Measurements executed on a CWD 161 D pump with different valve lifting heights

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CONTENTS

	Page
SUMMARY	1
1. INTRODUCTION	2
2. DESCRIPTION OF THE TEST STAND	3
3. DESCRIPTION OF THE MEASURED CONFIGURATIONS	4
3.1 Configuration 02	4
3.2 Configuration 03	4
4. ELUCIDATION OF THE MEASUREMENTS	5
4.1 Configuration 02	5
4.2 Configuration 03	5
5. CONCLUSIONS	7
6. RECOMMENDATIONS	7
ANNEX I Measurements configuration 02 (h=7.5 mm)	
ANNEX II Measurements configuration 03 (h=14.5 mm)	
FIGURES	

SUMMARY

In this report measurements are reported, performed on a CWD 161 D pump with a valve lifting height of 7.5 and 14.5 mm. The tests done showed that the influence of the valve lifting height on the shock force is less than expected according the CWD theoretical model $F_s = \sin \alpha_s \sqrt{k.m.}$
The CWD 161 D pump, with a valve lifting height of 7.5 mm, performed better than the one with 14 mm valve lifting height.

1. INTRODUCTION

Upto now it was assumed that increasing the valve lift height leads to higher shock forces.

However traditional valve design rules as given in "Pompen door J.C. Andriessen" and used by many pump manufacturers result in large valve lifting heights. These traditional design rules are based on the experience with spring loaded valves.

CWD pumps have small valve lifting heights to reduce the shock forces, which leads to very high flow speeds in the gap; i.e. 5 to 8 m/s. This results in a high pressure drop over the valves, a reduced netto suction height for surface pumps and cavitation. To avoid those problems valve lifting heights have to be increased and a balance must be found between shock forces and flow restrictions.

In this report measurements are reported performed on a CWD 161 D pump with a valve lifting height of 7.5 mm and 14.5 mm.

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 80 to 200 mm with steps of 40 mm. The speed range is from 0 upto 4 rps.

The force in the pump rod is measured with a force transducer type E. Brosa + 50 KN. The flow is measured with an inductive flow meter: Disco mag. DMI 6531/H50 Endress + Hauser. The data acquisition was done with a 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.

The accuracy of the components of the measuring system are:

force transducer: - linearity 0.15%

- hysteresis 0.15%

amplifier for force transducer $\pm$ 0.5%

flow transducer $\pm$ 1% of maximum flow range.

The accuracy of the A/D conversion is:

$$\left.\begin{array}{l} -10\ V \rightarrow 0\ bits \\ +10\ V \rightarrow 4096\ bits \end{array}\right\} \pm 0.05\ V$$

The well under the test rig has a depth of 33 meter. The CWD 161 D pump for the CWD 8000 was installed at a depth of 15.8 meter, ground level to foot valve. The static head was taken at 14.9 meter. For the rising main 2" GI pipe was used with a 3/4" pump rod inside. From the delivery T to the de-aeration vessel 3 meter 2" plastic hose was used. The stroke was adjusted at 200 mm.

3. DESCRIPTION OF THE MEASURED CONFIGURATIONS

3.1 Configuration 02

Pump tested: CWD 161 D pump for use with CWD 8000 windmill (drawing E8504-00/C, fig. 2.2).

stroke volume : 4 l

volume air chamber : 23 l

diameter rising main : 2" GI pipe (ID 52 mm)

diameter pump rod : $\frac{3}{4}$" GI pipe (OD 27 mm)

installation depth : 15.8 m (foot valve - ground level)

static load : 14.9 m

static pump rod force : 2900 N

The valve lifting height of foot and piston valve was taken at 7.5 mm.

3.2 Configuration 03

Pump tested CWD 161 D for use with CWD 8000 windmill (drawing E8504-00/C, fig. 2.2).

stroke volume : 4 l

volume air chamber : 23 l

diameter rising main : 2" GI pipe (ID 52 mm)

diameter pump rod : $\frac{3}{4}$" GI pipe (OD 27 mm)

installation depth : 15.8 m (foot valve - ground level)

static load : 14.9 m

static pump rod force : 2900 N

The valve lifting height of foot and piston valve was taken at 14 mm.

4. ELUCIDATION OF THE MEASUREMENTS

The results of the measurements are given in the annexes.

configuration 02 annex I P16102..

configuration 03 annex II P16103..

4.1 Configuration 02

Force, flow and speed are measured for n = 0.1 to 1.2 rps in steps of 0.1 rps. The results of the measurements are given in indicator diagrams (annex I-1 - I-13). An important value for the fatigue life of pump rods $\Delta F = F_{max} - F_{min}$ has been calculated.

Annexes I-14, 15, 16 and 17 give the results of ΔF, $\overline{Q}$, η_{mech} and η_{vol} versus the rotational speed. The best fitting polynomial aproximations have been calculated and are for $0.1 \leq \omega \leq 1.2$.

$$\Delta F = F_{max} - F_{min} = -0.005\omega^2 + 0.52\omega + 3.444 \quad [KN]$$

$$\overline{Q} = -6.06\omega^2 + 10.275\omega + 94.049 \quad [Nm]$$

$$\eta_{mech} = 0.005\omega^3 - 0.087\omega^2 + 0.368\omega + 0.3$$

$$\eta_{vol} = 0.005\omega^3 - 0.081\omega^2 + 0.393 + 0.347$$

4.2 Configuration 03

Force flow and speed are measured for n=0.1 to 1.1 rps in steps of 0.1 rps. The results of the measurements are given in indicator diagrams (annex II-1 - II-11). Annexes II-12, 13, 14, 15 give the results of ΔF, $\overline{Q}$, η_{mech} and η_{vol} versus the rotation speed. The best fitting polynomial aproximations have been calculated and are: $0.1 \leq \omega \leq 1.1$.

$$\Delta F = F_{max} - F_{min} = 0.016\omega^2 + 0.404\omega + 3.742 \quad [KN]$$

$$\overline{Q} = -0.089\omega^2 + 3.813\omega + 110.054 \quad [Nm]$$

$$\eta_{vol} = 0.005\omega^3 - 0.08\omega^2 + 0.372\omega + 0.415$$

$$\eta_{mech} = 0.005\omega^3 - 0.068\omega^2 + 0.291\omega + 0.362$$

Configuration 03 was more noisy than configuration 02 during operation. With configuration 02 the sound of opening and closing the valves could be heard clearly, a beating noise and configuration 03 was making a loud noise like a rattling car.

5. CONCLUSIONS

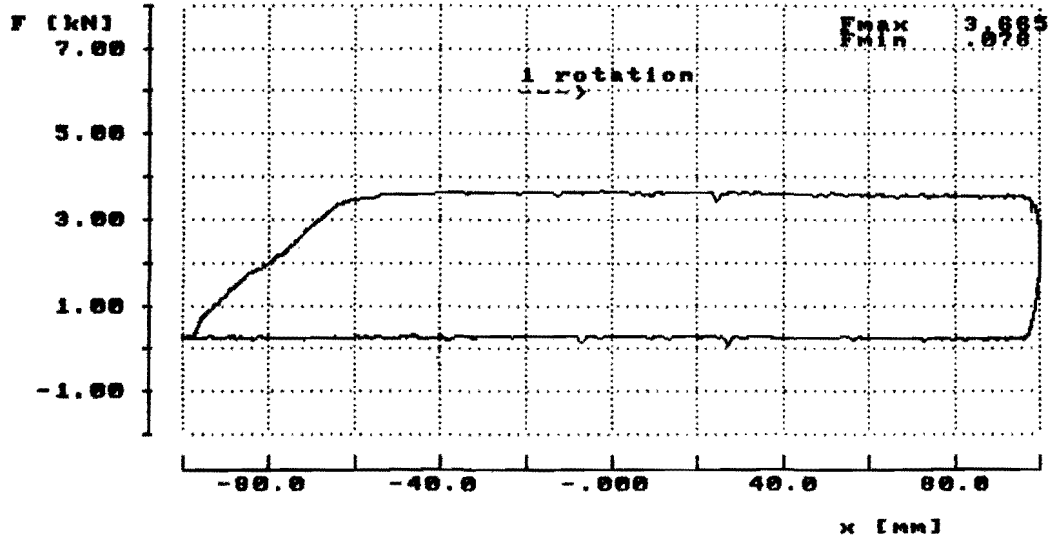
- At almost all rotational speeds ΔF is higher for configuration 03 (h=14.5 mm) than for configuration 02 (h=7.5 mm) (see annex III-1).
- For a 3/4" pump rod $n_{max} \leq 1.4$ rps to keep ΔF smaller than the maximum fatigue load of 7600 N.
- At almost all rotational speeds F_{max} is higher for configuration 03 (see annex III-4) than for configuration 02.
- For rotational speeds of $\pm$ 1 rps and higher, F_{min} is lower for configuration 03 (see annex III-4).
- For rotational speeds of 0.6 rps and higher, η_{mech} is better for configuration 03.
- For rotational speeds below 0.8 rps, η_{vol} is somewhat lower for configuration 02, above 0.8 rps the differences in η_{vol} for both configurations are very small.
- Configuration 03 is more noisy than configuration 02.

6. RECOMMENDATIONS

- The choice of the valve lifting height must be made by balancing the effect of shock force and flow friction in the valves on ΔF.
- The best valve lifting height for the CWD 161 D is $\pm$ 7 mm.
- More research has to be done on valve motion and opening pressure to understand their effects on the pump rod force.

BDC TDC

filename --> B:P1610215._



Pin [W]:
29.991
Pout[W]:
.588

Evol :
.019
Emech :
.019

head [m] :
14.9
pump [mm] :
161.0
stroke [m]:
.2

rotationspeed (rps): .050
meanflow (dm3/s) : .004 sample frequency (Hz): 102.427

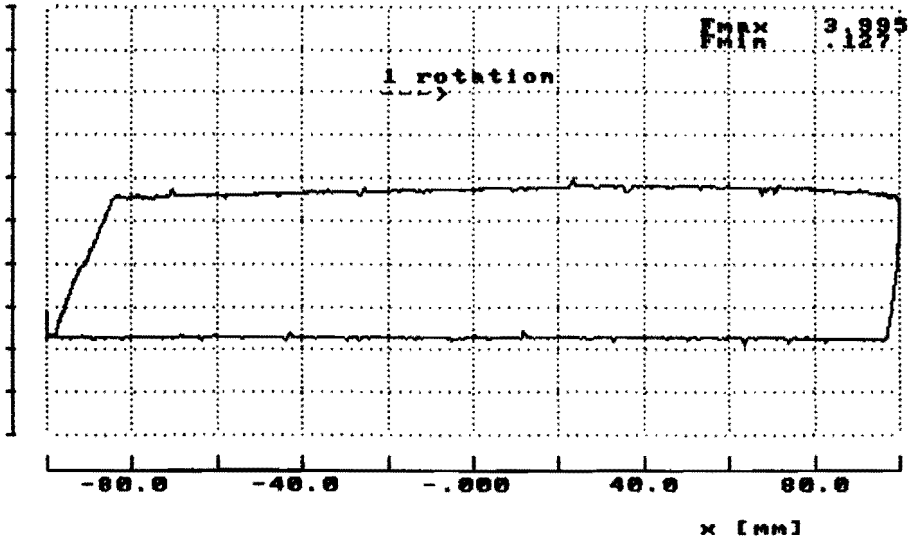
BDC TDC

filename --> B:P1810201._

Pin [W]:
67.821
Pout[W]:
31.707

Evol :
.517
Emech :
.473

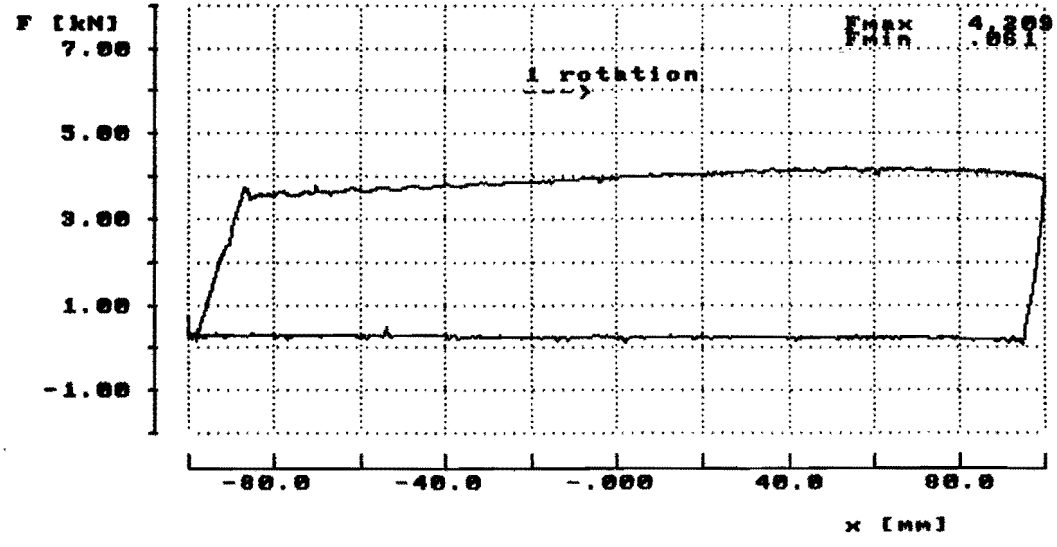
head [m] :
14.9
pump [mm] :
181.0
stroke [m]:
.2



