Check on initial production blades

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Version 2. Includes check with blades in rotational adjusters.
Version 3. Includes extra deflection check and conclusion.

1 Background

The quad blades were designed using FEA and proved on the noise prototype. When we went to tender for the main production run we included a provision that a test set of blades would be made which we could assess to see whether the combination of blade dimensions, bend radius, and material modulus would bring the blades flat under load.

2 References

The latest model is in Norna's conceptual design document T010103-05, appendix D. The blades drawings, numbers taken from the RFQ, are D060235-C, D060236-C and D060237-C for the top, middle and bottom blades respectively. The ANSYS macros which we believe were used (they have the right blade dimensions and credible suspended masses) are stored with this file.

3 Blades on arrival

Well packed – noted lack of central hole for magnetic damping in all three types.

4 Blade dimensions

Blade dimension given in the drawings are

blade	drawing	length	root	thick	E	mt	R(surface)
Top	D060235-C	480	95	4.3	186	61.82	404.85
Middle	D060236-C	420	59	4.6	186	70.775	421.2
bottom	D060237-C	370	49	4.2	186	39.5	393.8

The masses given in T010103-05, appendix D, page 39 note 5, are

		Sum from bottom	Mass on one blade		
Mn	22.1100	123.325	61.66		
M1	22.0110	101.211	50.6		
M2	39.6	79.2	39.6		

M3	39.6				

The masses in the macros are

			Mass on one blade	Inferred Sum from bottom	Inferred masses
Mn			61.82	123.64	22.12
M1			50.76	101.52	22.52
M2			39.5	79.0	39.5
M3					39.5

Checking with LASTI (Brett, SUS technical telecon 20 Jan 2009) tells me that the actual glass masses are 39.6kg

The upper masses can be adjusted; Joe and Brett tell me (SUS technical meeting, 20 Jan 2009) that in doing the noise prototype build the masses he aimed for were mn=m1=22.0kg

Further discussions (ALUK PMC, 28th Jan 2009, RAJ/KAS/JO) confirmed that 39.6kg was the modelled (ie target) mass of the test mass using the density value measured on the noise prototype test mass.

So the masses we will use for the tests are

		Sum from bottom	Mass on one blade		
Mn	22	123.2	61.6		
M1	22	101.2	50.6		
M2	39.6	79.2	39.6		
M3	39.6				

5 Masses to use for tests

Because the test rig uses a pulley to give the right wire angle, but allows the mass to hang straight, we need to bias the mass we use as follows:

