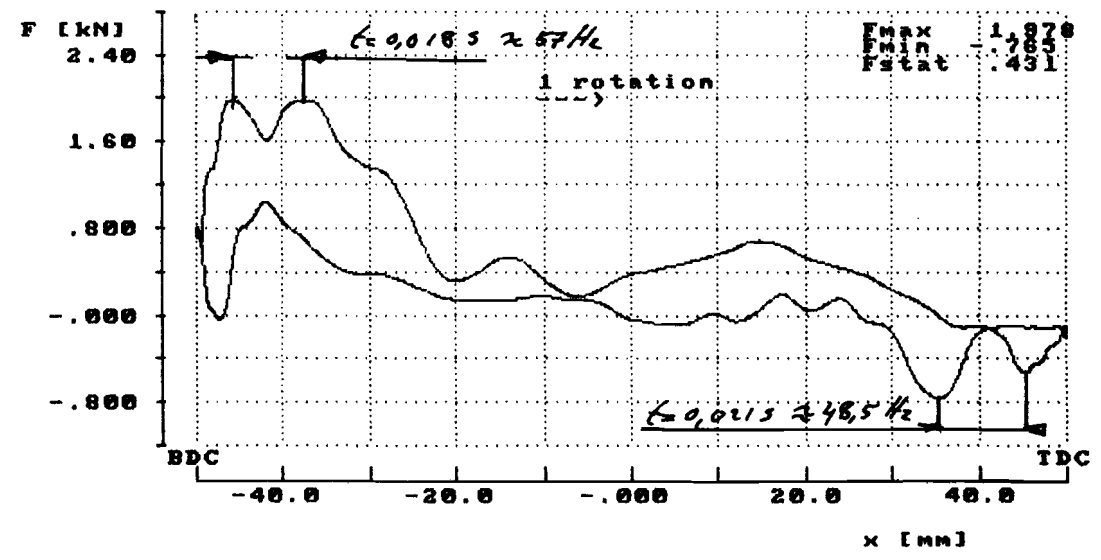
rotationspeed (rps): 2.396
meanflow (dm3/s) : .490 sample frequency (Hz): 4907.472

filename --> P0494113_

Pin [W]:
135.805
Pout[W]:
132.890

Evol :
1.144
Emech :
.979

head [m] :
23.3
pump [mm] :
49.0
stroke [mm]:
100.0



rotationspeed (rps): 2.694
meanflow (dm3/s) : .581 sample frequency (Hz): 5517.517

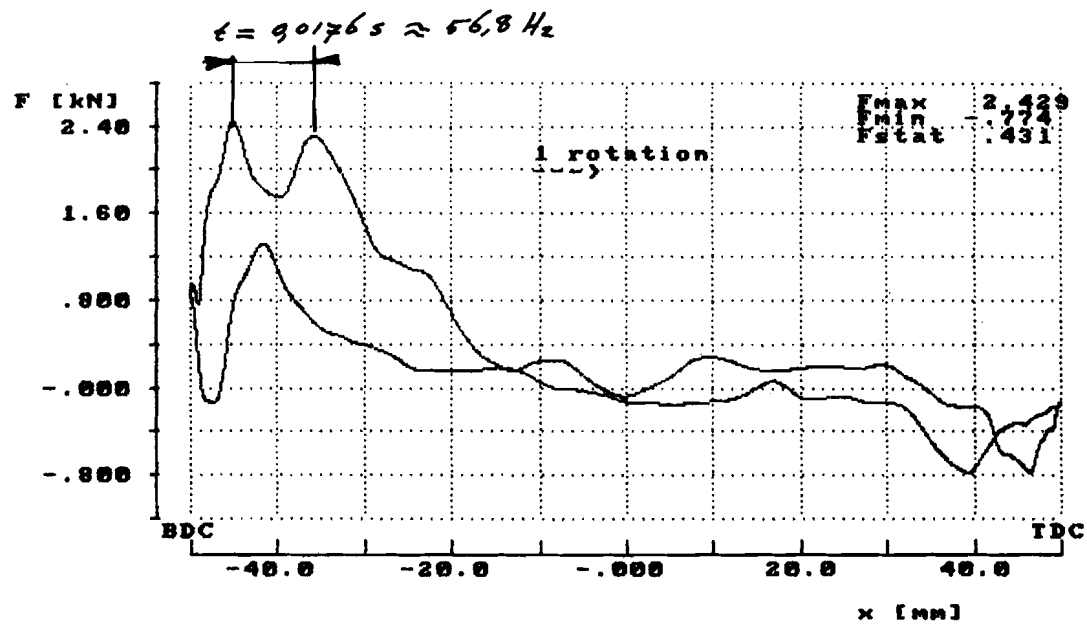
filename --> P0494114_

Pin [W]:
142.920
Pout[W]:
147.578

Evol :
1.141
Emech :
1.033

head [m] :
23.3
pump [mm] :
49.0
stroke [mm]:
100.0

rotationspeed (rps): 3.000
meanflow (dm3/s) : .646 sample frequency (Hz): 6144.131