rotationspeed (rps): .183
meanflow (dm3/s) : .217 sample frequency (Hz): 210.000

BDC TDC

filename --> B:P1610202._



Pin [W]:
140.257
Pout[W]:
91.957

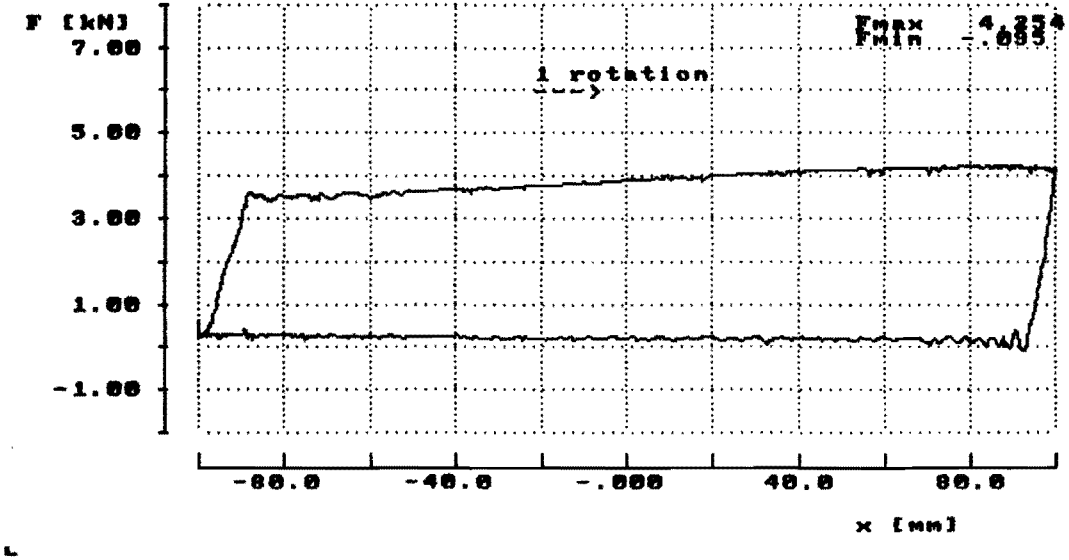
Evol :
.772
Emech :
.656

head [m] :
14.9
pump [mm] :
161.0
stroke [m]:
.2

rotationspeed (rps): .200
meanflow (dm3/s) : .628 sample frequency (Hz): 409.709

BDC TDC

filename --> B:P1810204._



Pin [W]:
287.418
Pout[W]:
158.983

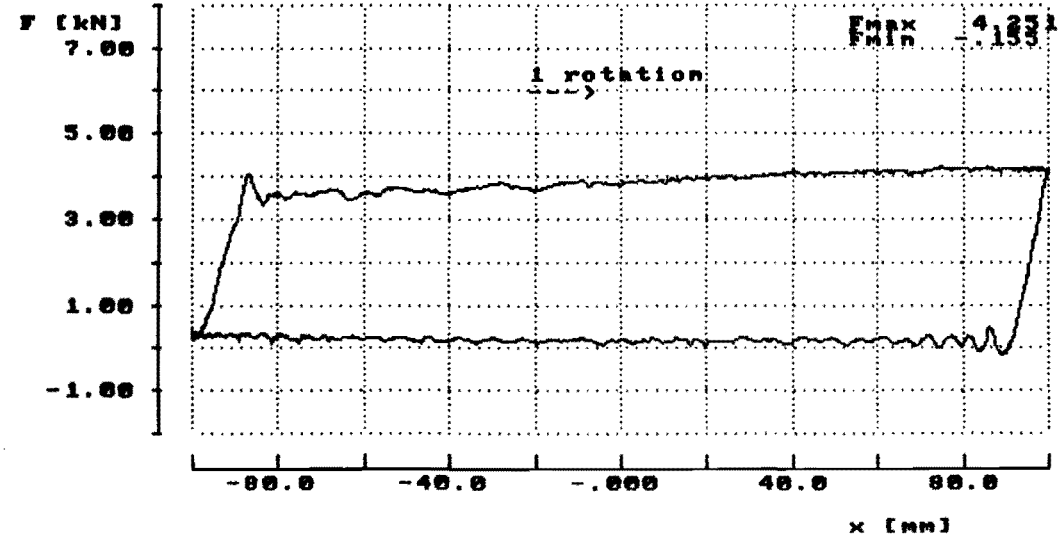
Evol :
.899
Emech :
.766

head [m] :
14.9
pump [mm] :
161.0
stroke [m]:
.2

rotationspeed (rps): .297
meanflow (dm3/s) : 1.007 sample frequency (Hz): 800.539

BDC TDC

filename --> B:P1610205._



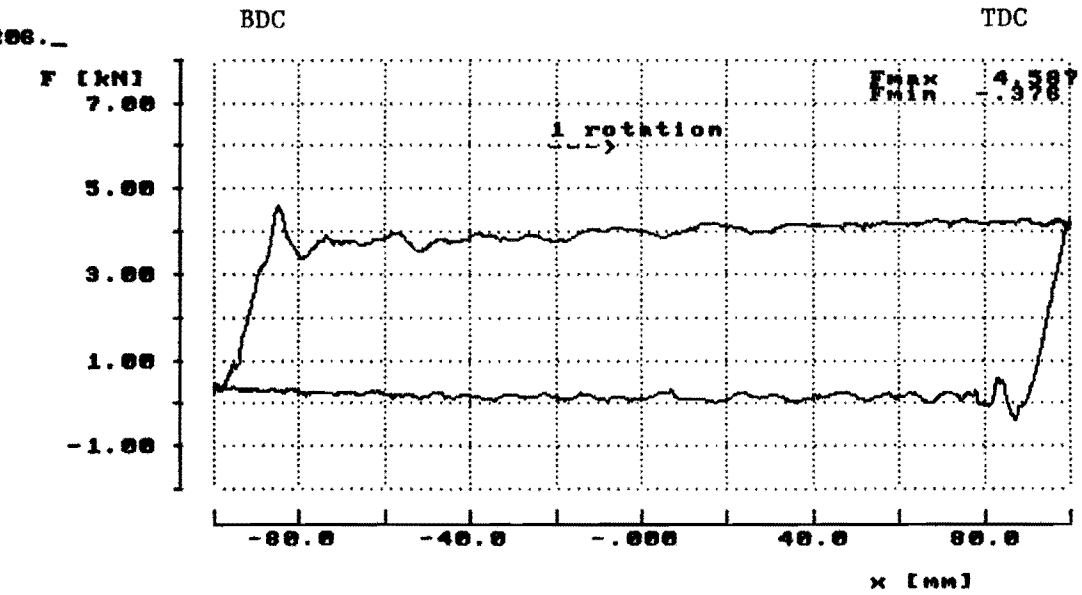
Pin [W]:
279.339
Pout[W]:
210.375

Evol :
.880
Emech :
.753

head [m] :
14.9
pump [mm] :
161.0
stroke [m]:
.2

rotationspeed (rps): .402
meanflow (dm3/s) : 1.439 sample frequency (Hz): 822.431

filename --> B:P1610206._



Pin [W]:
358.731
Pout[W]:
265.033

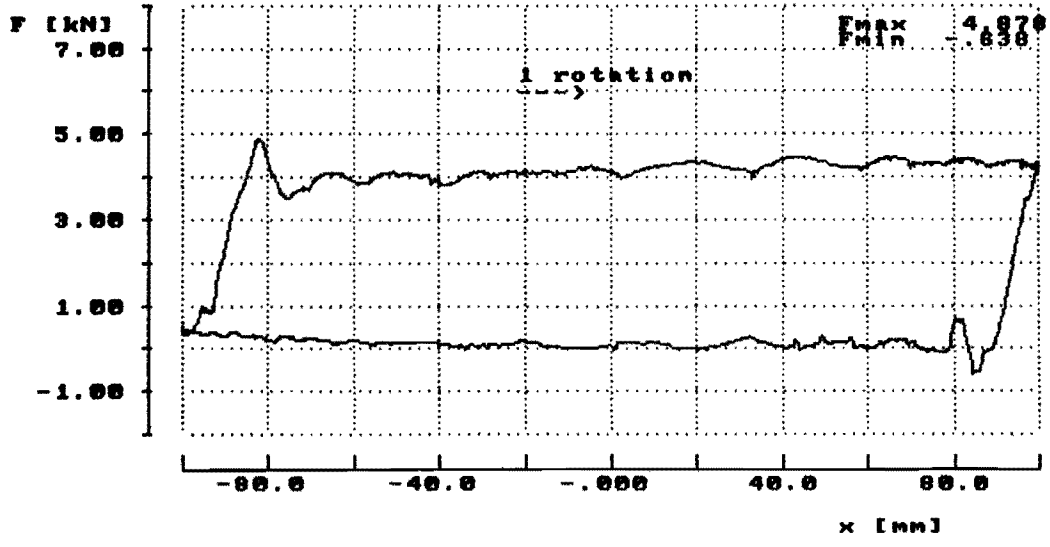
Evol :
.893
Emech :
.743

head [m] :
14.9
pump [mm] :
161.0
stroke [m]:
.2

rotationspeed (rps): .499
meanflow (dm3/s) : 1.813 sample frequency (Hz): 1021.260

BDC TDC

filename --> B:P1610207._



Pin [W]:
450.293
Pout[W]:
324.108

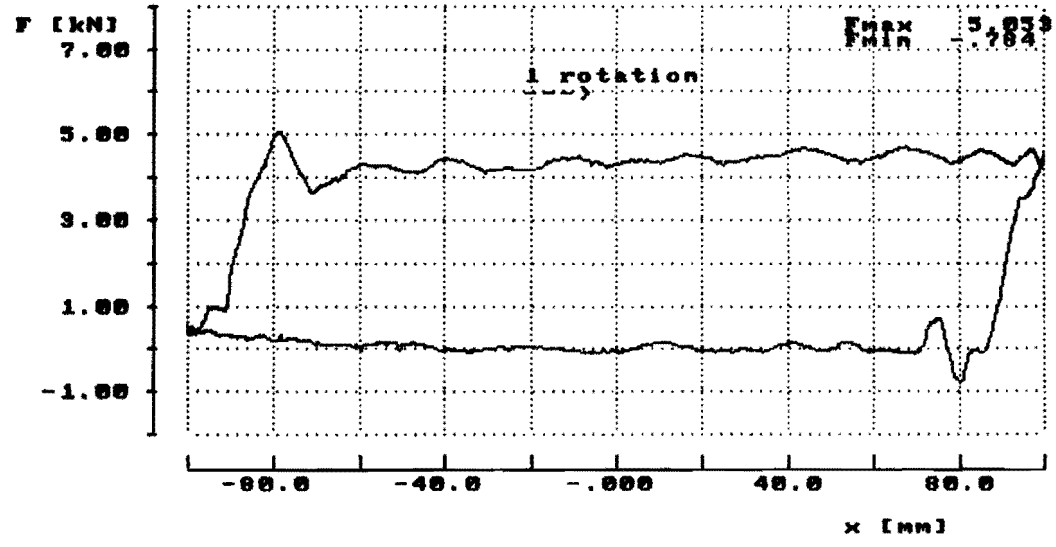
Evol :
.807
Emech :
.720

head [m] :
14.9
pump [mm] :
161.0
stroke [m]:
.2

rotationspeed (rps): .600
meanflow (dm3/s) : 2.217 sample frequency (Hz): 1229.127

