72. 3rd Duck Feet Endurance Test
UFO Doctor, Feb. 27th, 2014

1. Introduction

The duck feet, designed by Xavier Mauron (BFH Bachelor thesis 2013) and improved by David Luggen (Research Assistant BFH) is a mixed design of toes manufactured by the 3D-printer “Dimension Elite” of “Acrylnitril-Butadien-Styrol Copolymerisat” (ABS) and webbing feet of “Silicon rubber RTV/HE”

Inspired by a real duck, the left and right toe bend to the middle toe during forward movement and spread out during backward movement.

A Peak Torque Buffer has been designed which should prevent excessive torque shocks at the gear motor, when the feet start the backward movement of the feet.

2. Overview on Bionic Drive and Peak Torque Buffer

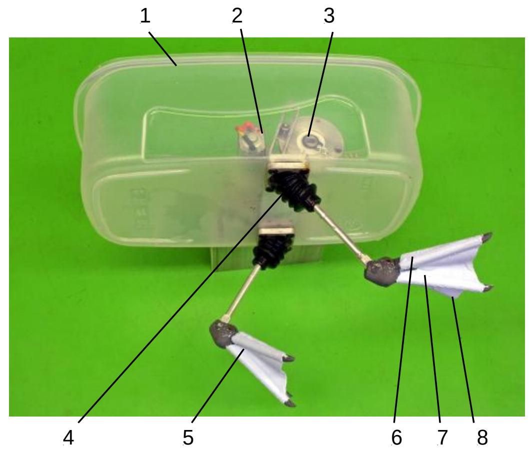

Fig.1. Bionic Drive
1: Submarine Duck Belly; 2: Motor; 3: Flange with lever; 4: Round bellow; 5: Foot; 6,8 flex toes; 7: fix middle toe

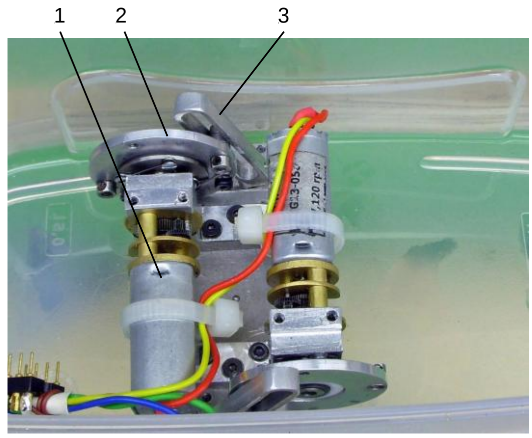

Fig. 2. Bionic Drive details
1: Gear motor SONTH SG13-50,Reduction Ratio 1/86, rpm 102, 6V, 0.21A, stall torque 3 kg.cm; 2: Flange with Peak Torque buffer; 3: Lever with groove

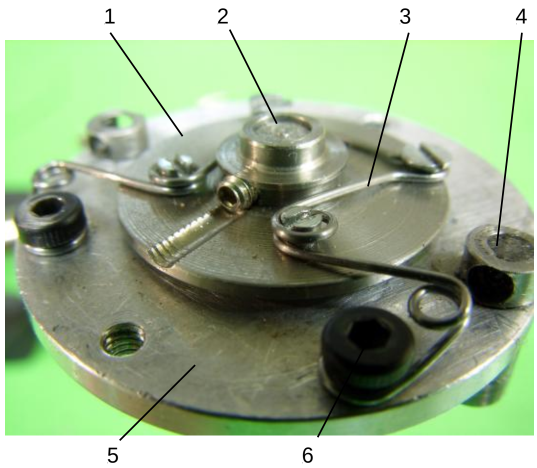

Fig. 3. Peak Torque Buffer
1: Shaft-hub joint; 2: Motor axis; 3: Steel Spring D0.5; 4: Crank shaft with magnet D2x2; 5: Flange; 6: Spring lock

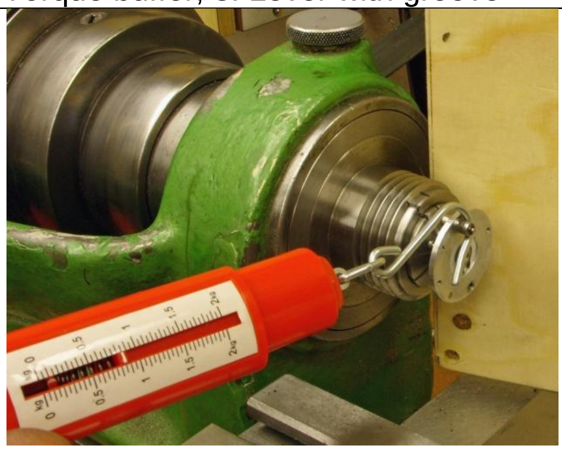

Fig. 4. Characteristics of the Peak Torque Buffer: 8N/20 degree at radius 12.5mm, This means 1 kg.cm, about 33% of the permissible torque

3. Experiments

The duck legs are moving forwards and backwards at an angle of about 40 degrees, motorized by the gear motor SONTH Motor SG13-050, DC 2 to 7V

There are two stroke options:

- 1^{st} : Slow Mode: Fast stretching the feet to the front and slowly paddle backward
- 2^{nd}: Fast Mode: Slow stretching the feet to the front and fast paddle backward

Endurance tests in July 2013 have shown that the 2^{nd} method provides a better stroke, but will destroy the gear of the motor due to excessive peak torque, just at the moment when the spread-out foot start to push the water backwards!