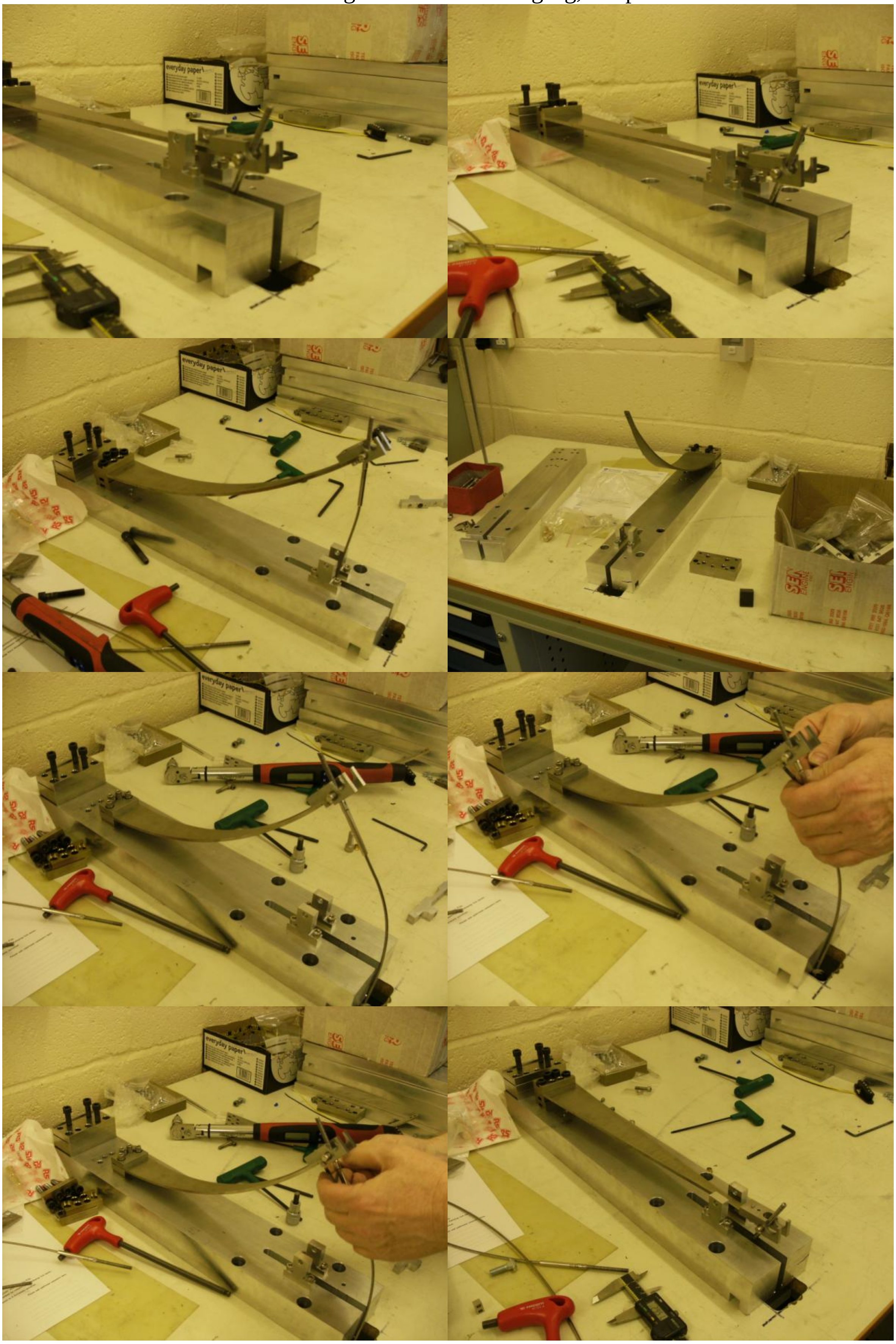
Blade	Wire angle (degrees, from macro)	Correction factor (1/cos(theta))	Suspended mass	Mass to use on the rig
Top	21	1.071	61.6	65.98
Middle	27	1.122	50.6	56.79
bottom	6	1.005	39.6	39.82

Masses used (measured using Atlas scale): top, 65.96kg.
Middle 56.78
Bottom, 39.80

Check of Atlas scale, loaded with 400N calibrated loads – scale read 40.86kg when it should have been 40.77, which is overreading by 0.2% (over a 200mm blade deflection that would be 0.4mm)

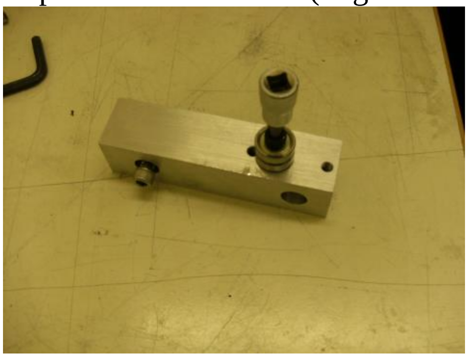
6 What to measure

The measurements were made using the blade checking rig, see photo.

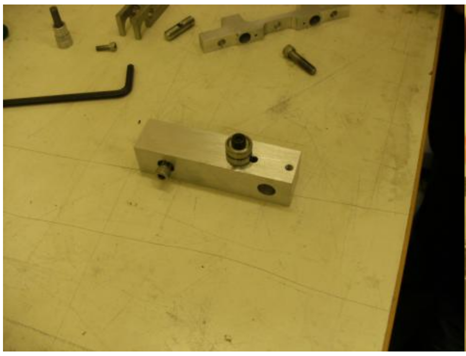
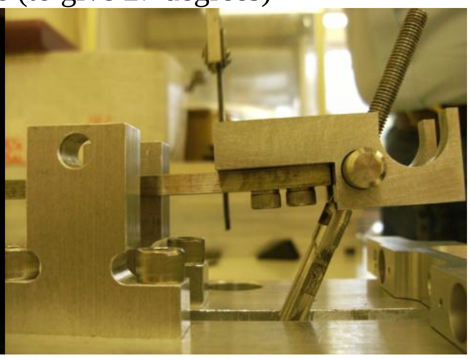


We checked the distance from the blade to the base of the rig near the tip and compared it to the same distance near the root., see photos:

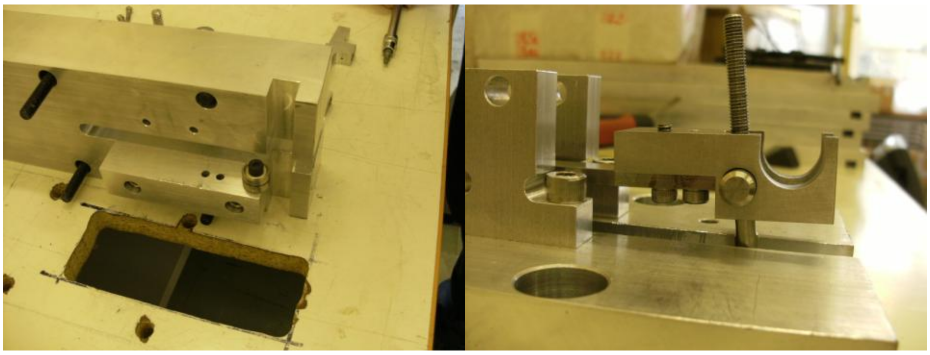
In using the jig, the puller wheel was put in the following positions
Top blade: middle hole (to give 21 degrees)



Middle blade: hole near middle hole (to give 27 degrees)

Bottom blade: hole distant from middle (to give -6 degrees)