BDC TDC

filename --> B:P1610200._



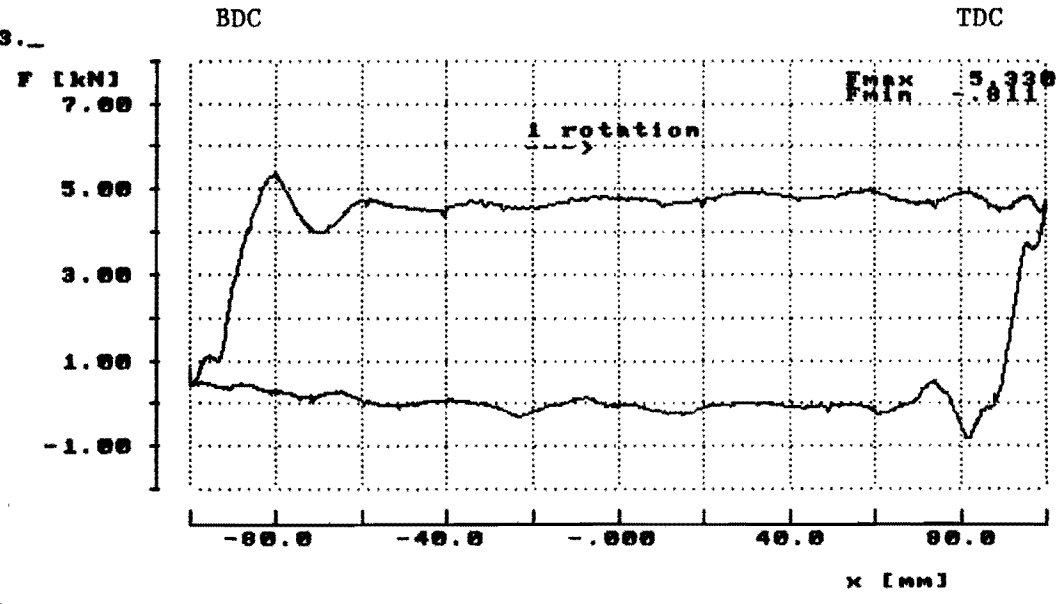
Pin [W]:
548.518
Pout[W]:
378.329

Evol :
.900
Emech :
.690

head [m] :
14.9
pump [mm] :
161.0
stroke [m]:
.2

rotationspeed (rps): .700
meanflow (dm3/s) : 2.588 sample frequency (Hz): 1433.982

filename --> B:P1610203._



Pin [W]:
898.894
Pout[W]:
436.739

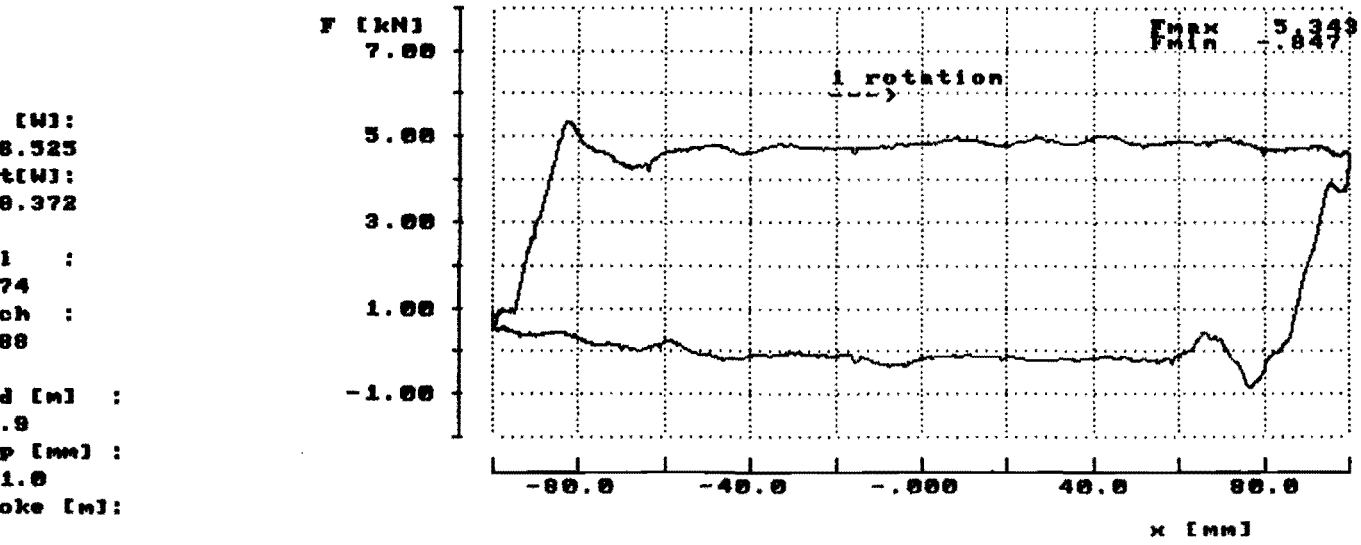
Evol :
.909
Emech :
.625

head [m] :
14.9
pump [mm] :
161.8
stroke [m]:
.2

rotationspeed (rps): .800
meanflow (dm3/s) : 2.988 sample frequency (Hz): 1653.899

BDC TDC

filename --> B:P1810209._



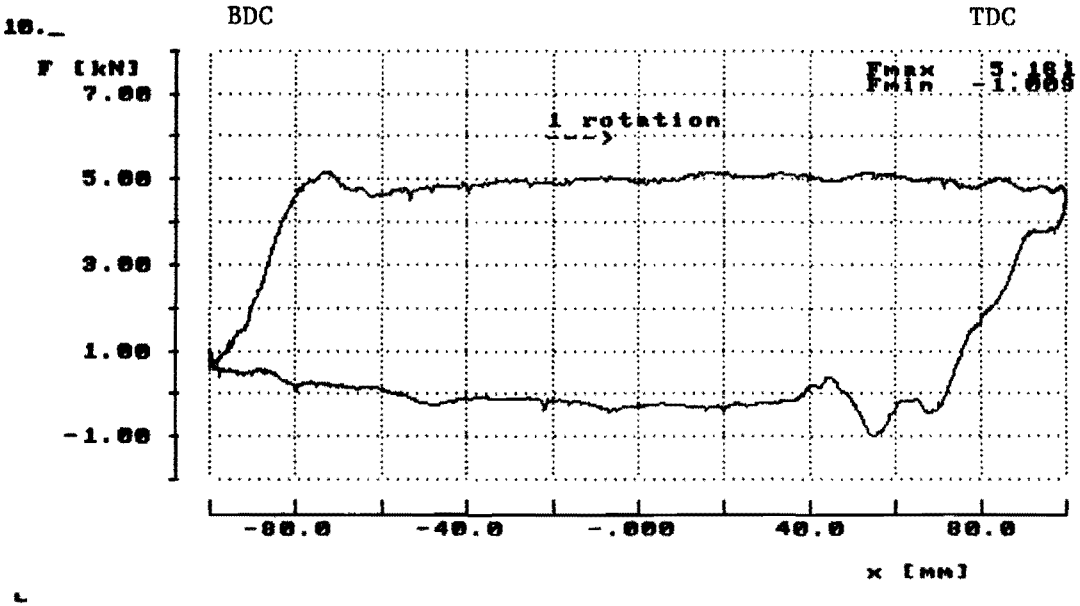
Pin [W]:
798.525
Pout[W]:
468.372

Evol :
.874
Emech :
.588

head [m] :
14.9
pump [mm] :
161.0
stroke [m]:
.2

rotationspeed (rps): .900
meanflow (dm3/s) : 3.204 sample frequency (Hz): 1843.691

filename --> B:P1610210._



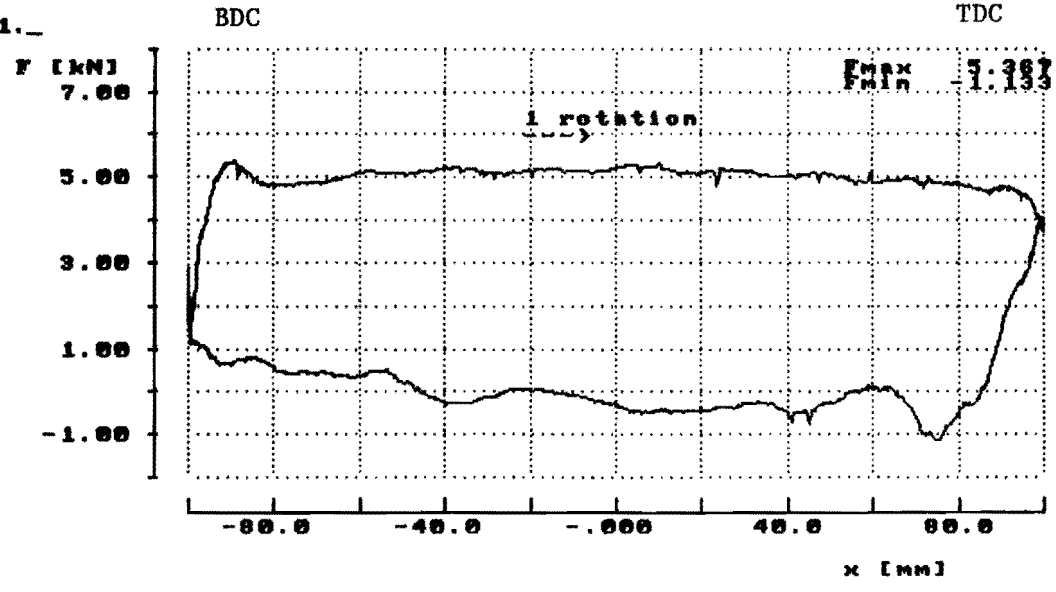
Pin [W]:
878.022
Pout[W]:
488.529

Evol :
.817
Emech :
.554

head [m] :
14.9
pump [mm] :
161.0
stroke [m]:
.2

rotationspeed (rps): 1.000
meanflow (dm3/s) : 3.329 sample frequency (Hz): 2048.546

filename --> B:P1610211._



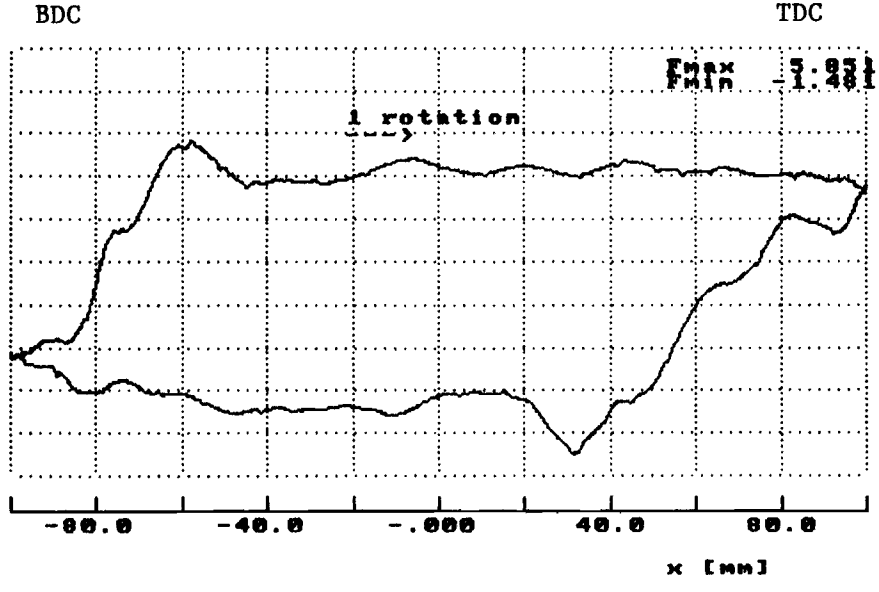
Pin [W]:
1086.408
Pout[W]:
522.185

Evol :
.797
Emech :
.480

head [m] :
14.9
pump [mm] :
161.0
stroke [m]:
.2

rotationspeed (rps): 1.100
meanflow (dm3/s) : 3.572 sample frequency (Hz): 2253.400

filename --> B:P1610214._



Pin [W]:
985.386
Pout[W]:
534.209

Evol :
.747
Emech :
.542

head [m] :
14.9
pump [mm] :
161.0
stroke [m]:
.2

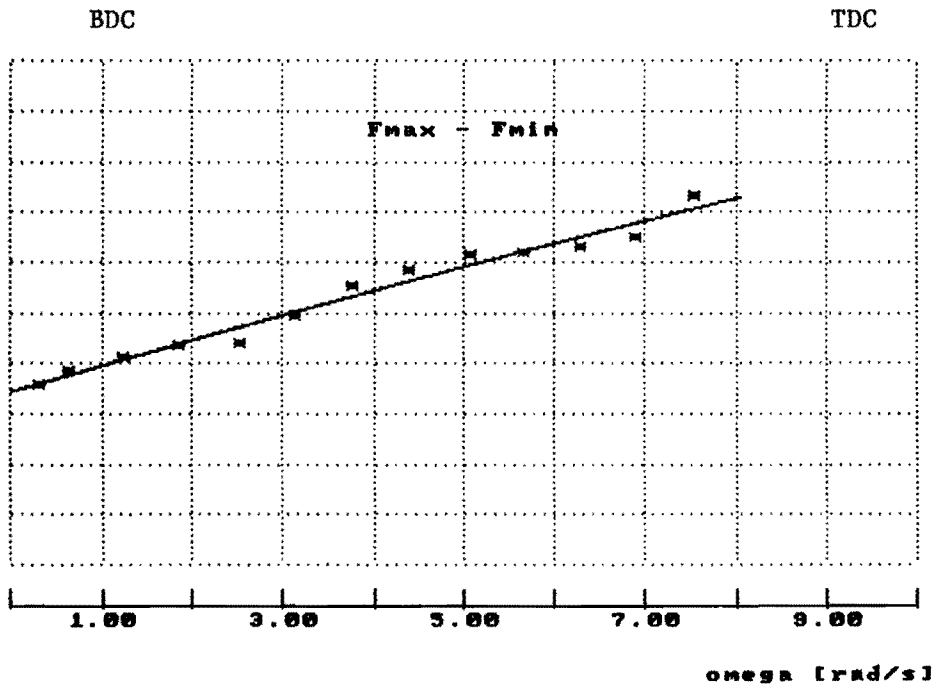
rotationspeed (rps): 1.202
meanflow (dm3/s) : 3.655 sample frequency (Hz): 2461.267

filename --> B:P16102 T._

differences :

n (rad/s)	%
.85	2.3
1.26	1.4
1.87	1.1
2.52	7.2
3.13	1.2
3.77	3.3
4.40	3.5
5.07	3.1
5.66	.5
6.28	3.3
6.91	4.5
7.55	3.5

degree
: 2
coefficients
:
-.005
.528
3.444



```
filename --> B:P16102
```

BDC TDC

```
                    Q [Nm]
differences  :          180.
n (rad/s)  %
 .65    3.8
 1.26   5.0          140.
 1.87   .0
 2.52   4.9
 3.13   5.6
 3.77   4.0          100.
 4.40   2.3
 5.07   5.2
 5.66   5.7
 6.28   3.6           60.0
 6.91   .0
 7.55   5.0
degree
: 2                   20.0
coefficients
:
-.606
 10.275
 94.049
```