The new Peak Torque Buffer solves this problem; the 100 hour endurance test in August 2013 was a success: Motor, gear and duck feet did not show any damage! The peak current is less than 2/3 of the specified continuous current now.

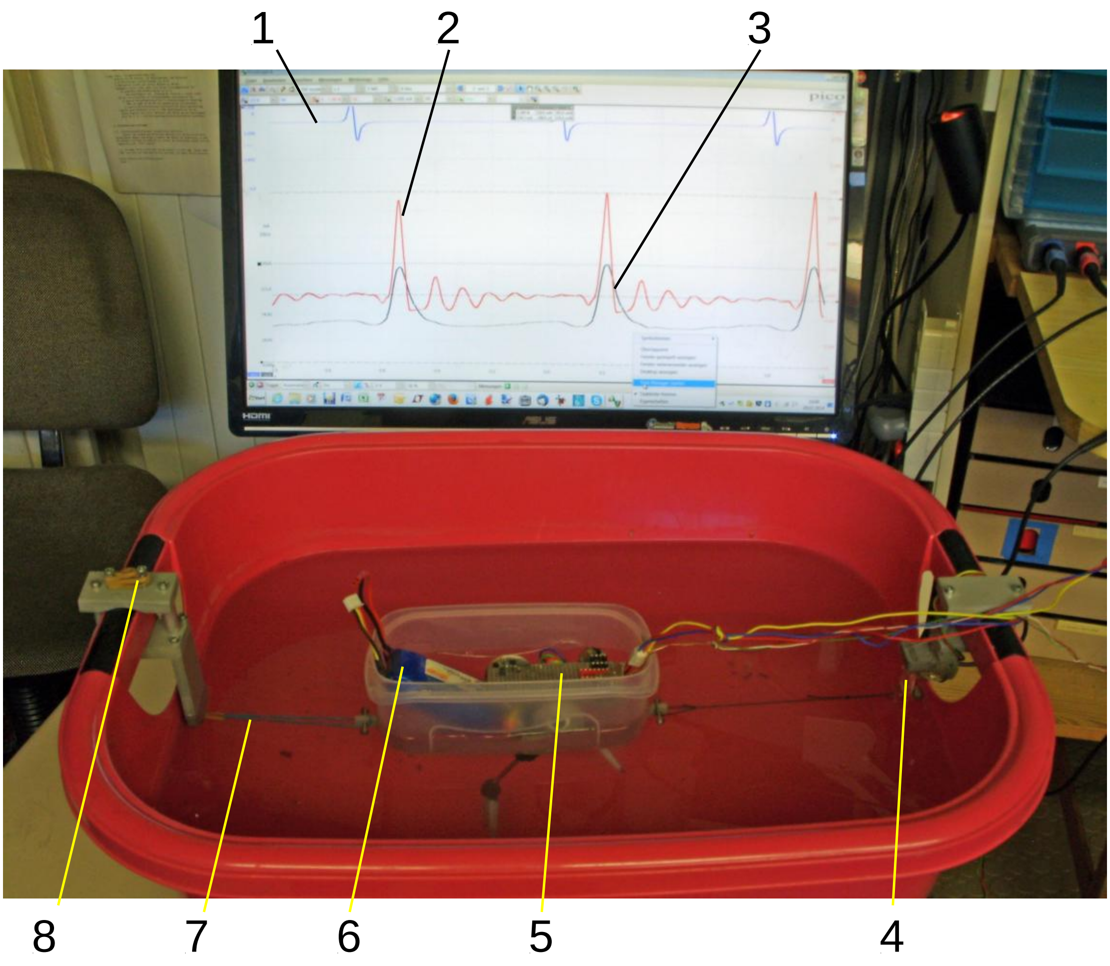

Fig. 5. Test Set-up for propulsion and endurance tests
1: Synchronization Hall Signal;
2: Drag force forward;
3: Motor current;
4: Drag Force Sensor Huba Control, 0-2.5N;
5: Bionic Duck Drive;
6: Payload 100 gram;
7: Rubber thread, drag pre-force about 0.5N
8: Holder Rubber Thread

4. Experimental Data for Slow Mode

Scope Data:
Top: Synchronization (Hall Signal left leg)
Middle: Propulsion Force
Bottom: Motor Current