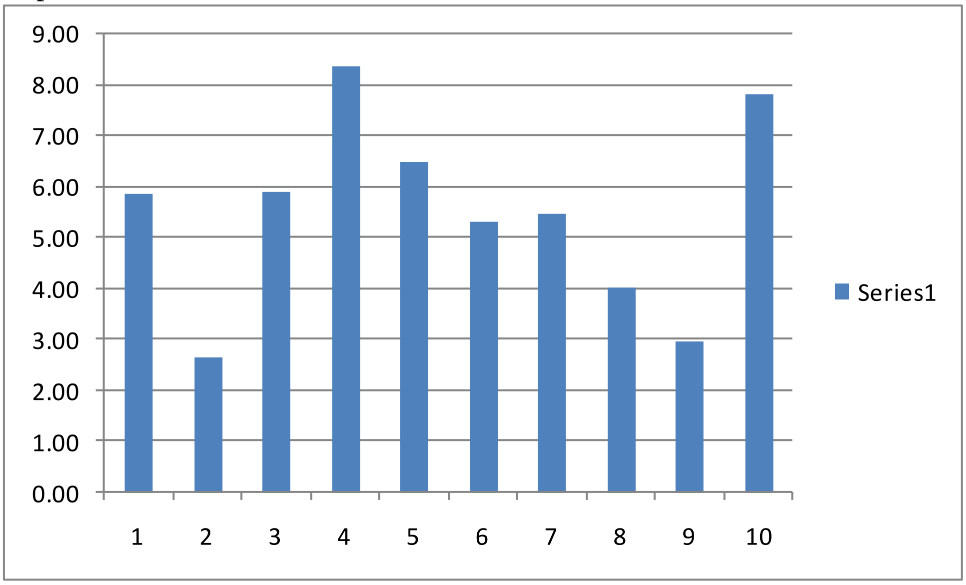


7 Results

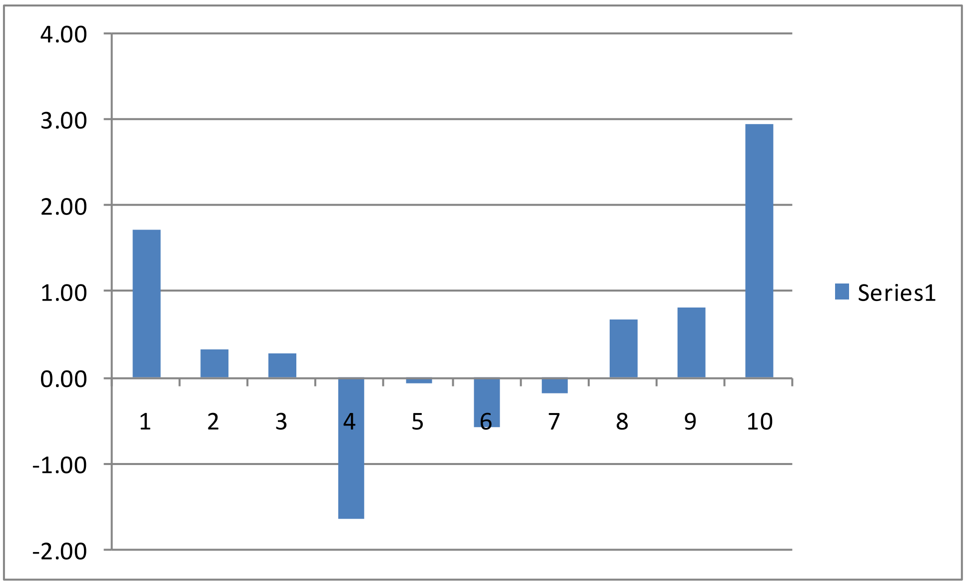
Blade		root height	Measured results		avg	error
D060235-0	23	30.10	36.02	35.91	35.97	5.87
	21	30.07	32.85	32.63	32.74	2.67
	32	30.12	36.70	35.32	36.01	5.89
	33	30.21	38.70	38.50	38.60	8.39
	24	30.15	36.69	36.62	36.66	6.51
	27	30.11	35.47	35.37	35.42	5.31
	35	30.16	36.41	34.90	35.66	5.50
	22	30.09	34.77	33.50	34.14	4.05
	29	30.10	33.12	33.06	33.09	2.99
	28	30.04	37.96	37.81	37.89	7.85
D060236-0	32	28.48	28.91	31.50	30.21	1.73
	23	28.55	28.87	28.88	28.88	0.32
	27	28.42	28.67	28.75	28.71	0.29
	33	28.55	26.99	26.83	26.91	-1.64
	24	28.55	28.52	28.43	28.48	-0.07
	22	28.41	28.43	27.23	27.83	-0.58
	30	28.51	28.37	28.27	28.32	-0.19
	31	28.45	29.75	28.51	29.13	0.68
	28	28.65	29.52	29.40	29.46	0.81
	29	28.63	31.67	31.50	31.59	2.96
D060237-0	21	18.48	16.02	16.04	16.03	-2.45
	32	18.28	16.53	16.31	16.42	-1.86
	36	18.53	14.78	14.85	14.82	-3.72
	24	18.41	14.86	15.43	15.15	-3.27
	23	18.27	16.21	15.92	16.07	-2.21
	39	18.35	13.62	16.64	15.13	-3.22

	41	18.37	14.35	14.27	14.31	-4.06
	38	18.22	14.73	14.44	14.59	-3.64
	25	18.44	14.75	14.53	14.64	-3.80
	34	18.10	14.74	14.71	14.73	-3.38