1.00 3.00 5.00 7.00 9.00

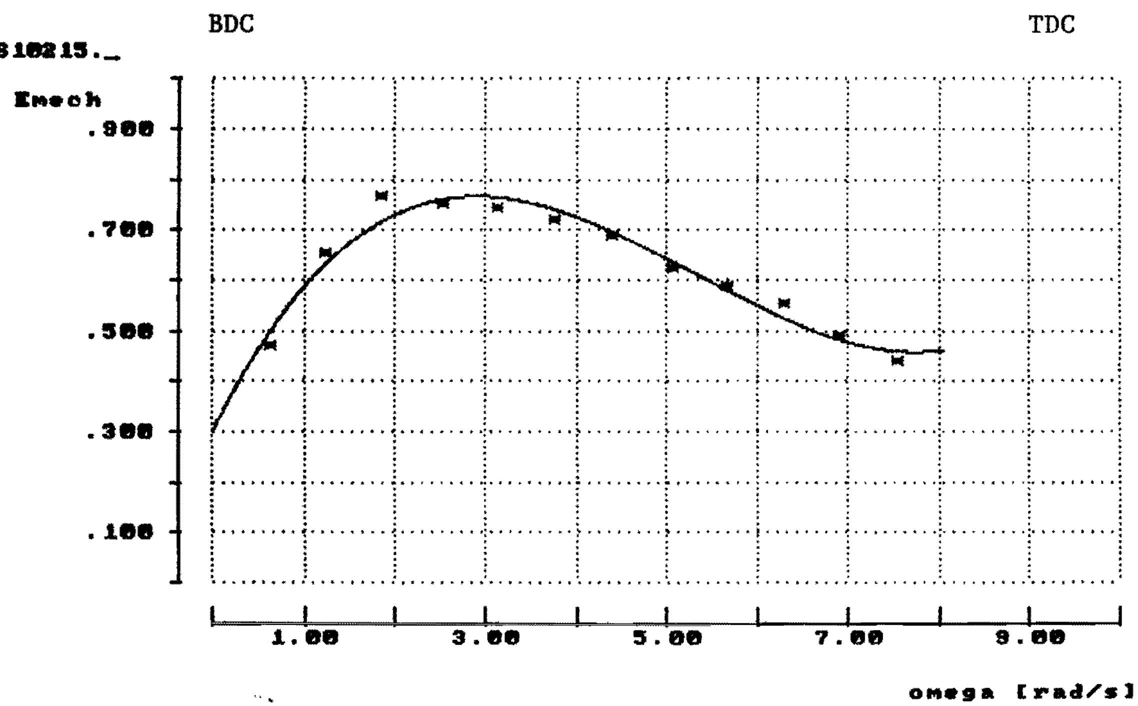
omega [rad/s]

filename --> B:P1610215._

differences :
n (rad/s) %

.65	8.3
1.26	3.1
1.87	6.3
2.52	1.0
3.13	2.9
3.77	2.0
4.40	.9
5.07	1.7
5.66	1.4
6.28	5.4
6.91	1.7
7.55	4.3

degree
: 3
coefficients
:
.005
-.087
.368
.300

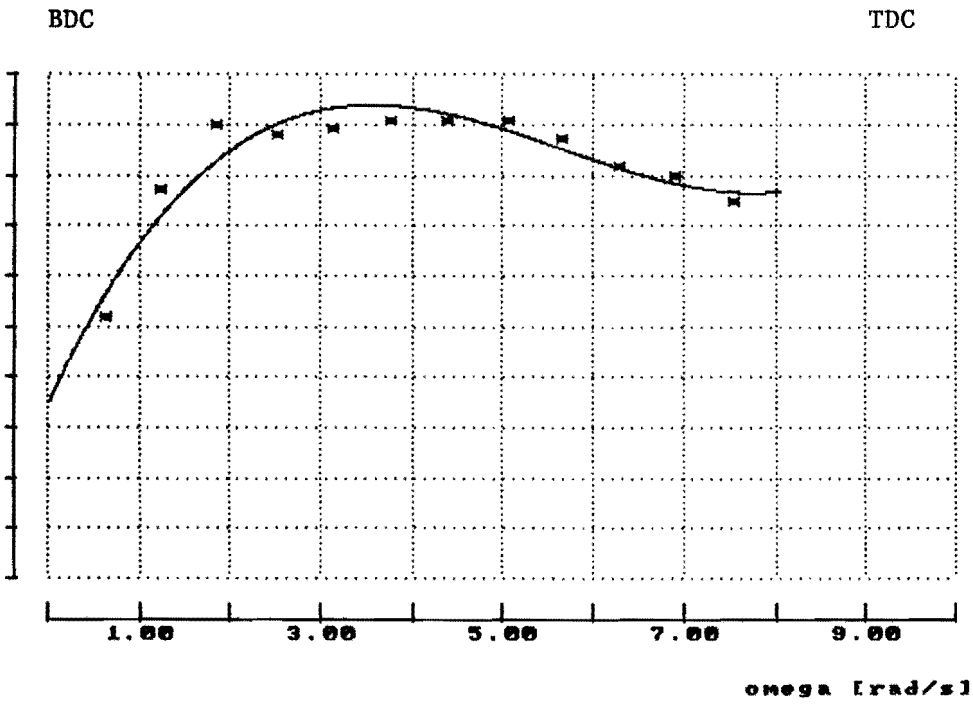


filename --> B:P1610215._

differences :

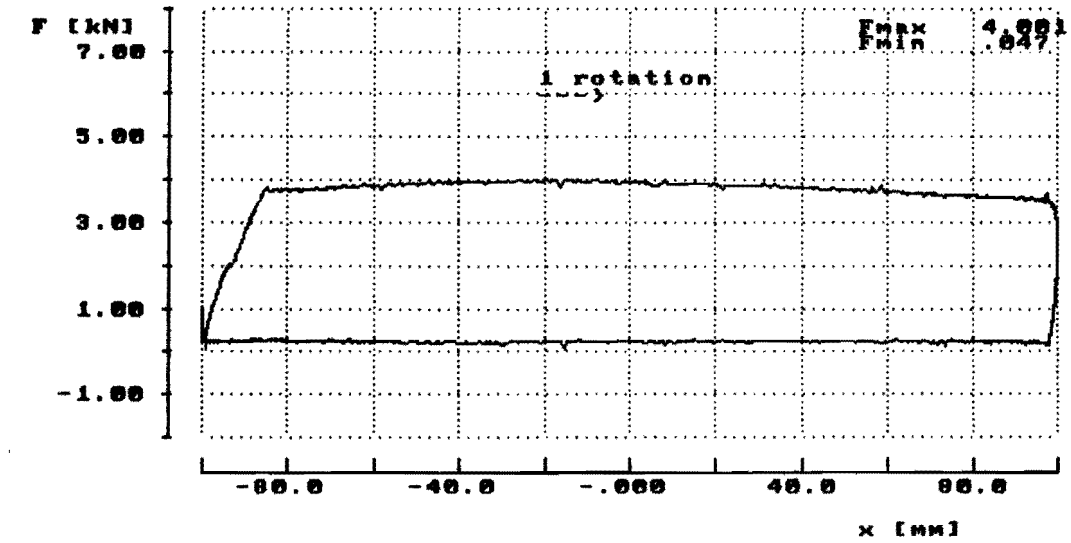
n (rad/s)	%
.65	9.8
1.26	6.4
1.87	7.5
2.52	2.5
3.13	4.6
3.77	3.4
4.40	1.5
5.07	2.3
5.66	2.5
6.20	.4
6.91	1.8
7.55	2.6

degree
: 3
coefficients
:
.005
-.081
.393
.347



BDC TDC

filename --> B:P1610301._



Pin [W]:
67.011
Pout[W]:
34.361

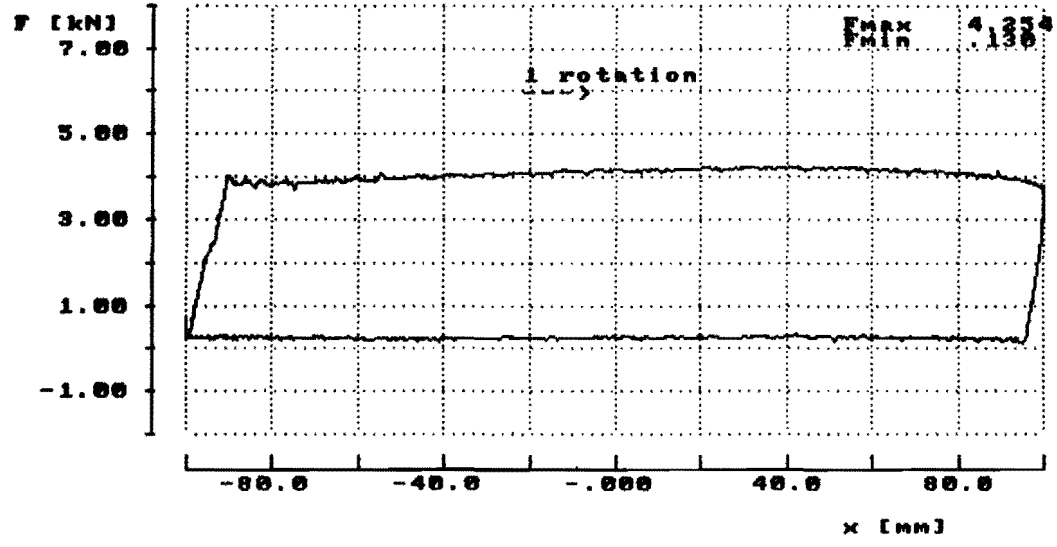
Evol :
.595
Emech :
.513

head [m] :
14.9
pump [mm] :
161.0
stroke [m]:
.2

rotationspeed (rps): .097
meanflow (dm3/s) : .235 sample frequency (Hz): 198.829

BDC TDC

filename --> B:P1610302._



Pin [W]:
147.697
Pout[W]:
93.460

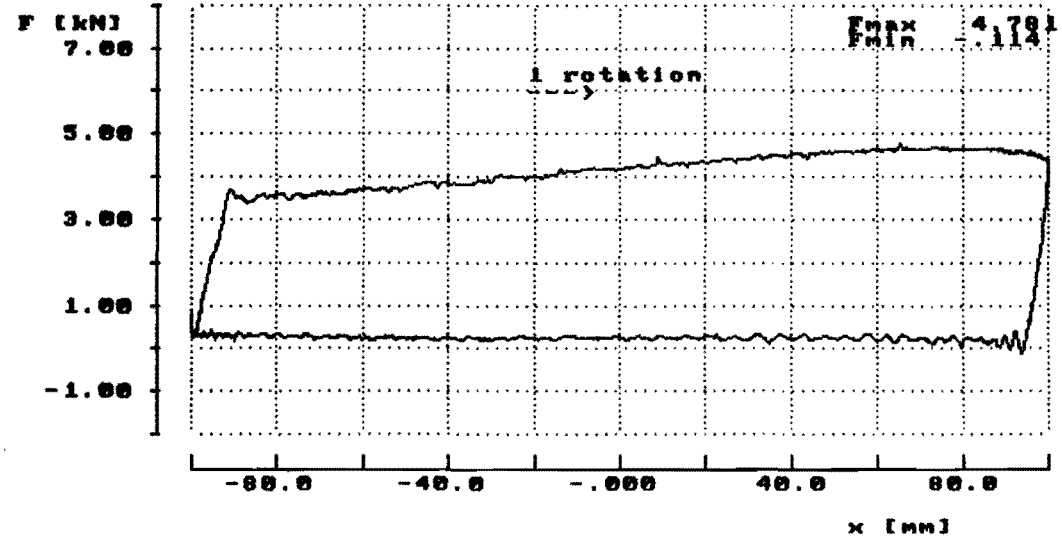
Evol :
.785
Emech :
.633

head [m] :
14.9
pump [mm] :
161.0
stroke [m]:
.2

rotationspeed (rps): .200
meanflow (dm3/s) : .839 sample frequency (Hz): 409.709

BDC TDC

filename --> B:P1810303._



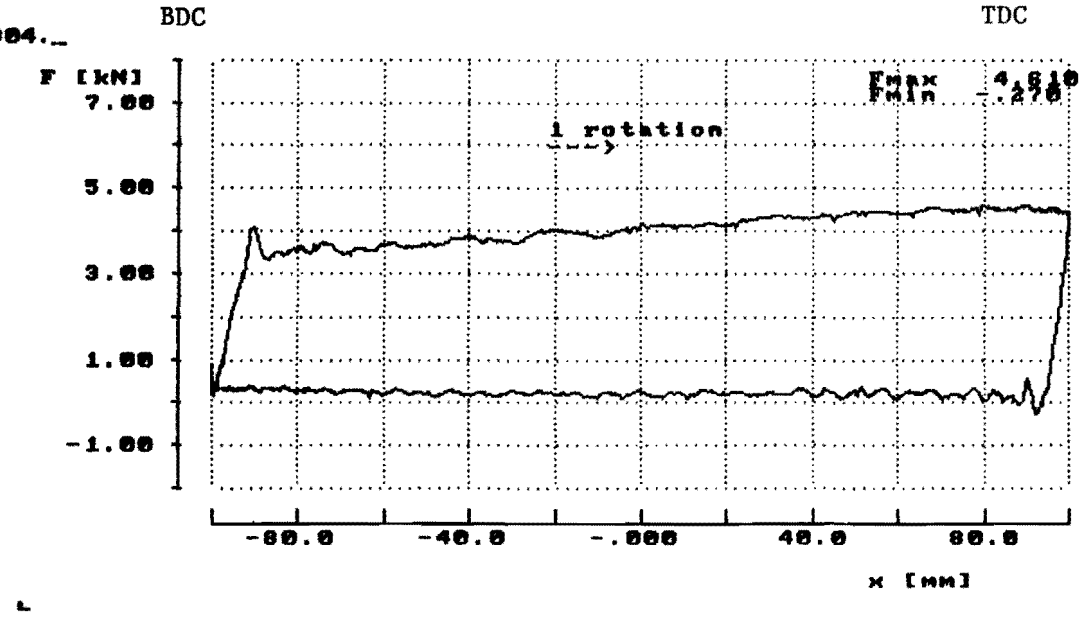
Pin [W]:
226.777
Pout[W]:
158.186

Evol :
.886
Emech :
.698

head [m] :
14.9
pump [mm] :
181.8
stroke [m]:
.2

rotationspeed (rps): .300
meanflow (dm3/s) : 1.002 sample frequency (Hz): 814.584