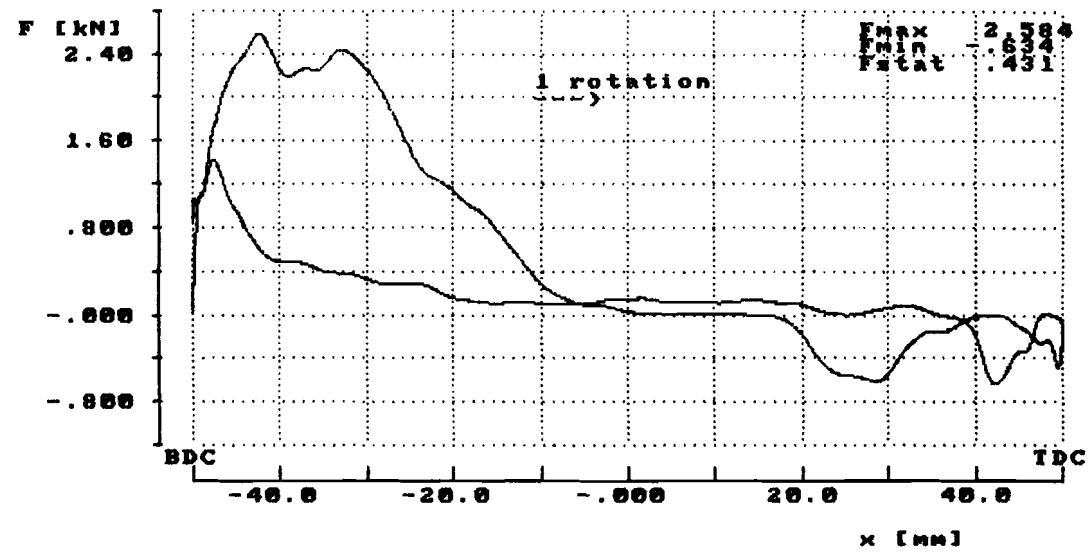


filename --> P0494115_

Pin [W]:
195.681
Pout[W]:
156.788

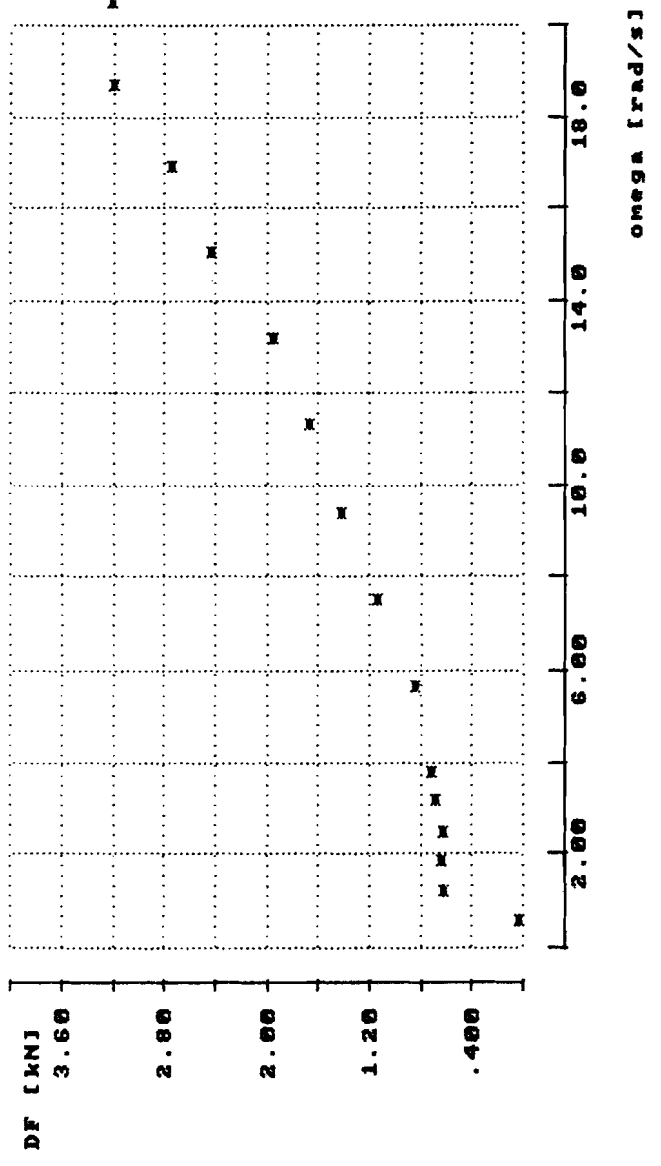
Evol :
1.182
Emech :
.801

head [m] :
23.3
pump [mm] :
48.0
stroke [mm]:
100.0

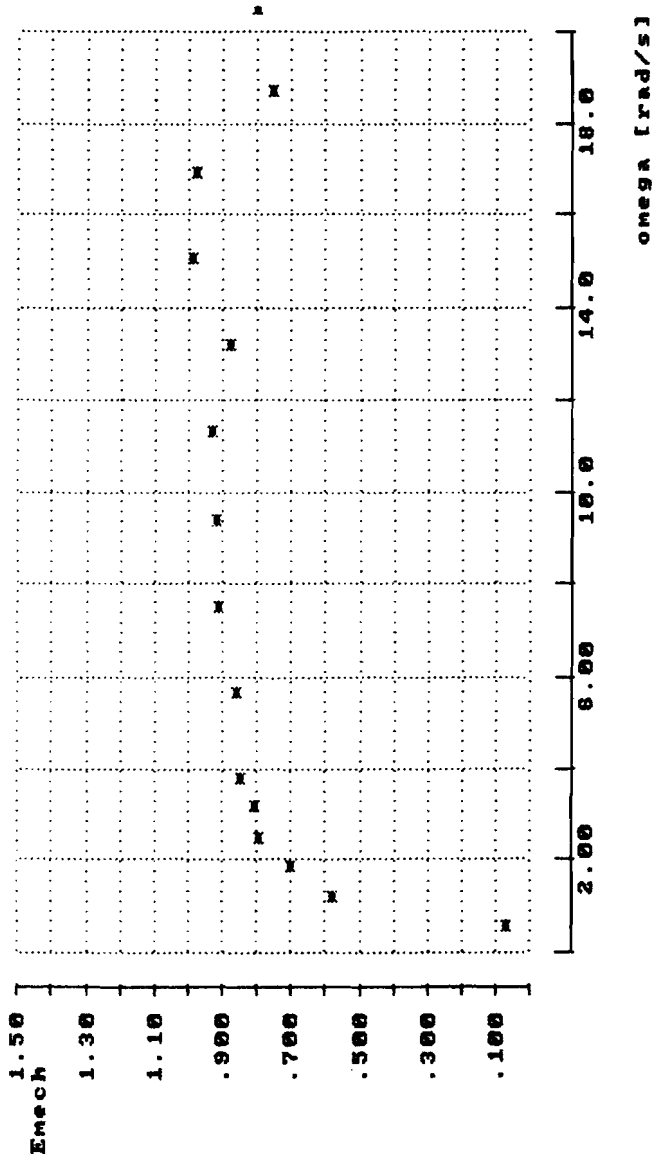


rotationspeed (rps): 3.300
meanflow (dm3/s) : .686 sample frequency (Hz): 6758.383