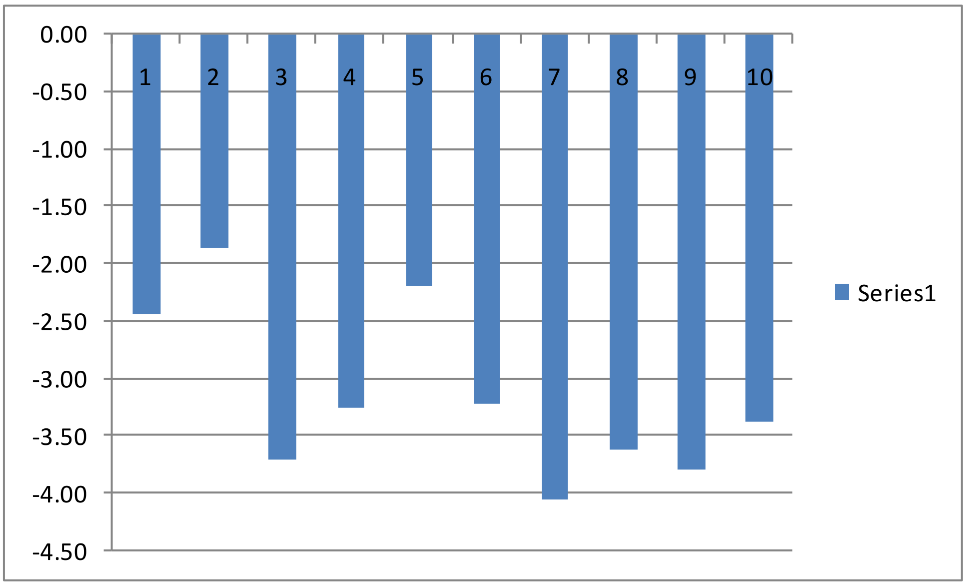
Top blades



Middle blades



Bottom blades



8 Checks

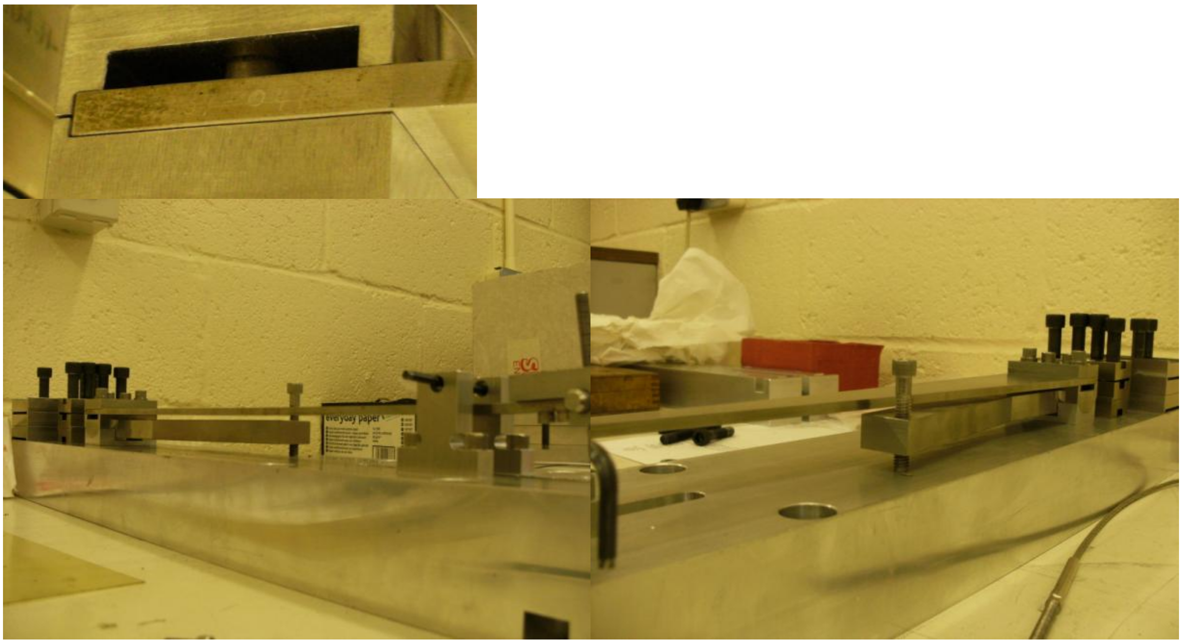
We assembled the lowest example of each of the middle and bottom blade and reloaded them in a clamp with a rotational adjuster as follows:

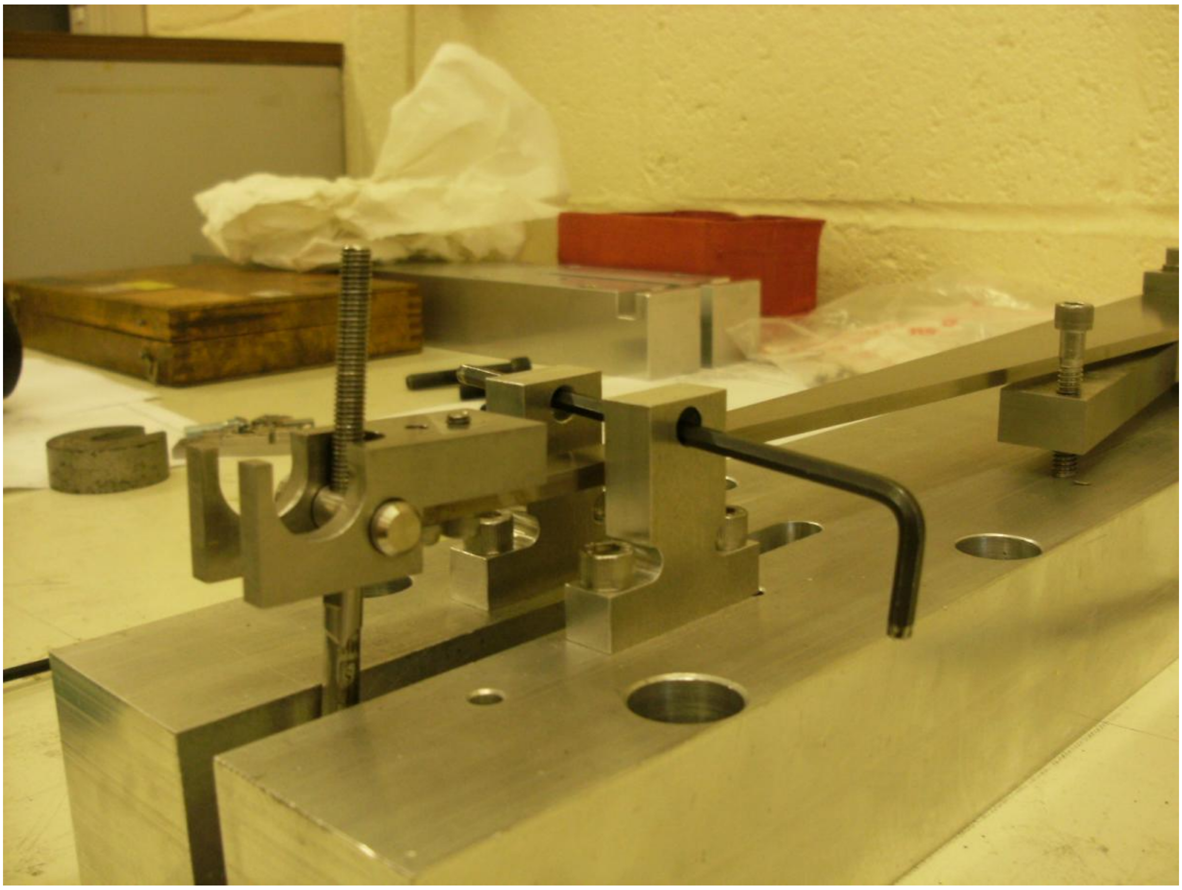
Bottom blade: blade number 41 (the seventh in the list above) loaded with 39.84kg.