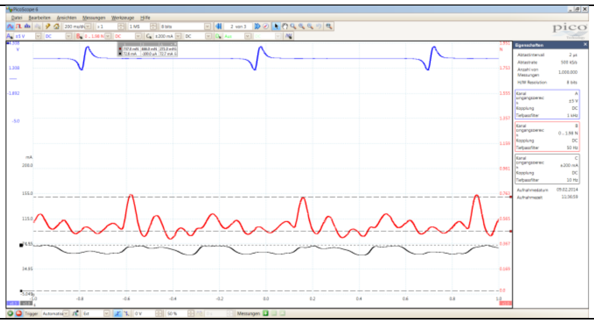

Fig. 6a: Right Leg Slow Mode 5V

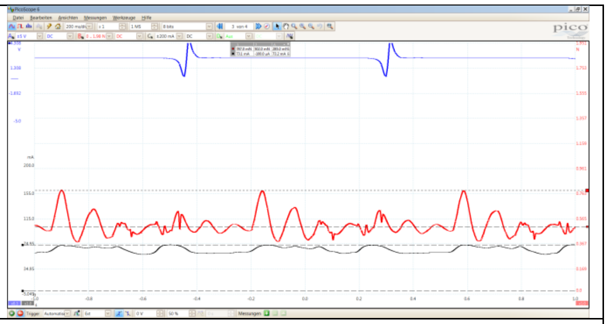

Fig. 6b: Left Leg Slow Mode 5V

Vcc	Right Leg Slow Mode			Left Leg Slow Mode		
2V	531.0 mN	466.0 mN	65.0 mN	758.0 mN	502.0 mN	256.0 mN
	57.6 mA	-100.0 µA	57.7 mA	55.1 mA	-100.0 µA	55.2 mA
3V	630.0 mN	466.0 mN	164.0 mN	840.0 mN	502.0 mN	338.0 mN
	64.9 mA	-100.0 µA	65.0 mA	60.4 mA	-100.0 µA	60.5 mA
4V	659.0 mN	466.0 mN	193.0 mN	319.0 mN	709.0 mN	390.0 mN
	73.2 mA	-100.0 µA	73.3 mA	8[illegible]8 mA	-100.0 µA	85.9 mA
5V	770.0 mN	466.0 mN	304.0 mN	319.0 mN	779.0 mN	460.0 mN
	74.5 mA	-100.0 µA	74.6 mA	68.8 mA	-100.0 µA	68.9 mA
6V	821.0 mN	466.0 mN	355.0 mN	319.0 mN	829.0 mN	510.0 mN
	81.9 mA	-100.0 µA	82.0 mA	84.3 mA	-100.0 µA	84.4 mA
7V	898.0 mN	466.0 mN	432.0 mN	1.013 N	466.0 mN	547.0 mN
	93.0 mA	-100.0 µA	93.1 mA	85.8 mA	-100.0 µA	85.9 mA

Table 1: PicoScope Data: Max Values, Zero-Reference, Differential Value (Stroke)

P

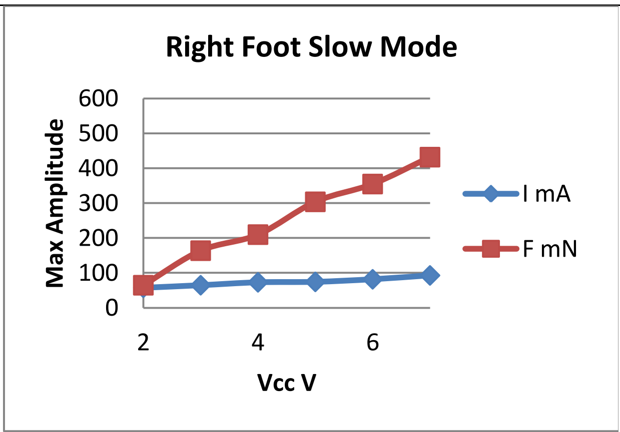

Fig. 7a: Characteristics Slow Mode Right

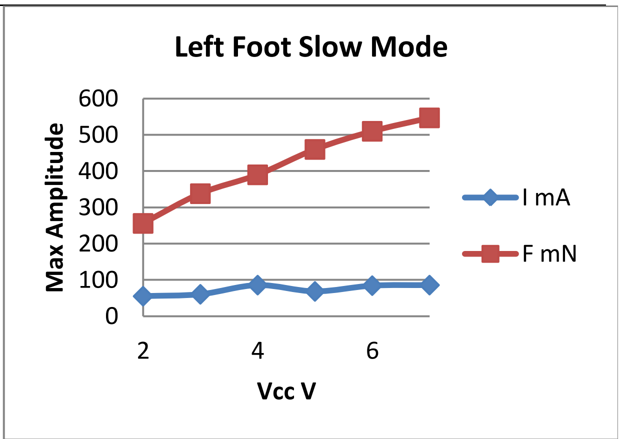

Fig. 7b: Characteristics Slow Mode Left

Comment:
Left and right foot shows almost the same characteristics
Stroke Force about 400mN, Peak-Current 70mA @5V