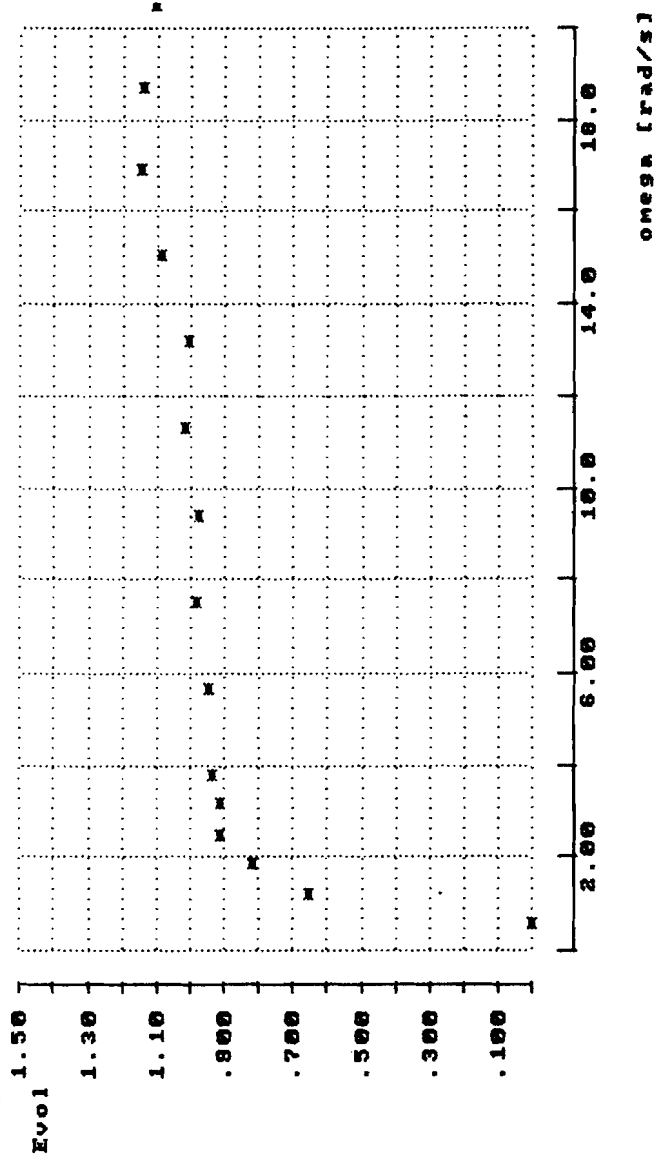
filename --> P049417 _



filename --> P04941.7 -



filename --> P049417 --

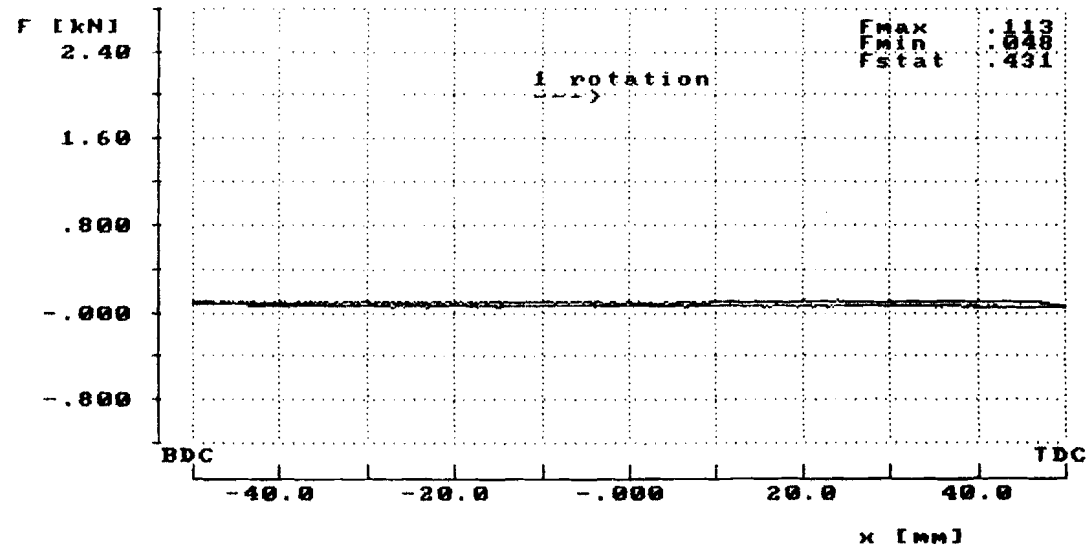


Annex 3

Configuration 42

filename --> A:P0494201_

Pin [W]:
.350
Pout[W]:
.369
Evol :
.086
Emech :
1.054
head [m] :
23.3
pump [mm] :
49.0
stroke [mm]:
100.0



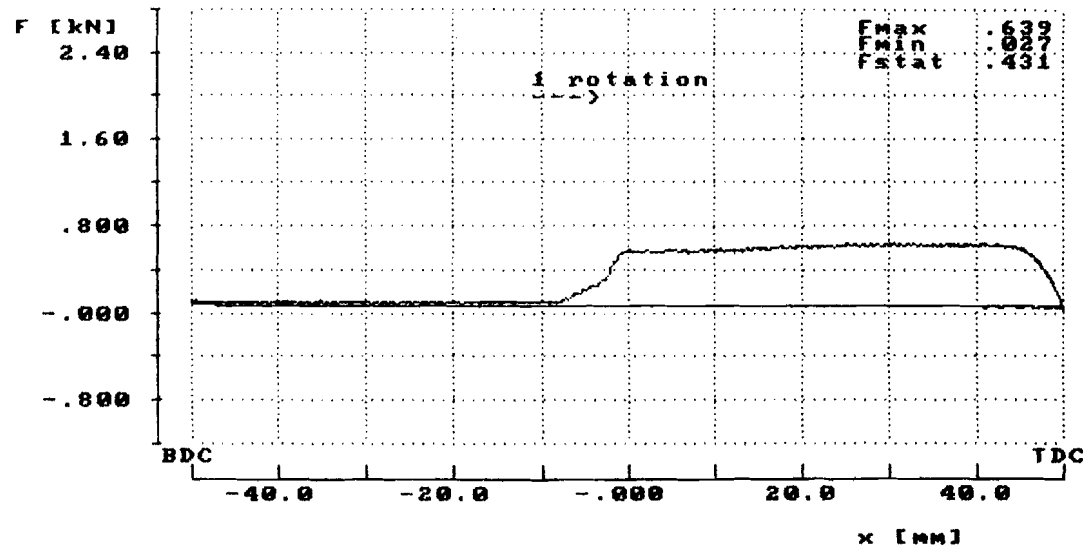
rotationspeed (rps): .100
meanflow (dm3/s) : .002 sample frequency (Hz): 204.855