filename --> B:P1810304._



Pin [W]:
294.942
Pout[W]:
218.121

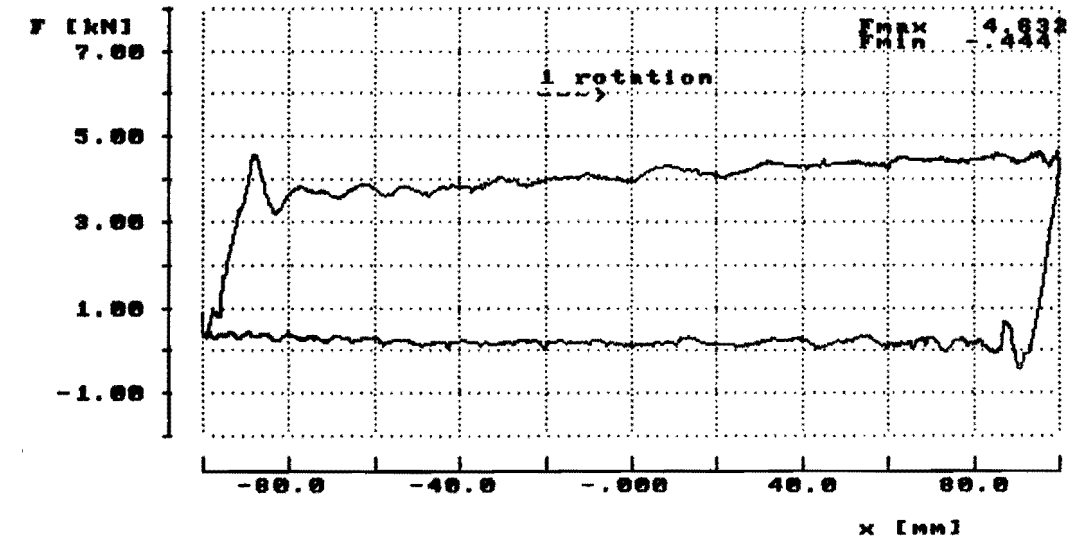
Evol :
.918
Emech :
.740

head [m] :
14.9
pump [mm] :
161.0
stroke [m]:
.2

rotationspeed (rps): .399
Meanflow (dm3/s) : 1.492 sample frequency (Hz): 816.400

BDC TDC

filename --> B:P1610365._



Pin [W]:
371.118
Pout[W]:
276.185

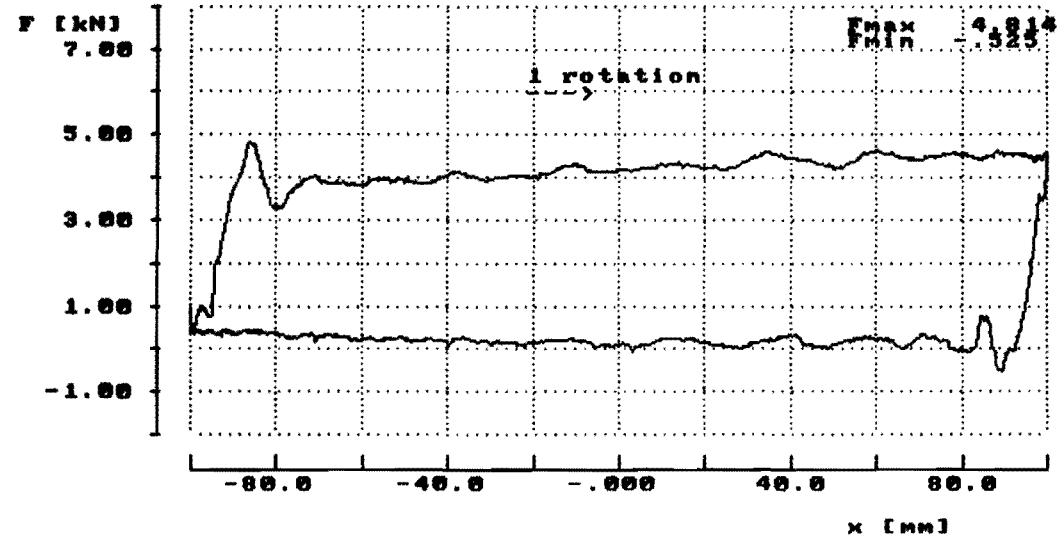
Evol :
.823
Emech :
.744

head [m] :
14.9
pump [mm] :
161.0
stroke [m]:
.2

rotationspeed (rps): .499
meanflow (dm3/s) : 1.889 sample frequency (Hz): 1022.767

BDC TDC

filename --> B:P1810306._



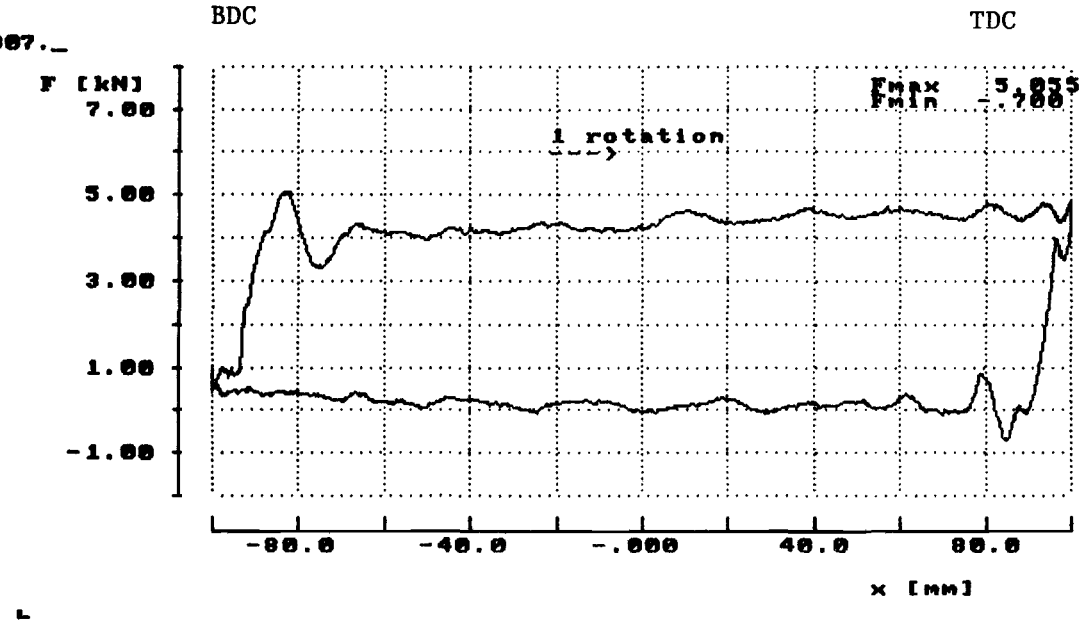
Pin [W]:
458.301
Pout[W]:
332.485

Evol :
.930
Emech :
.725

head [m] :
14.8
pump [mm] :
161.0
stroke [m]:
.2

rotationspeed (rps): .801
meanflow (dm3/s) : 2.275 sample frequency (Hz): 1230.031

filename --> B:P1610307._



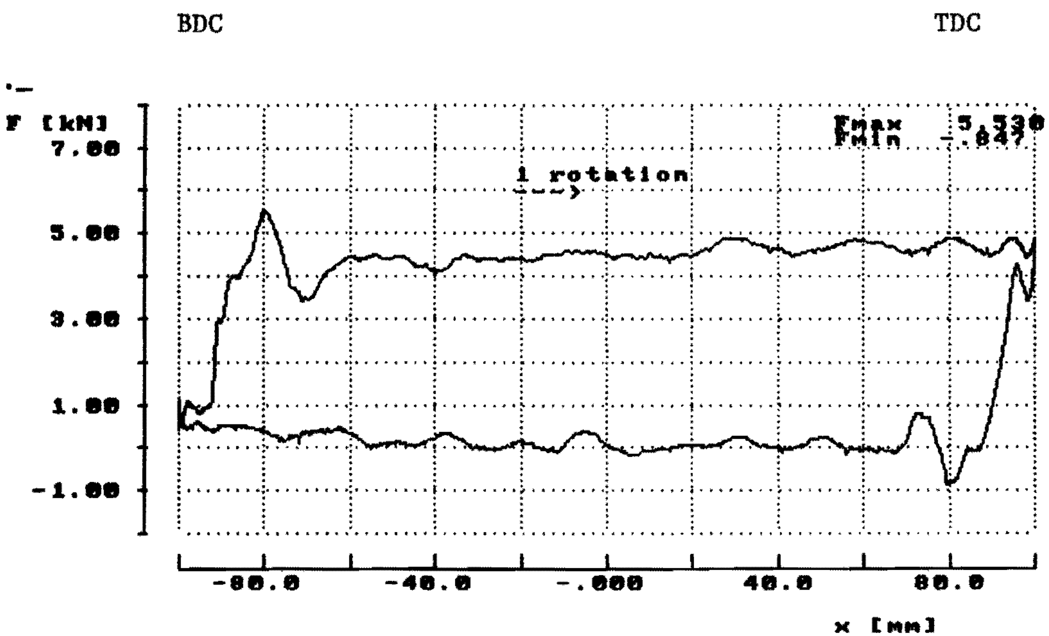
Pin [W]:
 550.024
Pout[W]:
 383.151

Evol :
 .919
Emech :
 .697

head [m] :
 14.9
pump [mm] :
 161.0
stroke [m]:
 .2

rotationspeed (rps): .701
meanflow (dm3/s) : 2.821 sample frequency (Hz): 1434.886

filename --> B:P1610300._



Pin [W]:
646.784
Pout[W]:
430.006

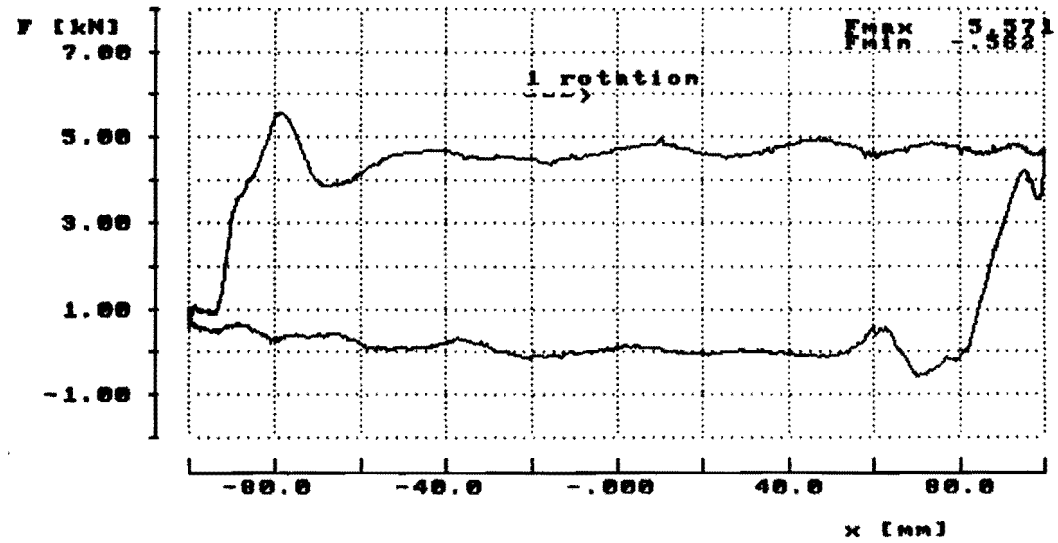
Evol :
.904
Emech :
.665

head [m] :
14.9
pump [mm] :
161.0
stroke [m]:
.2

rotationspeed (rps): .799
meanflow (dm3/s) : 2.942 sample frequency (Hz): 1636.427