5. Experimental Data for Fast Mode

Scope Data:
Top: Synchronization (Hall Signal left leg)
Middle: Propulsion Force
Bottom: Motor Current

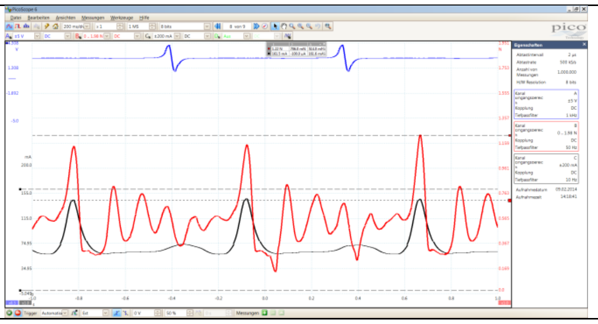

Fig. 8a: Right Leg Fast Mode 5V

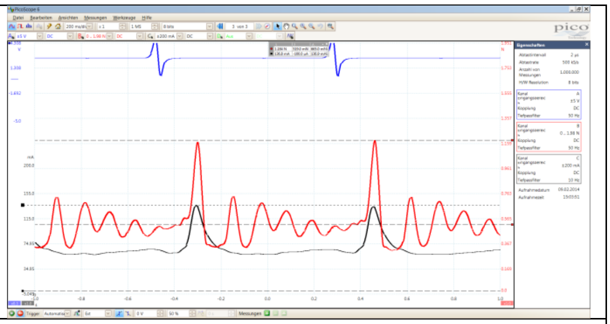

Fig. 8b: Left Leg Fast Mode 5V

Vcc	Right Leg Fast Mode			Left Leg Fast Mode		
2V	685.0 mN	527.0 mN	158.0 mN	800.0 mN	519.0 mN	281.0 mN
	79.4 mA	-100.0 µA	79.5 mA	85.8 mA	-100.0 µA	85.9 mA
3V	899.0 mN	527.0 mN	372.0 mN	1.026 N	519.0 mN	507.0 mN
	117.7 mA	-100.0 µA	117.8 mA	117.8 mA	-100.0 µA	117.9 mA
4V	953.0 mN	656.0 mN	297.0 mN	1.093 N	519.0 mN	574.0 mN
	140.6 mA	-100.0 µA	140.7 mA	130.4 mA	-100.0 µA	130.5 mA
5V	1.225 N	656.0 mN	569.0 mN	1.184 N	519.0 mN	665.0 mN
	148.4 mA	-100.0 µA	148.5 mA	136.8 mA	-100.0 µA	136.9 mA
6V	1.951 N	656.0 mN	1.295 N	1.288 N	519.0 mN	769.0 mN
	159.1 mA	-100.0 µA	159.2 mA	135.3 mA	-100.0 µA	135.4 mA
7V	1.951 N	656.0 mN	1.295 N	1.394 N	519.0 mN	875.0 mN
	160.6 mA	-100.0 µA	160.7 mA	121.2 mA	-100.0 µA	121.3 mA

Table 2: PicoScope Data: Max Values, Zero-Reference, Differential Value (Stroke)

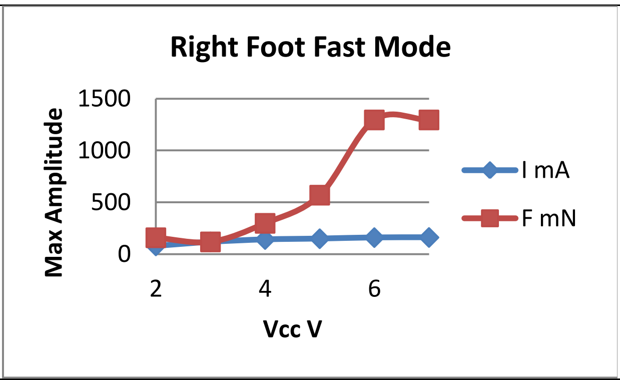

Fig. 9a: Characteristics Slow Mode Right

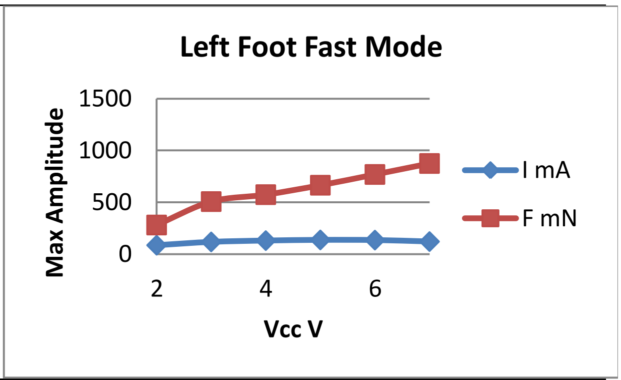

Fig. 9b: Characteristics Slow Mode Left

Comment:
Left and right foot do NOT show the same characteristics!
The left/right toes of the left foot show some friction; this is the reason for fewer forces at voltages above 5 V. These toe joints should be improved.
Stroke Force about 600mN at 5V, Peak-Current 140mA @5V