filename --> P0494202_

Pin [W]:
5.776
Pout[W]:
.916

Evol :
.106
Emech :
.159

head [m] :
23.3
pump [mm] :
49.0
stroke [mm]:
100.0



rotationspeed (rps): .200
meanflow (dm3/s) : .004 sample frequency (Hz): 409.709

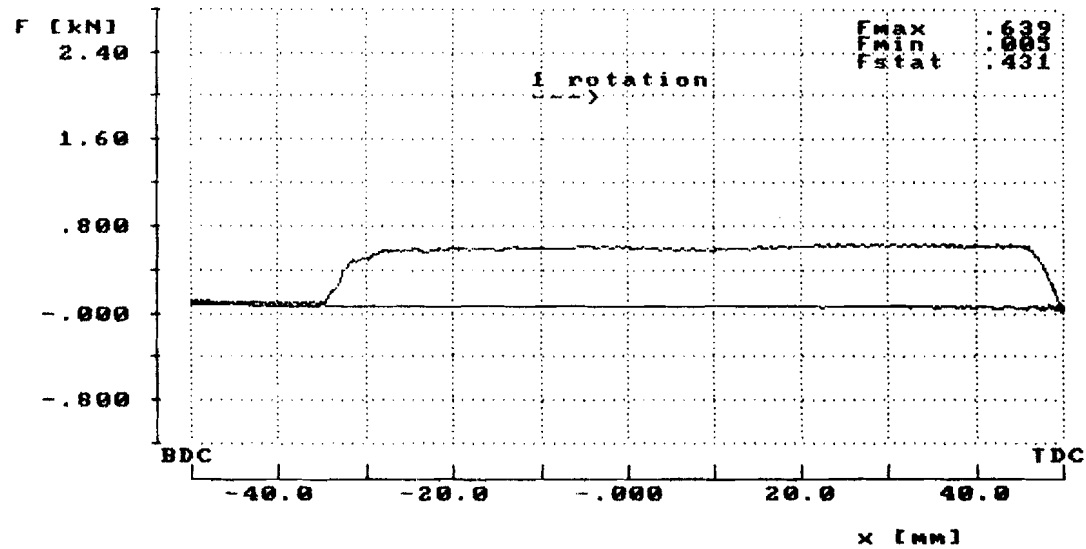
filename --> P0494203_

Pin [W]:
13.070
Pout[W]:
3.170

Evol :
.245
Emech :
.243

head [m] :
23.3
pump [mm] :
49.0
stroke [mm]:
100.0

rotationspeed (rps): .300
meanflow (dm3/s) : .014 sample frequency (Hz): 614.262

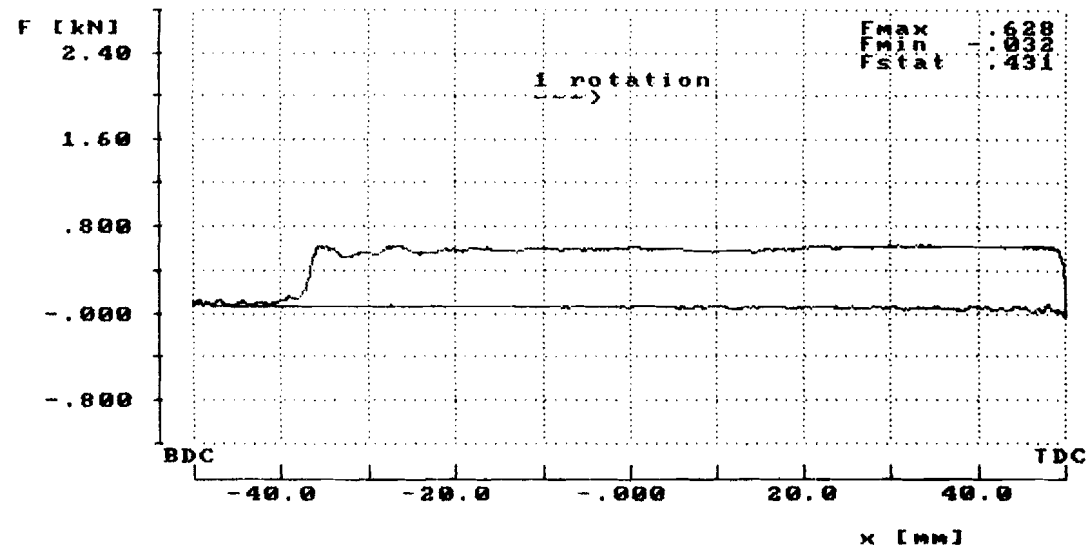


filename --> P0494204_

Pin [W]:
18.738
Pout [W]:
7.806

Evol :
.453
Emech :
.417

head [m] :
23.3
pump [mm] :
49.0
stroke [mm]:
100.0



rotationspeed (rps): .400
meanflow (dm3/s) : .034 sample frequency (Hz): 819.117

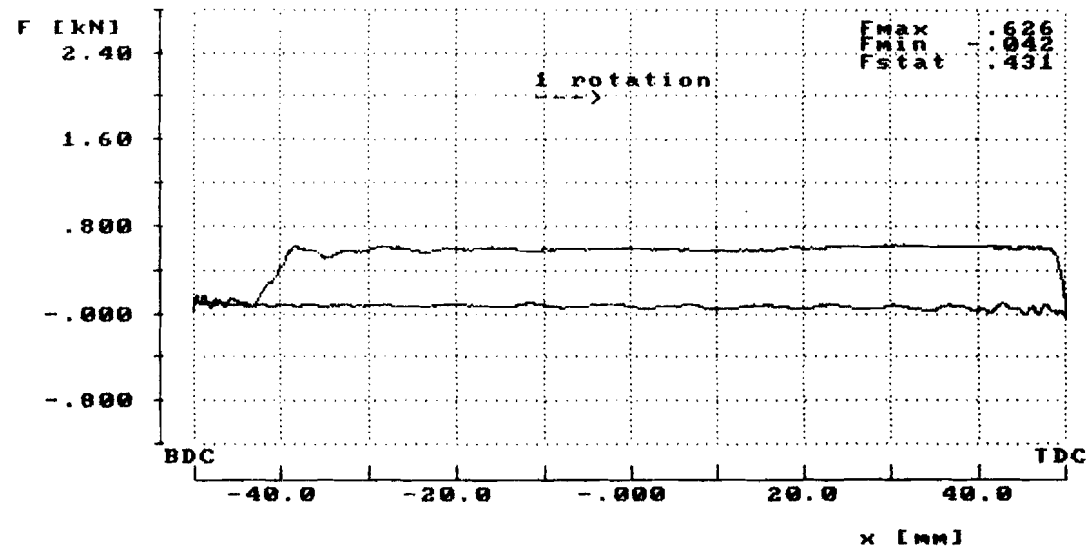
filename --> P0494205_

Pin [W]:
24.010
Pout[W]:
14.468

Evol :
.671
Emech :
.603

head [m] :
23.3
pump [mm] :
49.0
stroke [mm]:
100.0

rotationspeed (rps): .500
meanflow (dm3/s) : .063 sample frequency (Hz): 1023.972

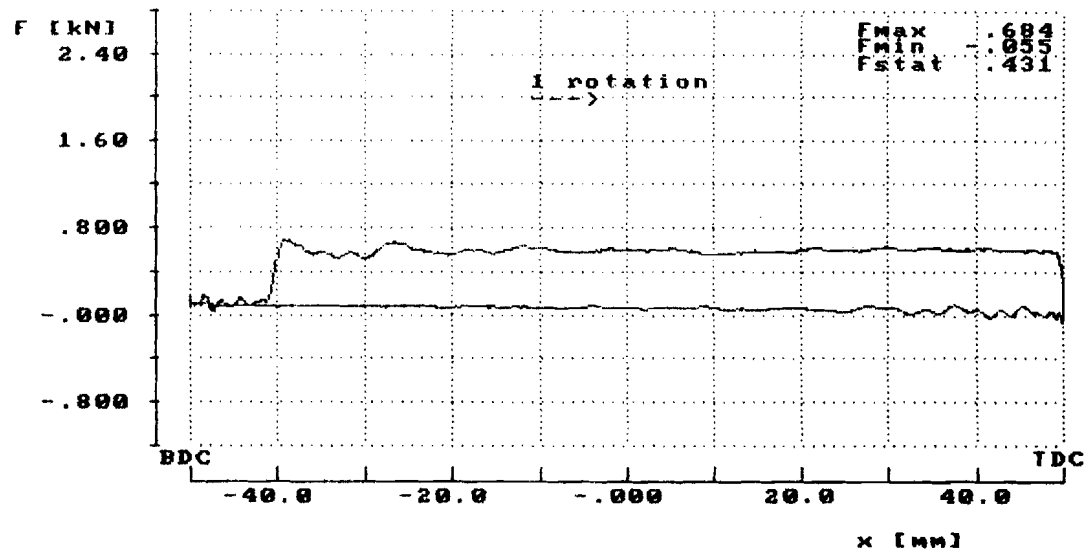


filename --> P0494206_

Pin [W]:
28.940
Pout[W]:
18.042

Evol :
.698
Emech :
.623

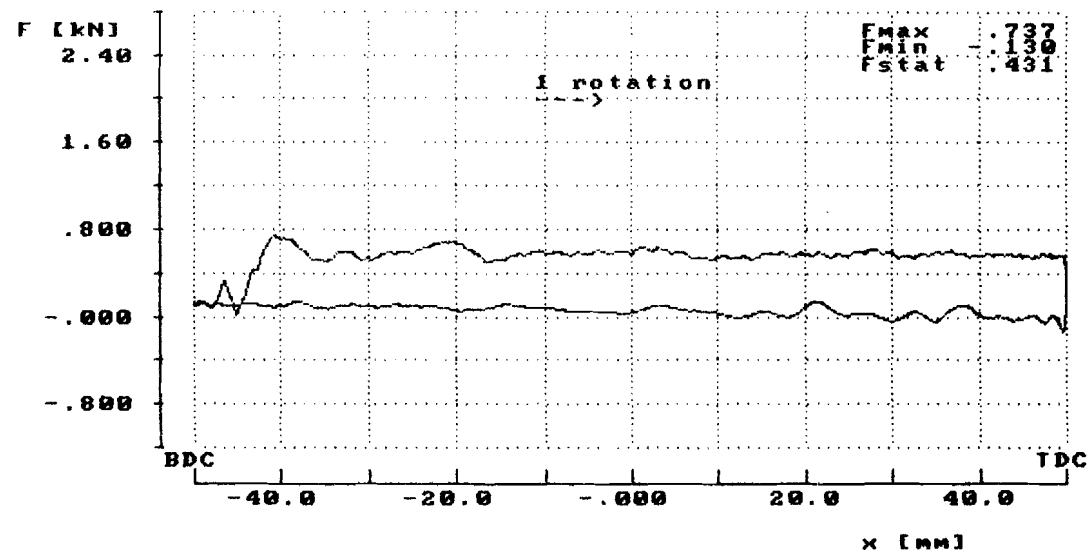
head [M] :
23.3
pump [mm] :
49.0
stroke [mm]:
100.0



rotationspeed (rps): .600
meanflow (dm3/s) : .079 sample frequency (Hz): 1228.826