Middle blade: blade number 33 (the fourth in the list above) loaded with 56.78 kg.

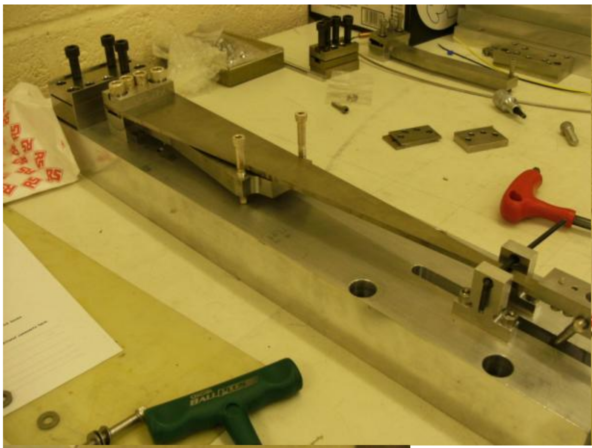
In both cases there was no interference between the blade and the adjuster.

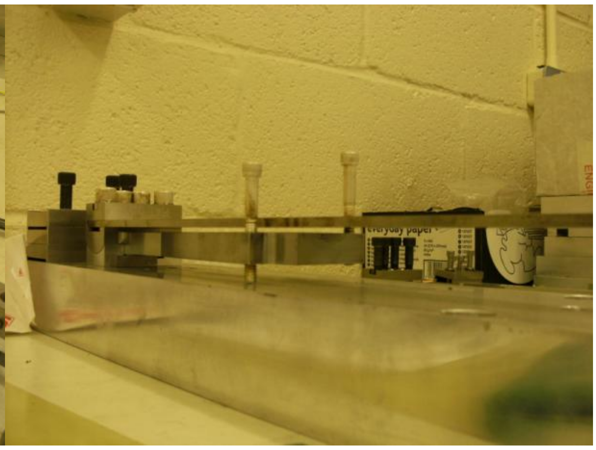
Bottom:





Bottom blades





9 Additional check

We (RJSG + JO) put a bottom blade back into the jig (serial number 32), and lowered the adjuster so that the height of the tip corresponded to the setting we need with the real blade tip clamp (about 7mm lower than you might think because of the removed prism). There was no sign of interference with the rotational adjuster.

10 Conclusion

- Top blades come a little low, but this easily be fixed during second-stage machining of the top stage blade clamps.
- Middle blades look really good.
- Bottom blades come a little lower than level (by about 4mm) but the nominal height is in fact 7mm low due to the removal of the prism from the clamp design, so in fact they are fortuitously very close to ideal.
- There is no sign of interference with the rotational adjuster that was problematic with the oversoft blades on the noise prototype.

On this basis we will proceed with the manufacture of the full blade set.