BDC TDC

filename --> B:P1610308._



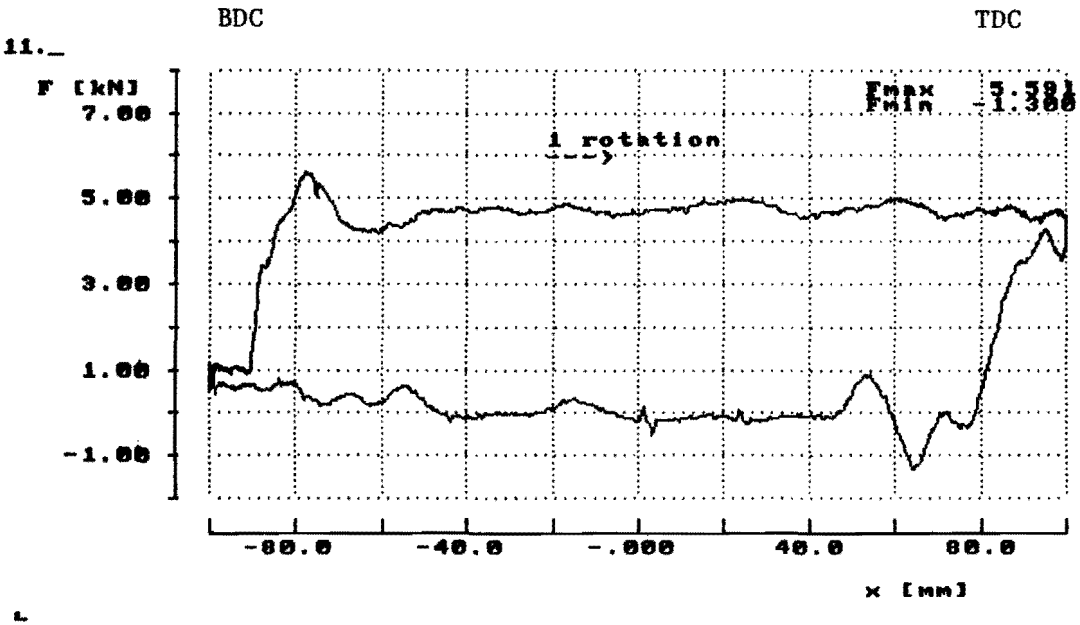
Pin [W]:
736.388
Pout[W]:
457.210

Evol :
.853
Emech :
.621

head [m] :
14.9
pump [mm] :
161.0
stroke [m]:
.2

rotationspeed (rps): .980
meanflow (dm3/s) : 3.128 sample frequency (Hz): 1843.691

filename --> B:P1610311._



Pin [W]:
819.915
Pout[W]:
485.595

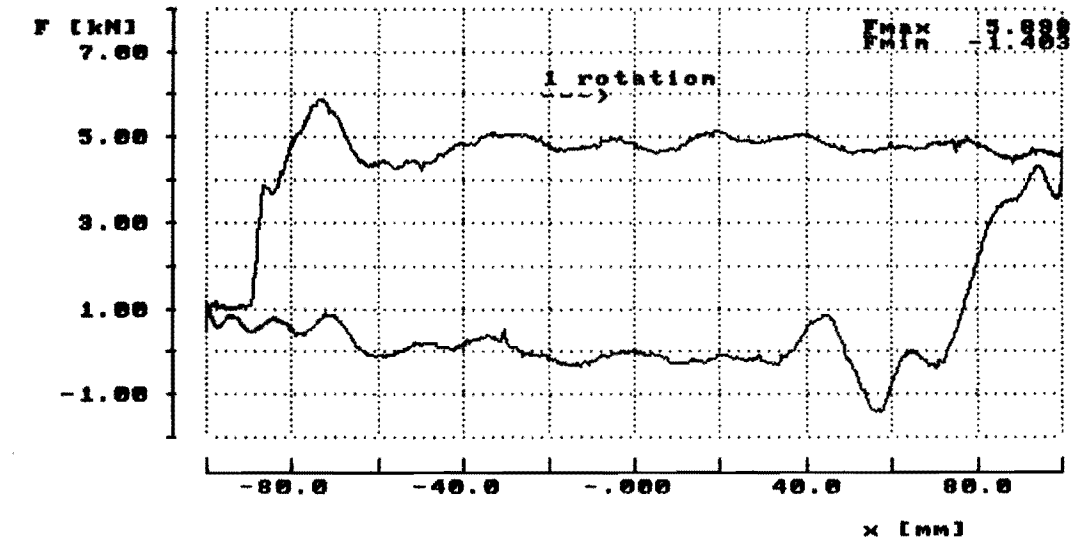
Evol :
.834
Emech :
.884

head [m] :
14.9
pump [mm] :
161.0
stroke [m]:
.2

rotationspeed (rps): .999
Meanflow (dm3/s) : 3.391 sample frequency (Hz): 2045.533

BDC TDC

filename --> B:P1610312._



Pin [W]:
 906.384
Pout[W]:
 515.980

Evol :
 .788
Emech :
 .589

head [m] :
 14.9
pump [mm] :
 161.0
stroke [m]:
 .2

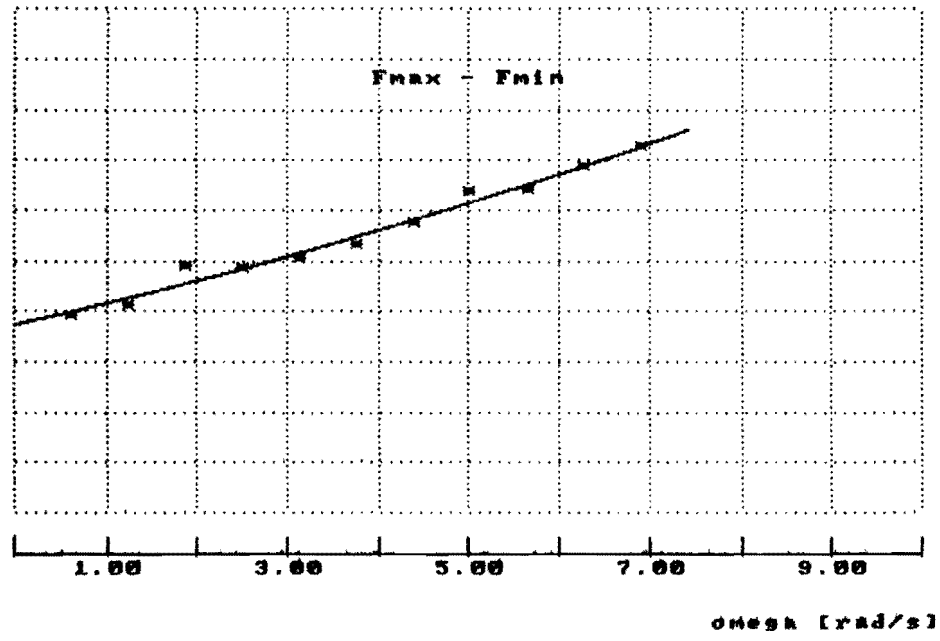
rotationspeed (rps): 1.100
meanflow (dm3/s) : 3.530 sample frequency (Hz): 2253.400

BDC TDC

```
filename --> B:P1810313._

differences  :
n (rad/s)  %

 .61    1.0
 1.26   3.7
 1.89   6.8
 2.50   .6
 3.14   1.7
 3.77   2.8
 4.40   1.2
 5.02   3.3
 5.66   1.5
 6.28   .0
 6.91   .3
degree
: 2
coefficients
:
 .018
 .404
 3.742
```

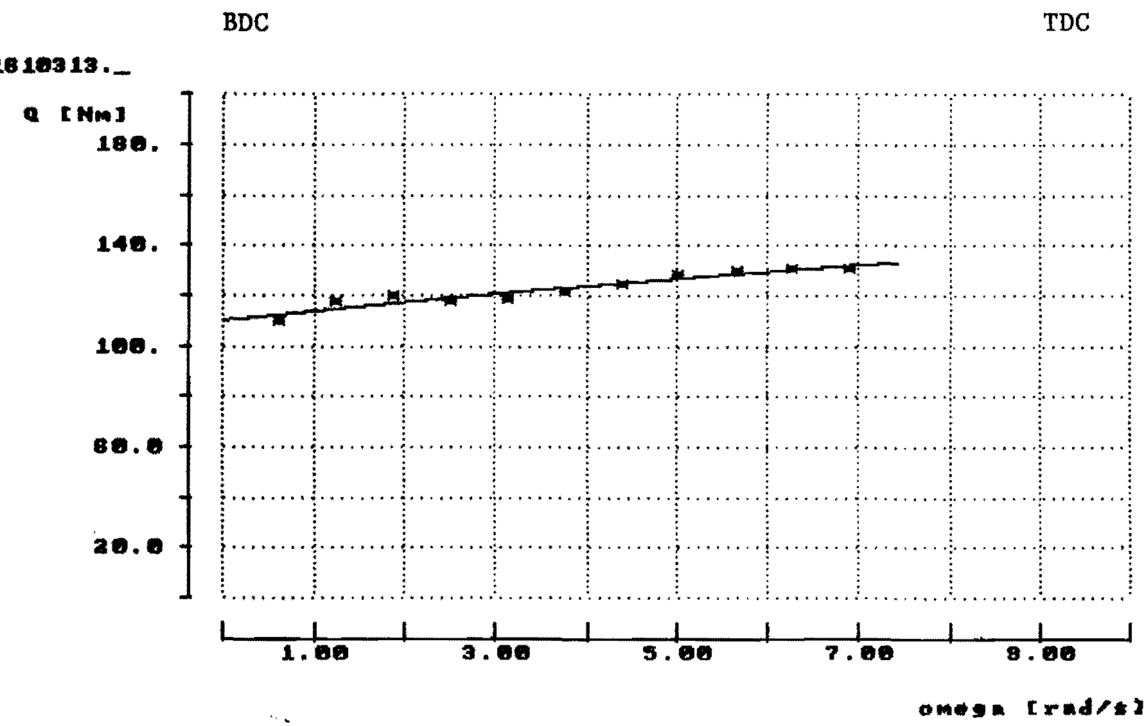


filename --> B:P1810313._

differences :
n (rad/s) %

.61	2.3
1.26	2.4
1.89	2.8
2.50	1.1
3.14	2.4
3.77	1.4
4.40	.1
5.02	1.5
5.66	1.1
6.28	.1
6.91	.8

degree
: 2
coefficients
:
-.089
3.913
110.054



37

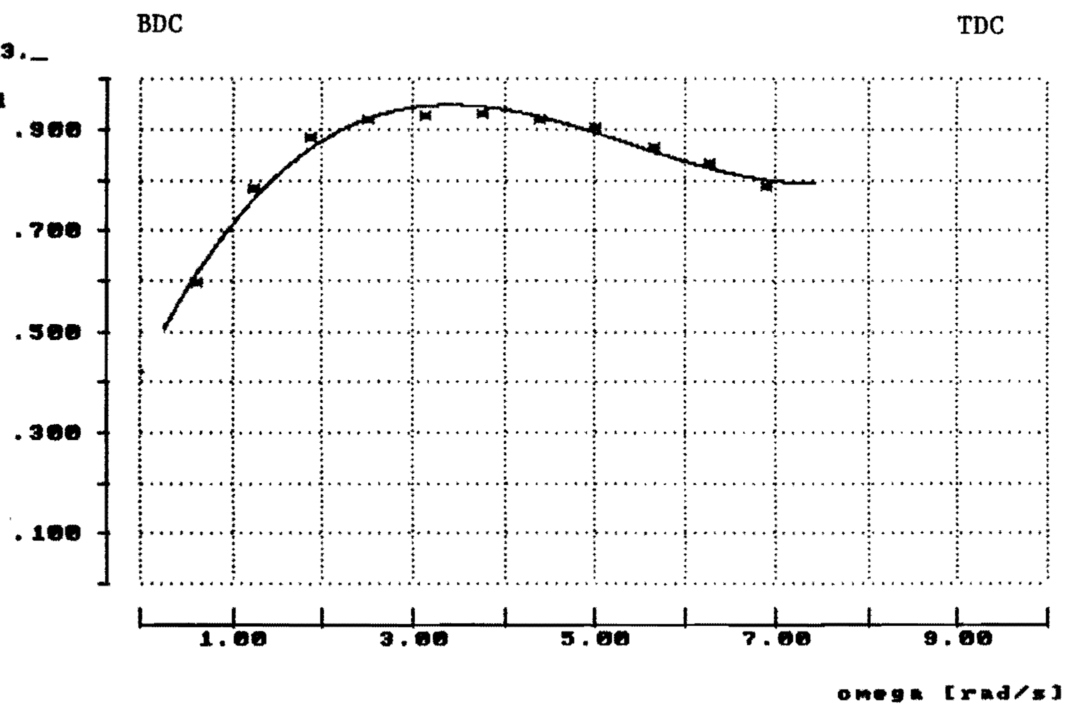
Annex II-13

filename --> B:P1610313._

differences :
n (rad/s) %

.61	3.0
1.26	2.5
1.89	2.4
2.50	.3
3.14	1.9
3.77	1.6
4.40	.6
5.02	1.3
5.66	1.1
6.28	1.3
6.91	1.6