filename --> P0494207_

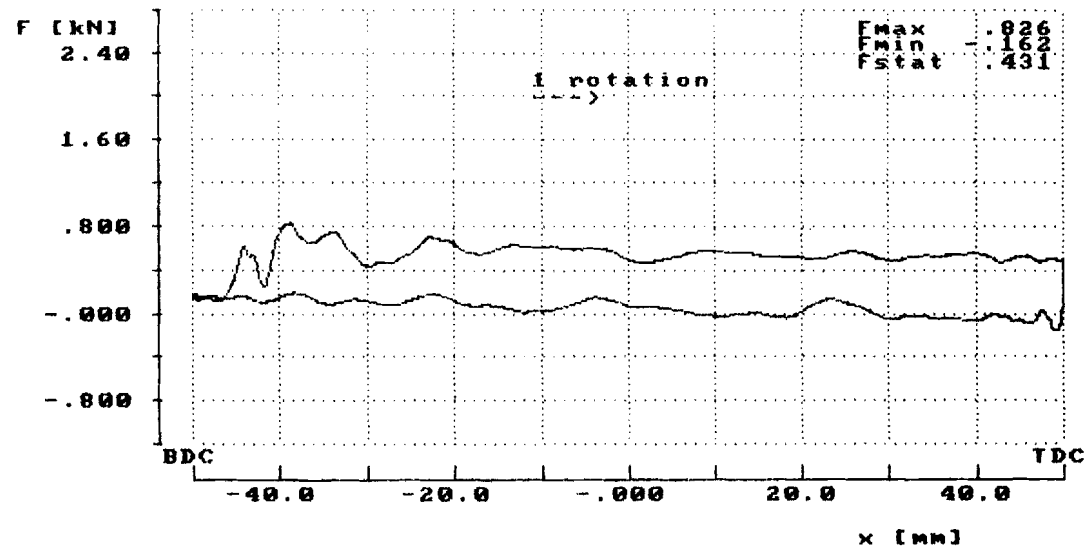
Pin [W]:
44.412
Pout[W]:
30.814
Evol :
.794
Emech :
.694
head [m] :
23.3
pump [mm] :
49.0
stroke [mm]:
100.0



rotationspeed (rps): .900
meanflow (dm3/s) : .135 sample frequency (Hz): 1843.089

filename --> P0494208_

Pin [W]:
58.000
Pout[W]:
43.238
Evol :
.836
Emech :
.745
head [m] :
23.3
pump [mm] :
49.0
stroke [mm]:
100.0



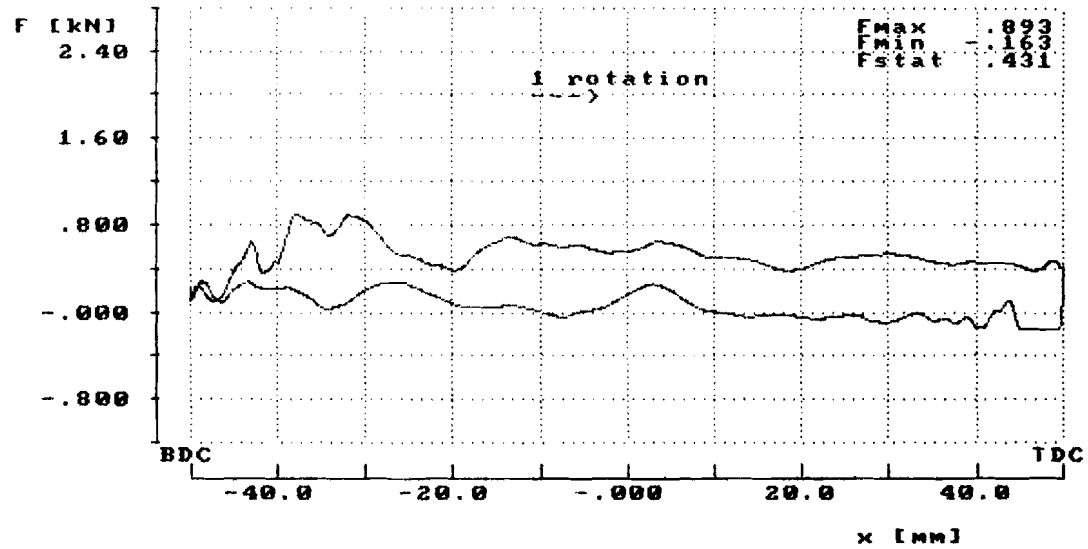
rotationspeed (rps): 1.200
meanflow (dm3/s) : .189 sample frequency (Hz): 2457.652

filename --> P0494209_

Pin [W]:
71.097
Pout[W]:
55.284

Evol :
.855
Emech :
.778

head [m] :
23.3
pump [mm] :
49.0
stroke [mm]:
100.0



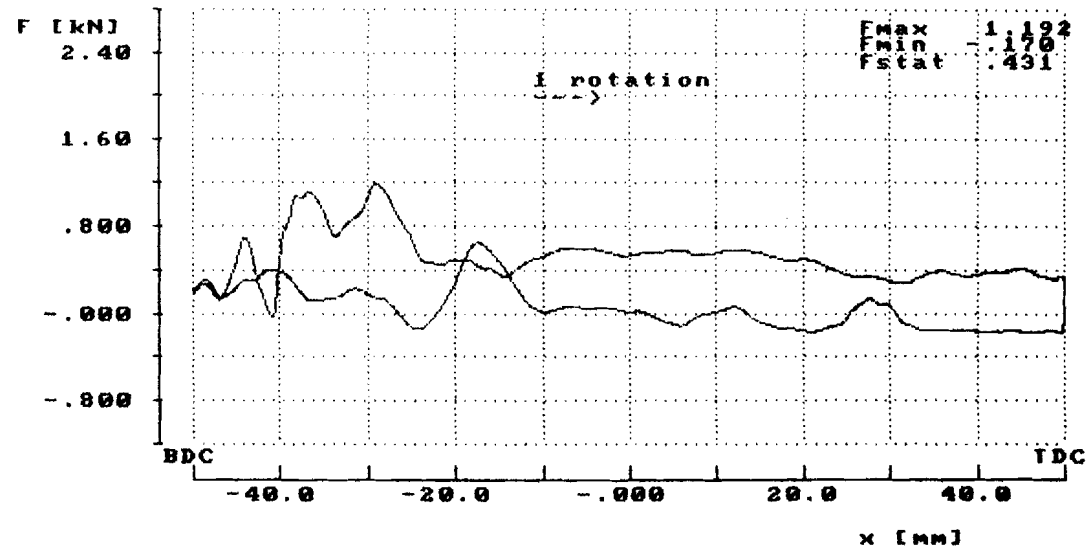
rotationspeed (rps): 1.500
meanflow (dm3/s) : .242 sample frequency (Hz): 3071.915