6. Drawings of the Bionic Drive

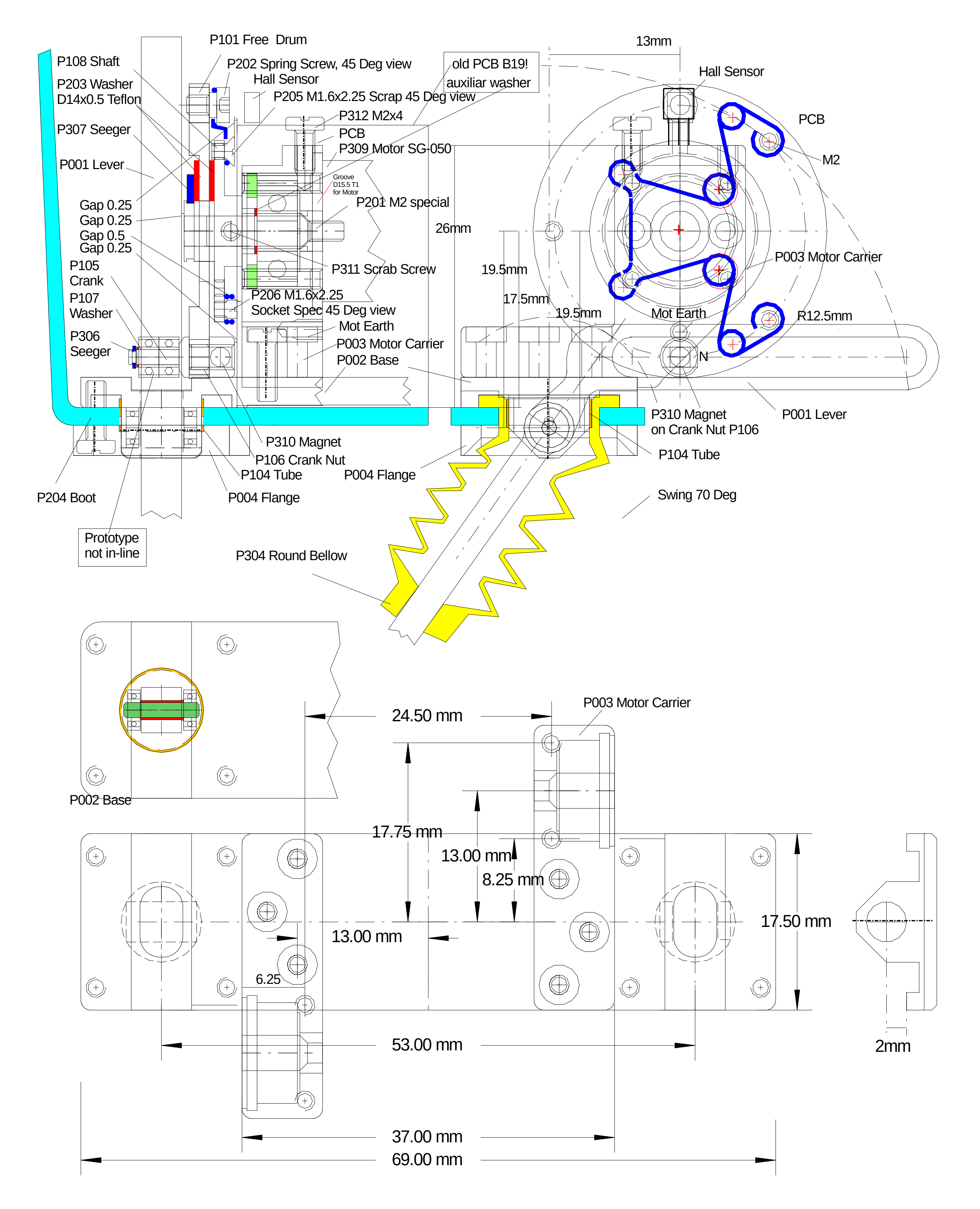

Fig. 9. Overview

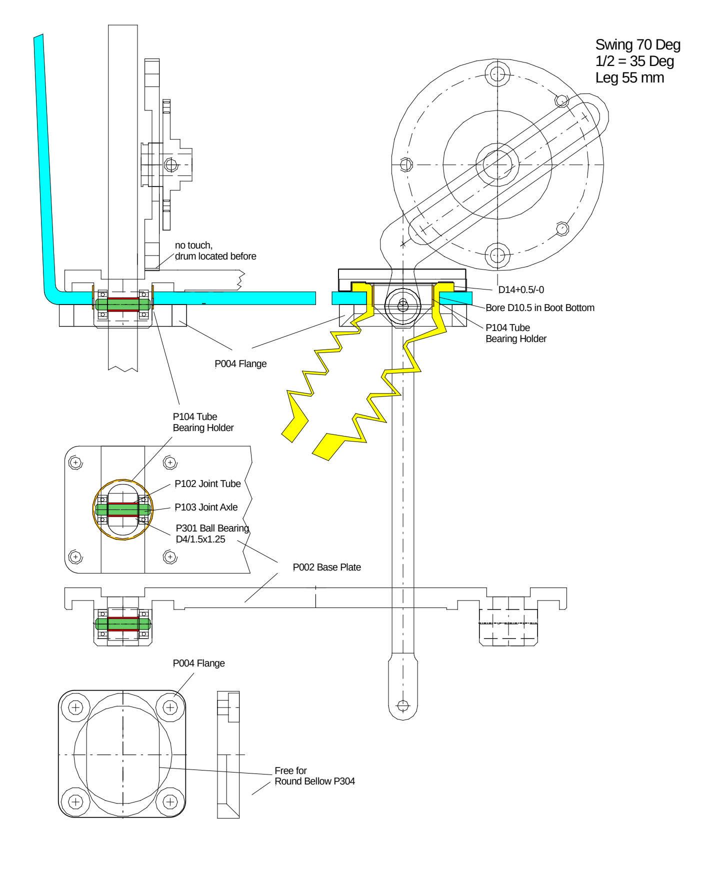

Fig. 10. Joint Details

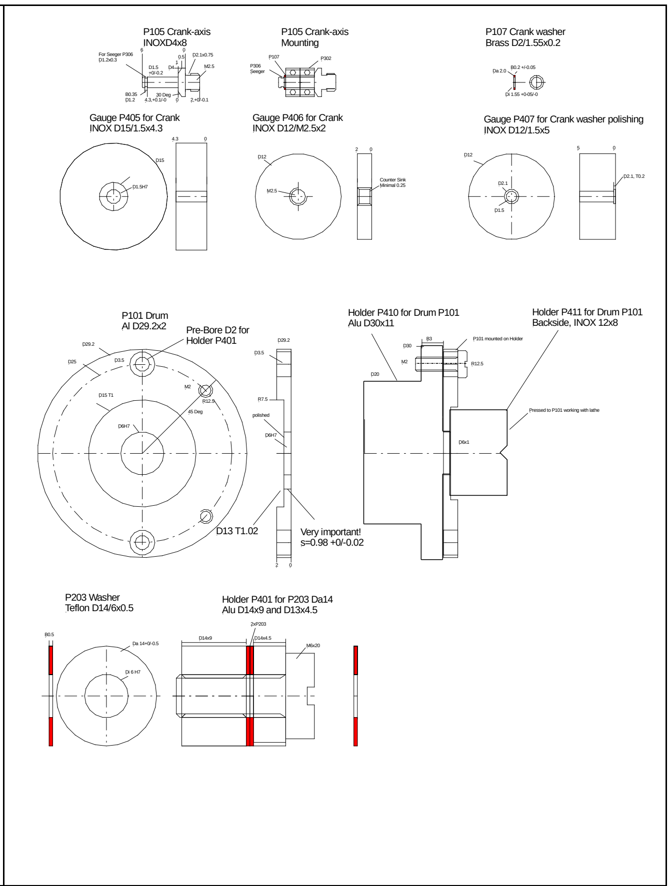

Fig. 11. Drum, Crank and Teflon Washers

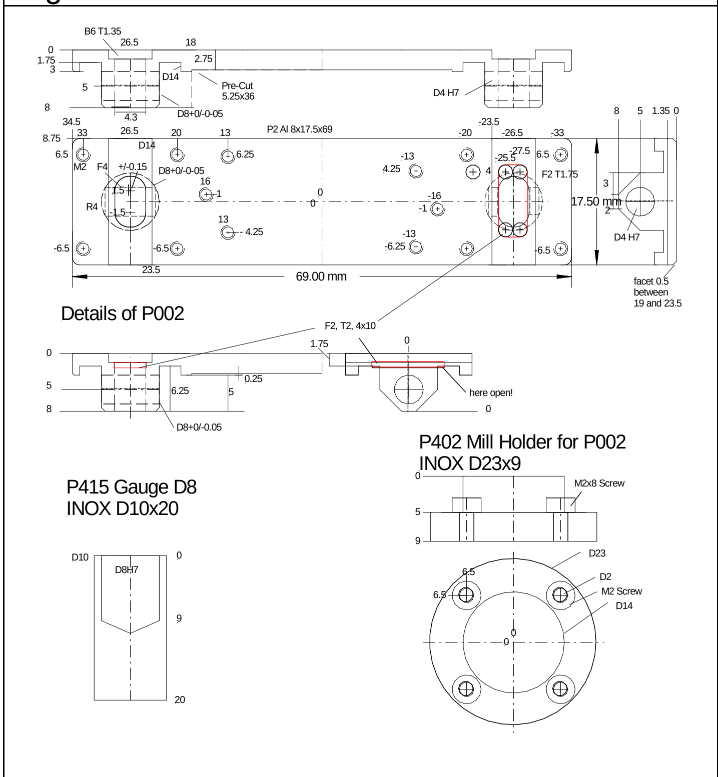

Fig. 12. Base Plate

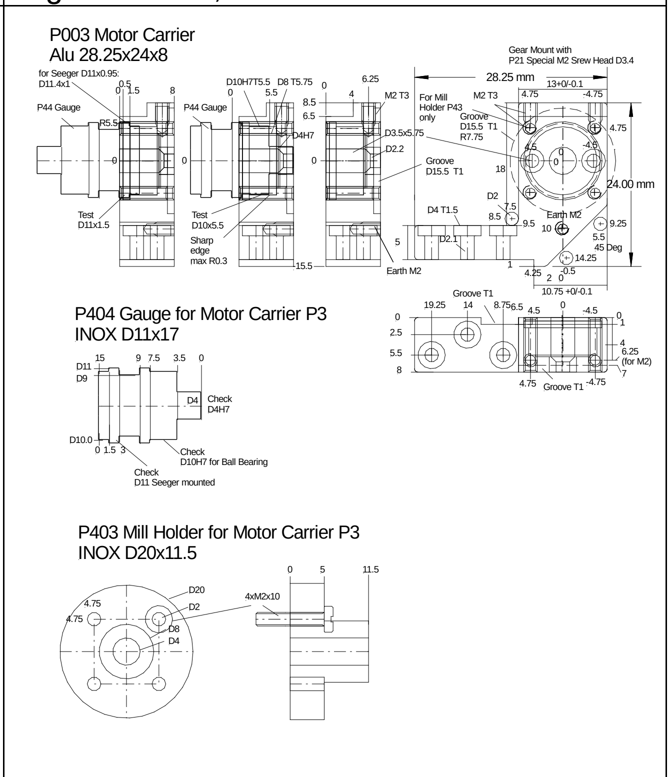

Fig. 13. Motor Carrier

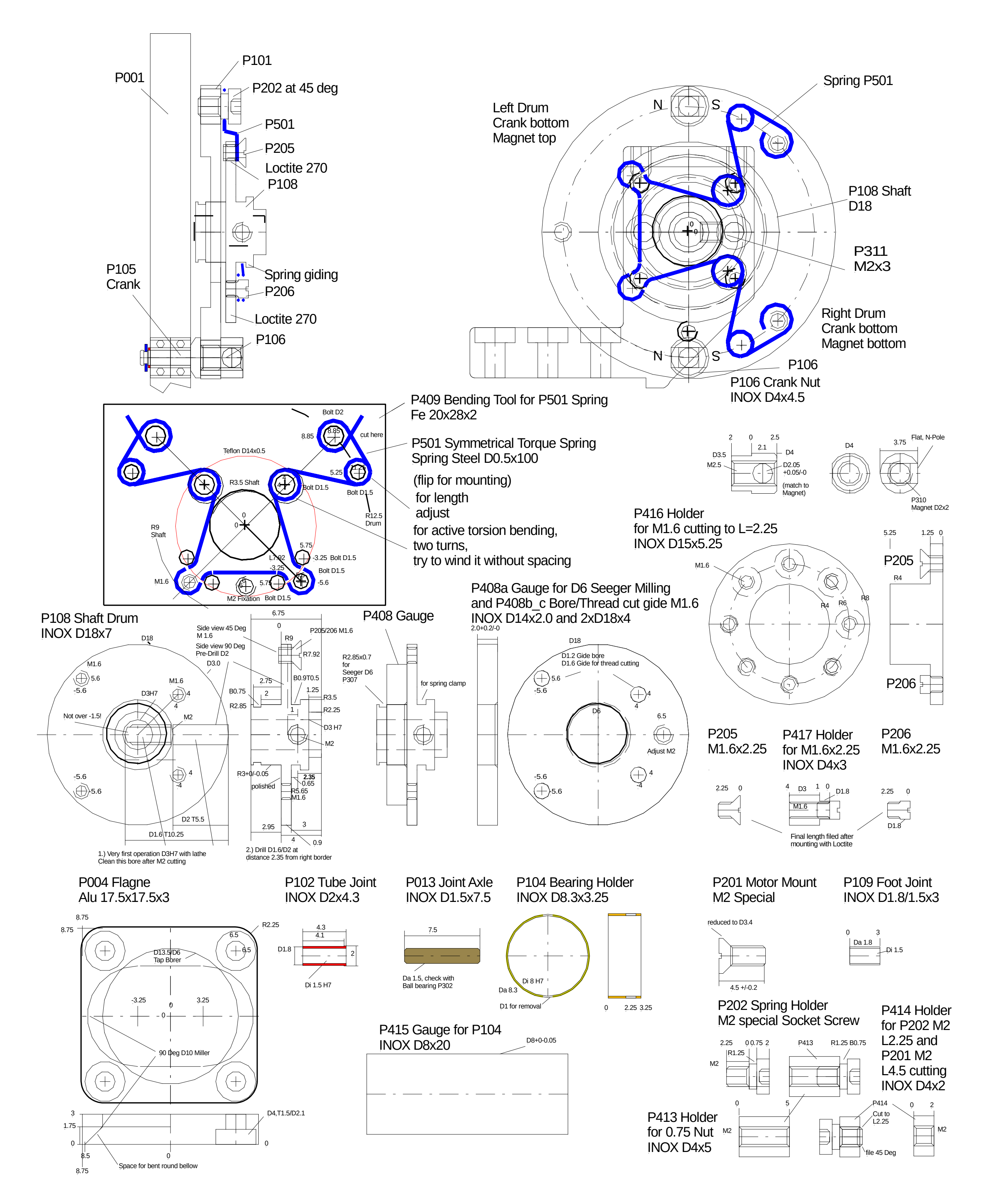

Fig. 14. Small Parts and bending Tool for the spring

Bill of Mechanical Duck Drive Material

Milled parts

Pos	Quan	Description	Material
001	2	Leg Lever	Al-Sheet 4mm, 68x60 (for short old legs)
002	1	Base Plate	Al-Sheet 8mm, 17.5x69
003	2	Motor Carrier	Al-Sheet 8mm, 24.0x28.25
004	2	Flange	Al-Sheet 3mm,17.5x17.5x3

Turned parts

Pos	Quan	Description	Material
101	2	Drum	AL D29.2x2