degree
: 3
coefficients
:
.005
-.080
.372
.415

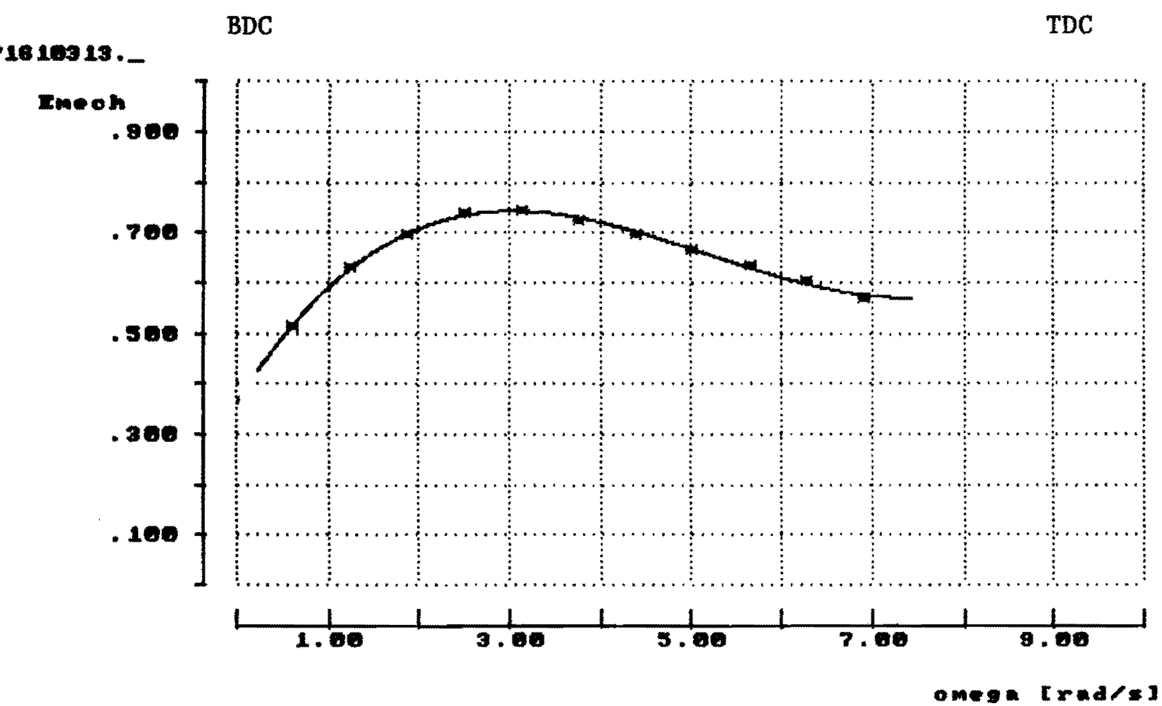


filename --> B:P1610313._

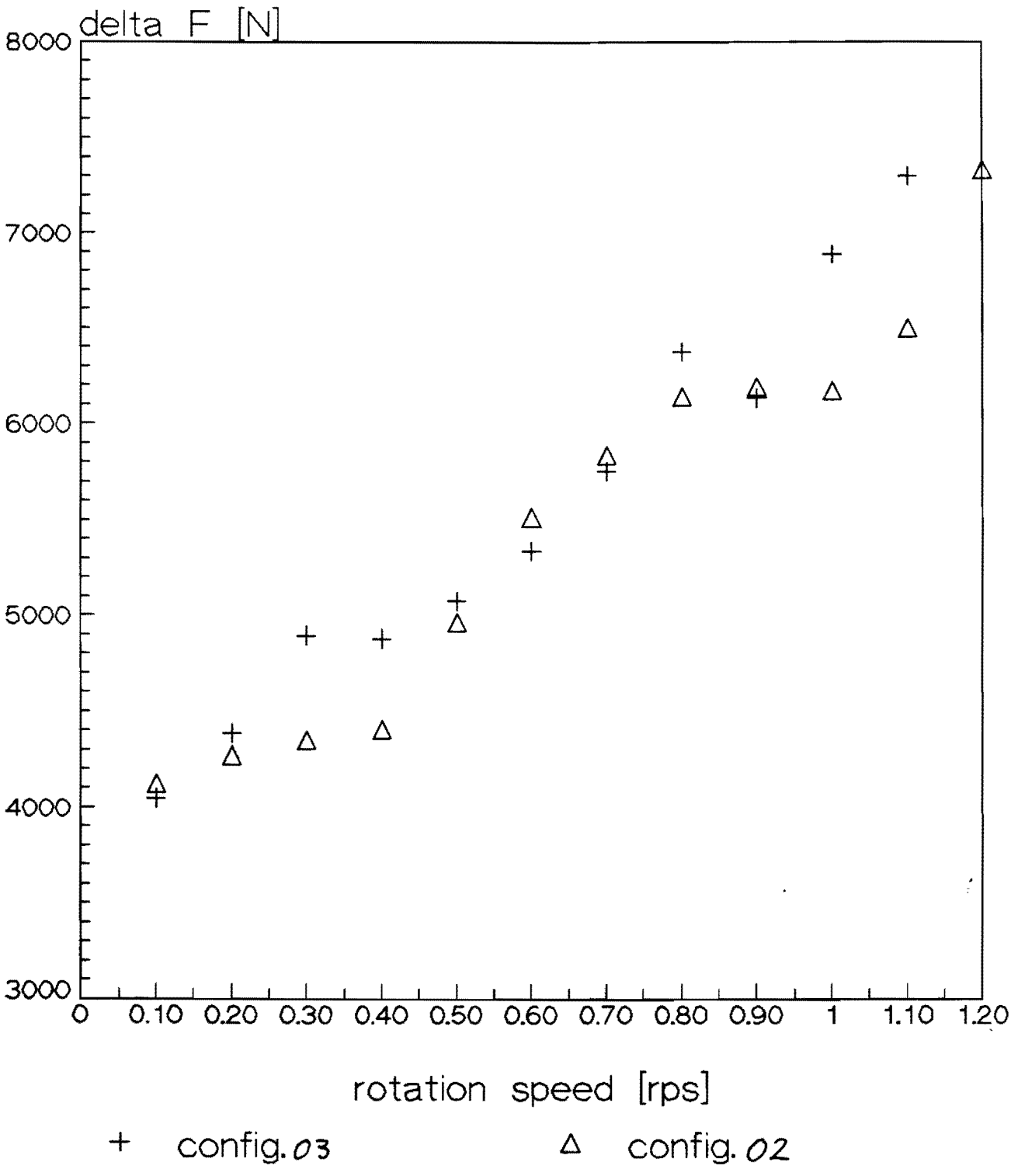
differences :
n (rad/s) %

.61	.5
1.28	.5
1.89	.2
2.50	.7
3.14	.2
3.77	.6
4.40	.8
5.02	.3
5.66	.7
6.28	1.3
6.91	1.0

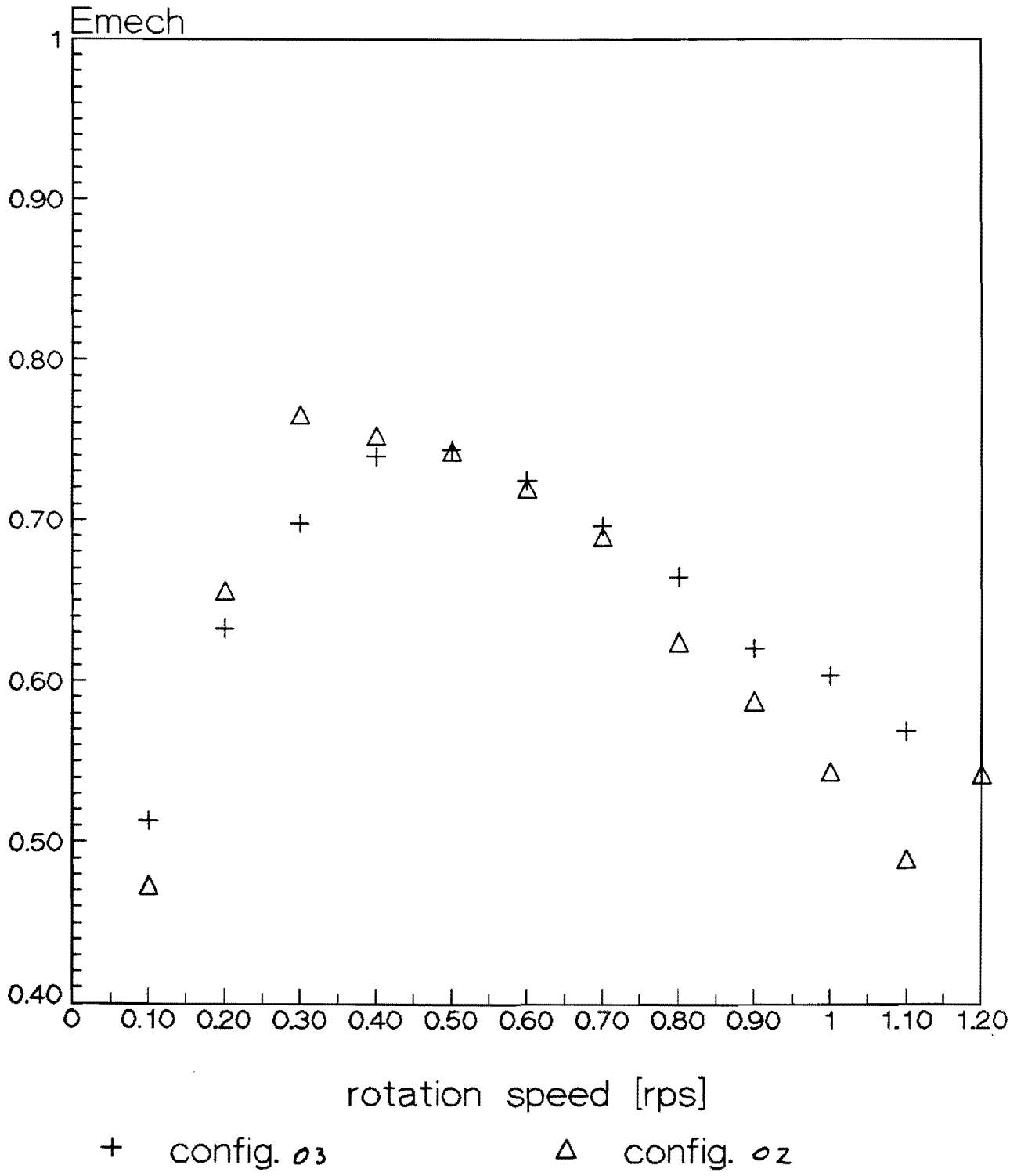
degree
: 3
coefficients
:
.004
-.060
.291
.362