filename --> P0494210_

Pin [W]:
83.344
Pout[W]:
67.634

Evol :
.872
Emech :
.812

head [m] :
23.3
pump [mm] :
49.0
stroke [mm]:
100.0



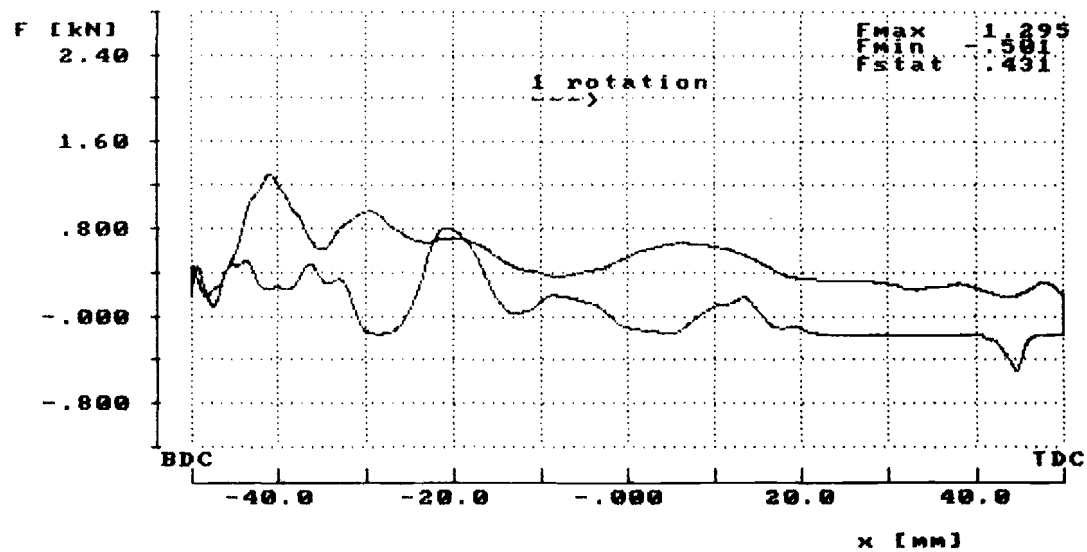
rotationspeed (rps): 1.800
meanflow (dm3/s) : .296 sample frequency (Hz): 3686.479

filename --> P0494211_

Pin [W]:
97.140
Pout[W]:
81.750

Evol :
.903
Emech :
.842

head [m] :
23.3
pump [mm] :
49.0
stroke [mm]:
100.0



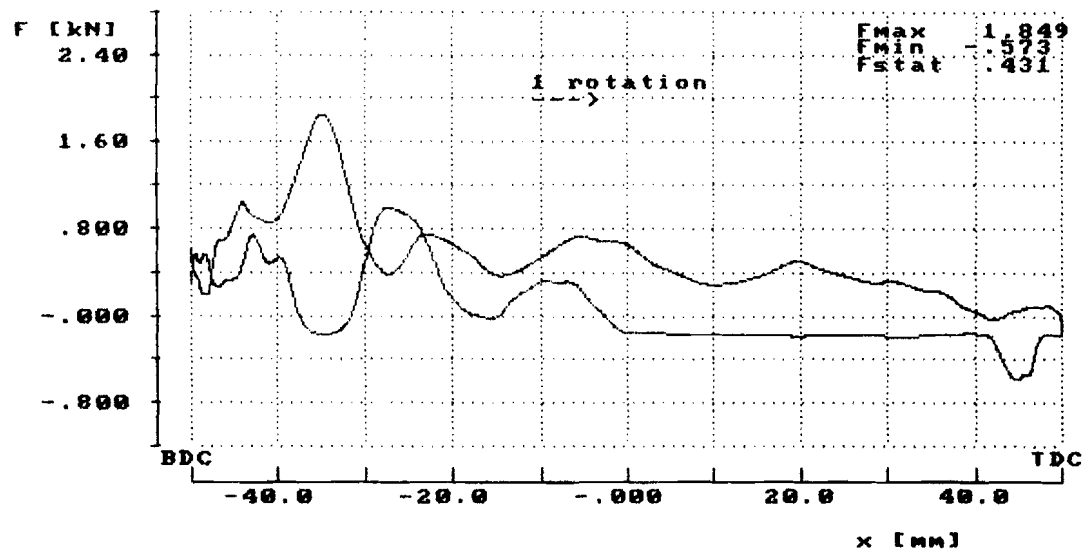
rotationspeed (rps): 2.100
meanflow (dm3/s) : .358 sample frequency (Hz): 4300.741

filename --> P0494212_

Pin [W]:
114.240
Pout[W]:
98.423

Evol :
.951
Emech :
.862

head [m] :
23.3
pump [mm] :
49.0
stroke [mm]:
100.0



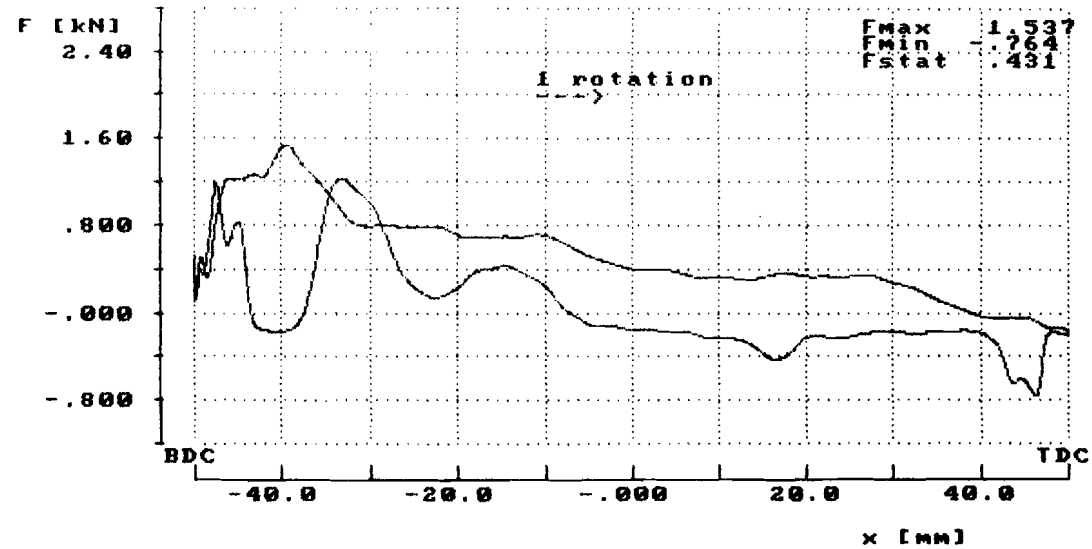
rotationspeed (rps): 2.400
meanflow (dm3/s) : .431 sample frequency (Hz): 4915.305

filename --> P0494213_

Pin [W]:
130.577
Pout[W]:
111.918

Evol :
.962
Emech :
.857

head [m] :
23.3
pump [mm] :
49.8
stroke [mm]:
100.0



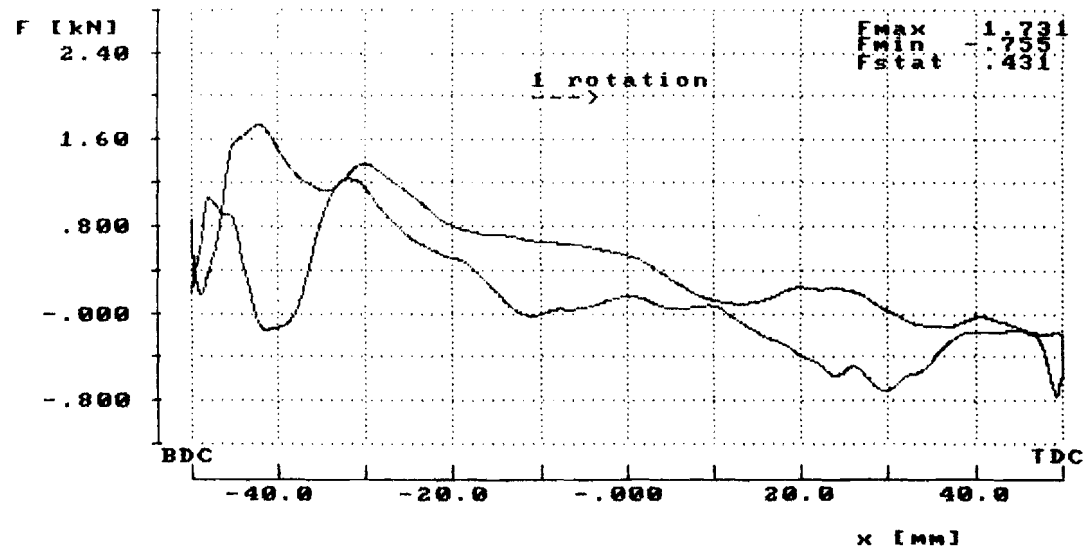
rotationspeed (rps): 2.700
meanflow (dm3/s) : .490 sample frequency (Hz): 5529.567

filename --> B:P0494214_

Pin [W]:
132.837
Pout[W]:
135.131

Evol :
1.045
Emech :
1.017

head [m] :
23.3
pump [mm] :
49.0
stroke [mm]:
100.0



rotationspeed (rps): 3.000
meanflow (dm3/s) : .591 sample frequency (Hz): 6144.131