102	2	Joint Tube	INOX D2/1.5x4.3
103	2	Joint axle	INOX D1.5x7.5
104	2	Bearing holder tube	INOX D8.3/8x3
105	2	Crank	INOX D4x8
106	4	Crank Nut (for Magnet, too)	INOX D4x4.5
107	2	Crank Washer	Brass D1.5x0.2
108	2	Shaft Drum	INOX D18x7
109	2	Foot Joint	INOX D1.8/1.5x3

Modified Standard Parts

Pos	Quan	Description	Material
201	4	Flat Head Screw M2, D3.5	Flat Head M2x4.5, Head D3.5
202	4	Socked Screw Special M2 for Spring	Socked M2x2.5
203	4	Washer D14/6x0.5	Teflon
204	1	Boot: Migros Topline Container	Plastic 7029.664.00000 166x90x65
205	2	M1.6x3 Flat Head screw milled to L2.25	Fe Zinc plated
206	4	M1.6x5 Socket screw milled to L2.25, Da 1.8	Fe Zinc plated

Standard material

Pos	Quan	Description	Material
301	4	Ball-bearing D4/1.5x1.25	Conrad
302	4	Ball-bearing D4/1.5x2	Conrad
303	4	Ball-bearing D10/3x4	Conrad
304	2	Round Bellow F1092 NBR	Zwahlen 1092 NBR, Internet cheaper
305	2	Seeger D11x0.95	Fe
306	2	Seeger D1.2x0.3	Fe
307	2	Seeger D6x0.7	Fe
308	6	Socked Screw M2x6	Fe black
309	2	Motor SG-050, Red 1/88	Sonth, China
310	2	Magnet D2x2	Neodyn, Supermagnete CH
311	2	Grub Screw M2x3	Fe zinc plated
312	4	Socked Screw M2x4	Fe black
313	8	Socked Screw M2x8	Fe black

400. Gauges and Turn/Mill-Holders

Pos	Quan	Description	Material
401	1	P203 Washer holder	Alu D14x9
402	1	P002 Mill holder	Alu D23x9
403	1	P003 Mill holder	Alu D20x11.5
404	1	P003 Gauge for Check Da 10 Ball-bearing	INOX D11x15
405	1	P105 Gauge for Check Di 1.5 Ball-bearing	INOX D15x4.3
406	1	P105 Gauge for M2.5 Check	INOX D12x2
407	1	P107 Gauge for Washer-Thickness Polishing	INOX D12x5
408	1	P108 Gauge for Seeger D6	INOX D14x2
409	1	P501 Bending Tool	Fe 20x20x2
410	1	P101 Holder for Groove D15.5 T1 turning	Alu D30x11
411	1	P101 Holder for back side turning (if needed!)	INOX D12x8
412	1	P104 Gauge D8	INOX D8x30
413	1	P202 Holder for 0.7 Nut on M2 screw	INOX D4x5
414	1	P202 Holder for M2 cutting L2.5	INOX D4x2
415	1	P002 Gauge D8	INOX D10x20
416	1	P205/206 Holder M1.6 Length Cutter	INOX D16x5.25
417	1	P206 Holder Socket Screw Head Milling	INOX D3x4
418	1	P001 Leg holder for foot joint milling	Alu 15x15x30

Hand crafted special parts

Pos	Quan	Description	Material
501	2	Torque Spring	Spring Steel D0.5x100

Tools

Pos	Quan	Description	Material
601	1	P306 Mounting Tool Seeger D1.2	Brass 6x1x50
602	1	P311 Hexagon socket screw key Grub Screw	INOX D3x60 with Hexagon standards
603	1	P205 Magnetic screw driver for M1.6 Screw	INOX D3 x30 with D3x3 Magnet