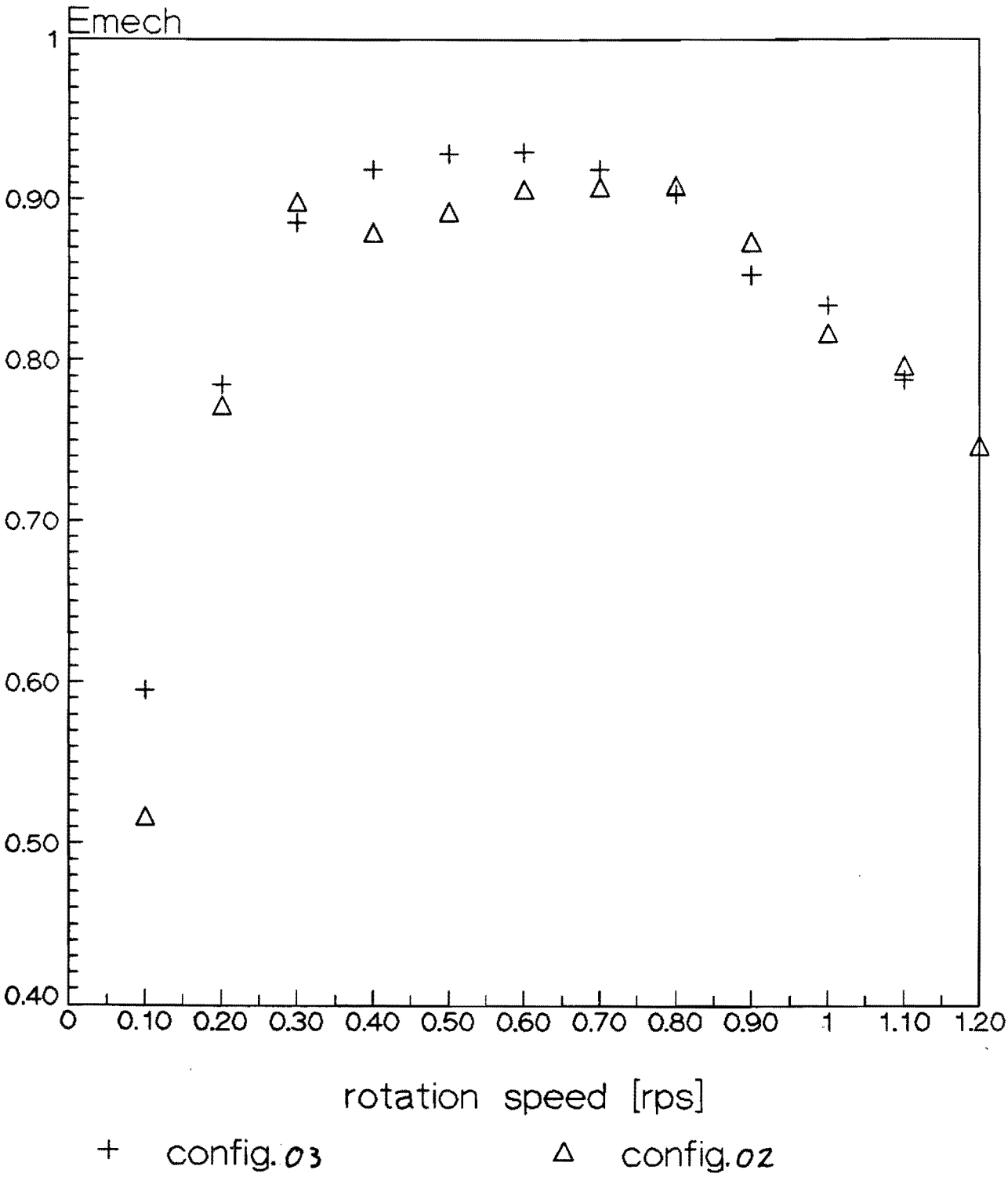
delta F

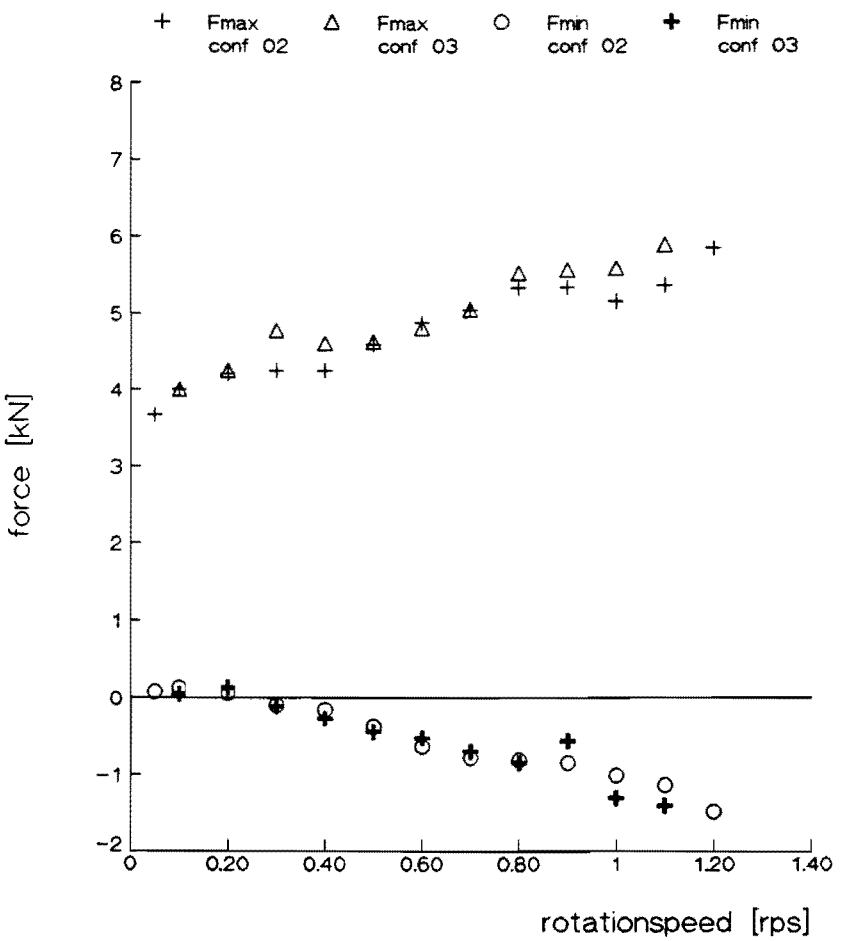

delta F [N]
8000
7000
6000
5000
4000
3000
0
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1
1.10
1.20
rotation speed [rps]
+ config. 03
Δ config. 02

Emech


Emech
1
0.90
0.80
0.70
0.60
0.50
0.40
0
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1
1.10
1.20
rotation speed [rps]
+ config. o3
Δ config. o2

Evol


Emech
1
0.90
0.80
0.70
0.60
0.50
0.40
0
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1
1.10
1.20
rotation speed [rps]
+ config. 03
Δ config. 02


Fmax conf 02
Fmax conf 03
Fmin conf 02
Fmin conf 03
force [kN]
8
7
6
5
4
3
2
1
0
-1
-2
0
0.20
0.40
0.60
0.80
1
1.20
1.40
rotationspeed [rps]

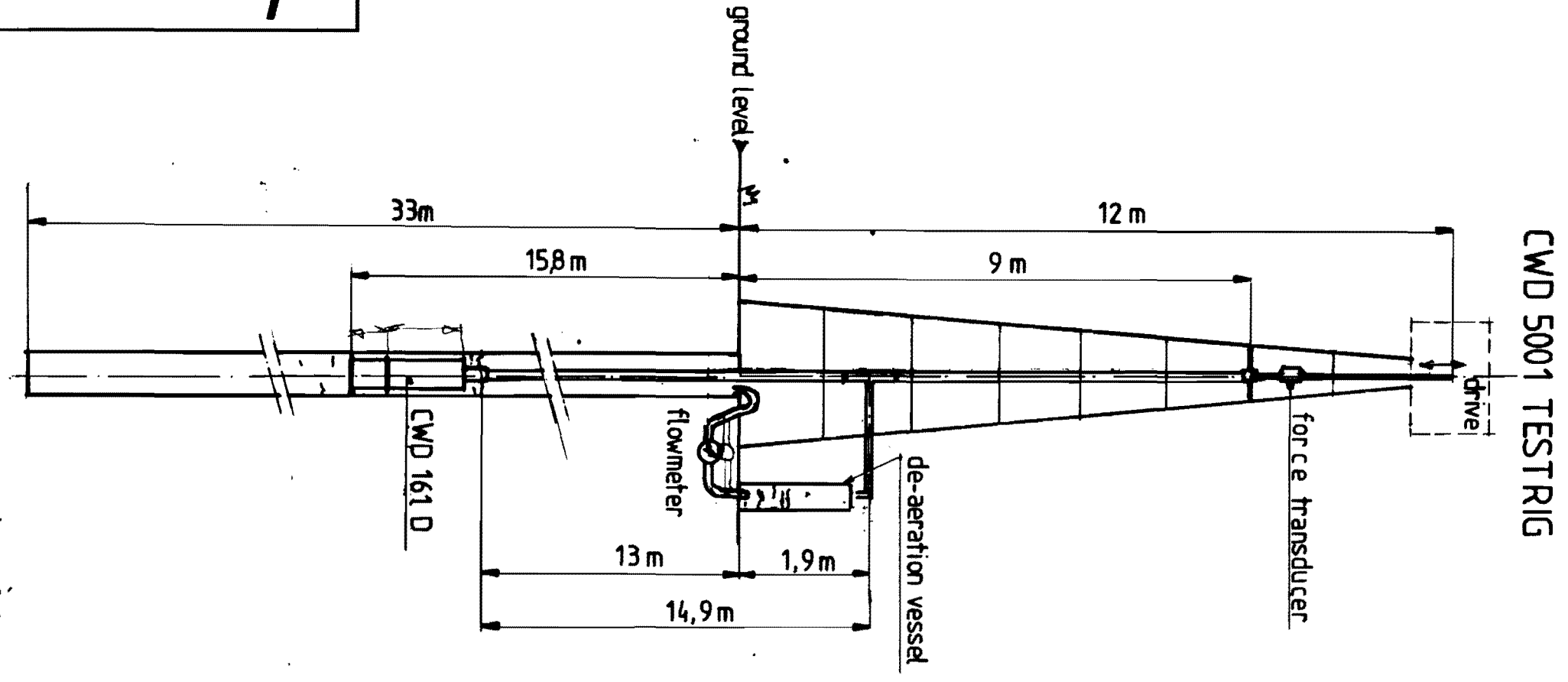


Figure 2.1

If not shown apply:	Tolerance:	Welds:	Roughness:	Modification-description	Date	Initials	Mod

CONSULTANCY SERVICES WIND ENERGY DEVELOPING COUNTRIES
P.O. BOX 85 3990 AB AMERSFOORT THE NETHERLANDS

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Format	Scale	Drawing Standards	
A4		ISO	American projection

All dimensions in mm

Material:

Treatment:

Mass: kg

Subject:

Quantity per assembly:

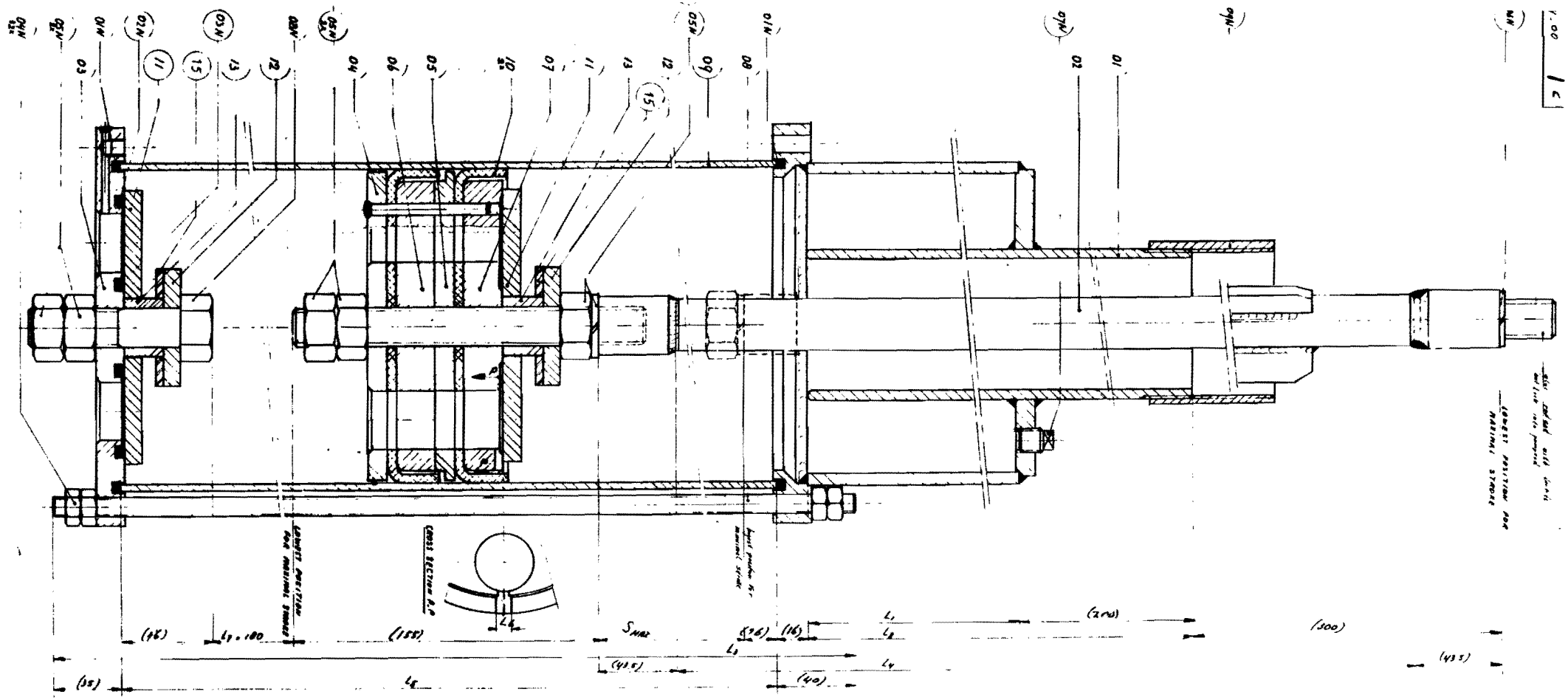
Drawn by:

Date:

Approved by:

Date:

Drawing No.: /



	CWD 6000	CWD 8000
S_{max}		
L_1	180	180
L_2	320	320
L_3	1200	1200
L_4	1240	1240
L_5	1440	1440
L_6	822	822
L_7	$S_{max}+26+16+L_2+100=2,925$	2,925
L_8	$46+L_7+100+S_{max}+16$	3,085
L_9	7.7	7.7
L_{10}	8.5	8.5
L_{11}	7.5	7.5
L_{12}	180	180

	CWD 5000	CWD 6000	CWD 8000
TOTAL MASS (kg)	38	45	85

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 ⬡ refers to PARTS LIST / standard parts

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

SEE MORE DRAWINGS
SEE MORE DRAWINGS
ITEMS 15+16 CANCELLED + MORE DETAILS CHANGED

CWD 161 D PUMP ASSEMBLY

LABORATORY OF FLUID DYNAMICS AND HEAT TRANSFER
DEPARTMENT OF PHYSICS WINDENERGY GROUP
EINDHOVEN UNIVERSITY OF TECHNOLOGY

A. BRAGTEN
2-03-85

E8504-00 1

Figure 2.2