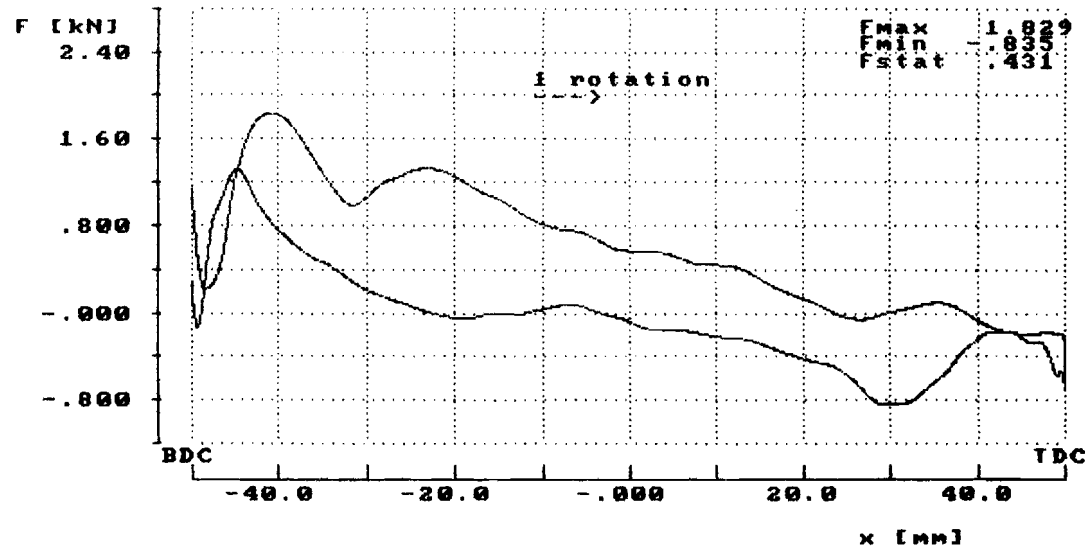
filename --> P0494215_

Pin [W]:
219.994
Pout[W]:
142.779

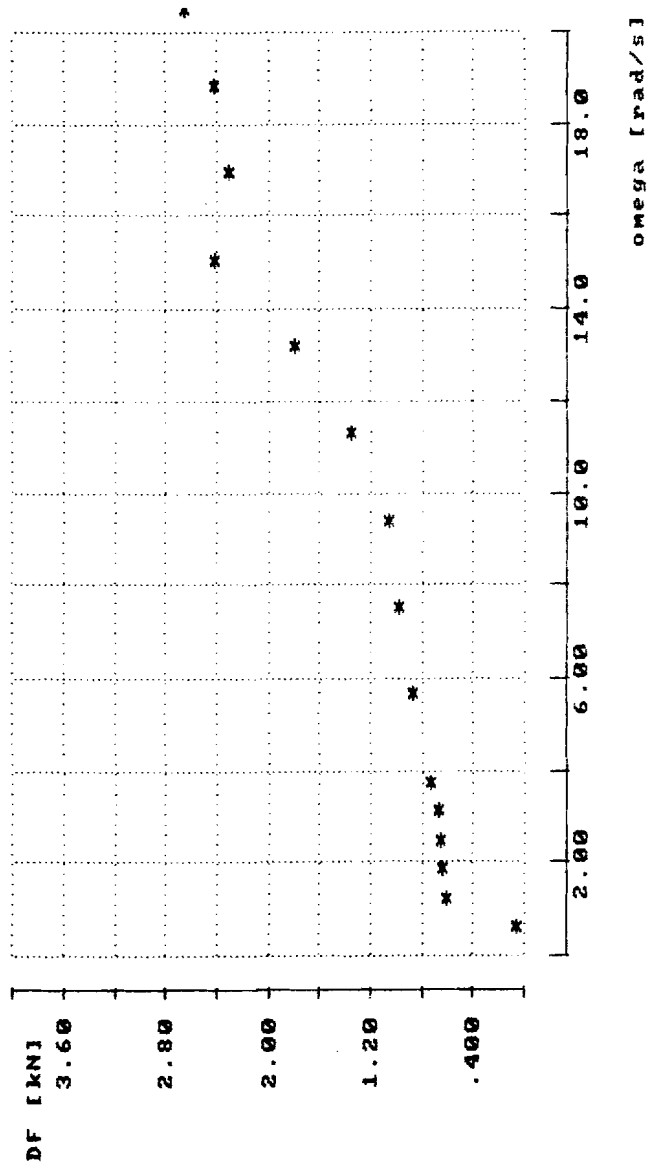
Evol :
1.004
Emech :
.649

head [m] :
23.3
pump [mm] :
49.0
stroke [mm]:
100.0

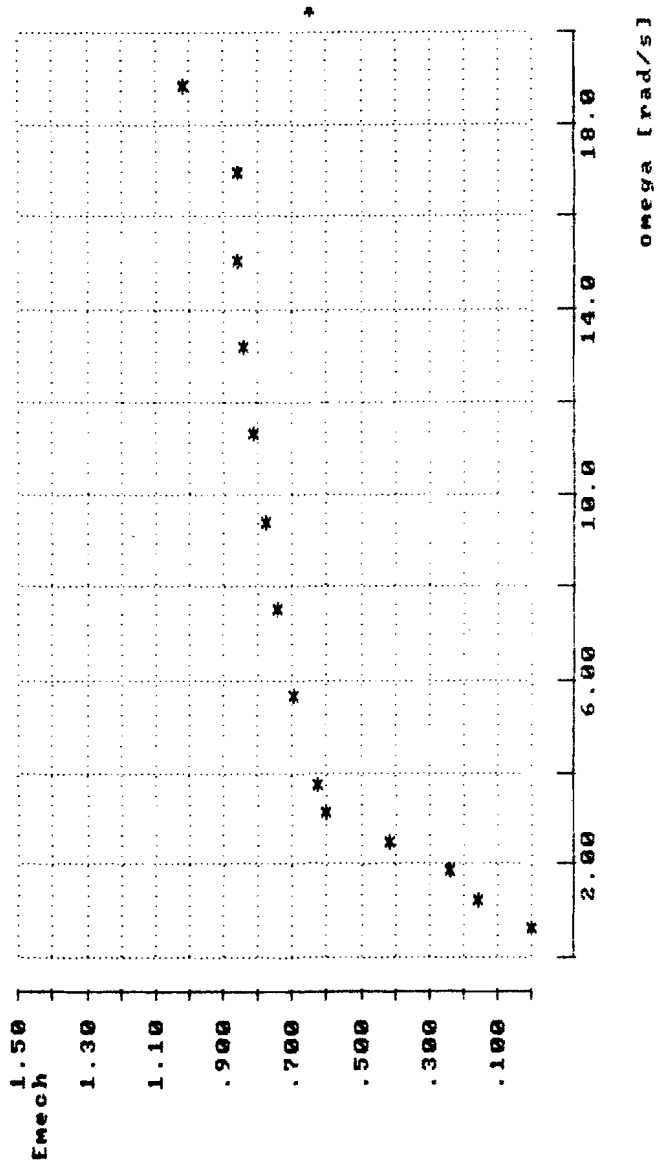
rotationspeed (rps): 3.300
meanflow (dm3/s) : .625 sample frequency (Hz): 6758.393



filename --> P0494215_



filename --> P0494215_



filename --> P0494215_

1.50
Evol

1.30

1.10

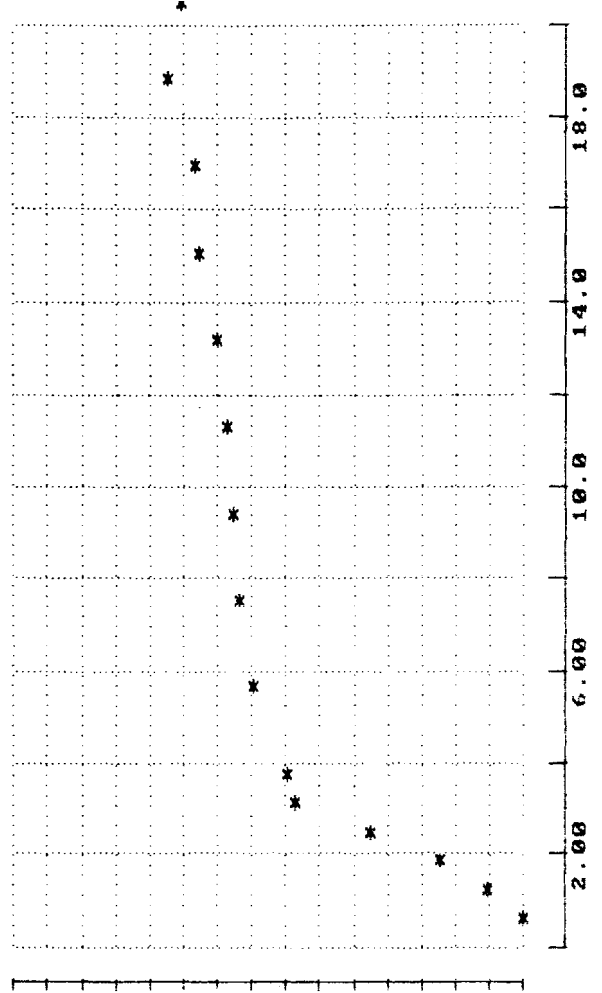
.900

.700

.500

.300

.100



omega [rad/s]

ANNEX VII

ANALYSIS OF ERRORS IN MEASURED SIGNALS

Random errors

1. Measured quantities with absolute error

Head:	$H \pm 0.05$	[m]
Stroke:	$s \pm 0.2$	[mm]
Pump diameter:	$D \pm 1$	[mm]
Rotational speed:	$H \pm 0.05$	[m]

2. Signal relative errors

Error in force (F) signal	1% of full-scale output
Error in flow (q) signal	2% of full-scale output
Error in speed (v) signal	1% of full-scale output

3. Hardware relative error

DASH 16 interface	0.01%
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The error in calculated quantities is a combination of errors from the measured quantities, signals and hardware.

Two calculated quantities are E_{mech} and E_{vol} . In this case only the relative error has been taken into account. The absolute error can be calculated from the relative error by multiplying the error with the actually calculated or measured quantity.

$$\text{Relative error: } \frac{\Delta E_{\text{mech}}}{|E_{\text{mech}}|} \quad \text{Absolute error: } \frac{\Delta E_{\text{mech}}}{|E_{\text{mech}}|} * |E_{\text{mech}}|$$

Error in E_{mech} :

$$E_{\text{mech}} = \frac{\overline{P_{\text{out}}}}{\overline{P_{\text{in}}}}$$

$$\overline{P_{\text{out}}} = \rho g H \cdot \overline{q}$$

$$\overline{P_{\text{in}}} = \overline{F \cdot v}$$

First the error in the mean—force, —speed and —flow must be known. After that it is possible to calculate the error in the input/output power.

The speed, flow and force have been sampled into the computer. Each sample has his own error. One measurement exist of 2048 samples. Data in a file on disk is a mean of m measurements. One sample from a measured signal, F (or v , q), is called F_{ij} .

The relative force error is:

$$\frac{\Delta F_{ij}}{|F_{ij}|} = 0.01$$

i = number of measurements, 1 to m

j = sample number, 1 to 2048 per measurement

The means of m measurements reduce the absolute error per sample with a factor \sqrt{m} :

$$\overline{F_j} = \frac{\sum_{i=1}^m F_{ij}}{m}$$

$$\Delta \overline{F_j} = \frac{\Delta F_{ij}}{\sqrt{m}}$$

$$\Delta \overline{v_j} = \frac{\Delta v_{ij}}{\sqrt{m}}$$

$$\Delta \bar{q}_j = \frac{\Delta q_{ji}}{\sqrt{m}}$$

The relative error:

$$\frac{\Delta F_j}{|F_j|} = \frac{\Delta F_{ji}}{\sqrt{m} |F_{ji}|}$$

$$\frac{\Delta \bar{v}_j}{|v_j|} = \frac{\Delta v_{ji}}{\sqrt{m} |v_{ji}|}$$

$$\frac{\Delta \bar{q}_j}{|q_j|} = \frac{\Delta q_{ji}}{\sqrt{m} |q_{ji}|}$$

The result of this calculation is an average sample \bar{F}_j , \bar{v}_j or \bar{q}_j with a relative error which is lower as the relative error of the rough signal.

The mean input power per sample is: $\bar{P}_{in j} = \bar{F}_j * \bar{v}_j$.

The total average input power over 2048 samples is:

$$\bar{P}_{in} = \sum_{j=1}^{2048} \frac{1}{2048} [\bar{F}_j * \bar{v}_j] = \bar{F} * \bar{v}.$$

The relative error:

$$\frac{\Delta P_{in}}{|P_{in}|} = \frac{\Delta F}{|F|} + \frac{\Delta v}{|v|}$$

$$\frac{\Delta E_{mech}}{|E_{mech}|} = \frac{\Delta P_{in}}{|P_{in}|} + \frac{\Delta H}{|H|} + \frac{\Delta \bar{q}}{|q|} = \frac{\Delta F}{|F|} + \frac{\Delta v}{|v|} + \frac{\Delta q}{|q|} + \frac{\Delta H}{|H|}$$

$$= \frac{0.01}{\sqrt{m}} + \frac{0.01}{\sqrt{m}} + \frac{0.02}{\sqrt{m}} + \frac{0.05}{H} = 4 \left[\frac{0.01}{\sqrt{m}} \right] + \frac{0.05}{H}$$

Error in E_{vol} :

$$E_{vol}: \quad \frac{\bar{q}}{n^2 s} = \frac{\bar{q}}{[D/2]^2 s n \pi}$$

$$\frac{\Delta E_{vol}}{|E_{vol}|} = \frac{2\Delta D}{|D|} + \frac{\Delta s}{|s|} + \frac{\Delta n}{|n|} + \frac{\Delta \bar{q}}{|\bar{q}|}$$

$$= \frac{2}{|D|} + \frac{0.2}{|s|} + \frac{0.001}{n} + \frac{0.02}{|m}$$

In the configuration as described in chapter [3] the relative errors are:

configurations

$$\frac{\Delta E_{mech}}{|E_{mech}|} = 0.015$$

$$\frac{\Delta E_{vol}}{|E_{vol}|} = n = 0,1 \rightarrow 0,059$$

$$n = 3,3 \rightarrow 0,049$$