Fomrhi Comm. 2093 **Ton Pel**

3D printed conical crook for a baroque bass racket

Introduction

A crook for a bassoon or a racket is also called an Es or S, according to its form.

As early as 1685 we read the following in the Amsterdam builder Richard Haka's fee statement for the delivery of musical instruments to Sweden: 'Kooper Es tot dulcian Basson' (which probably meant a baroque bassoon).

An Es was and still is made by first folding a flat piece of brass around a conical spine, then soldering the joint and finally bending the straight piece of soldered brass into the Es form.

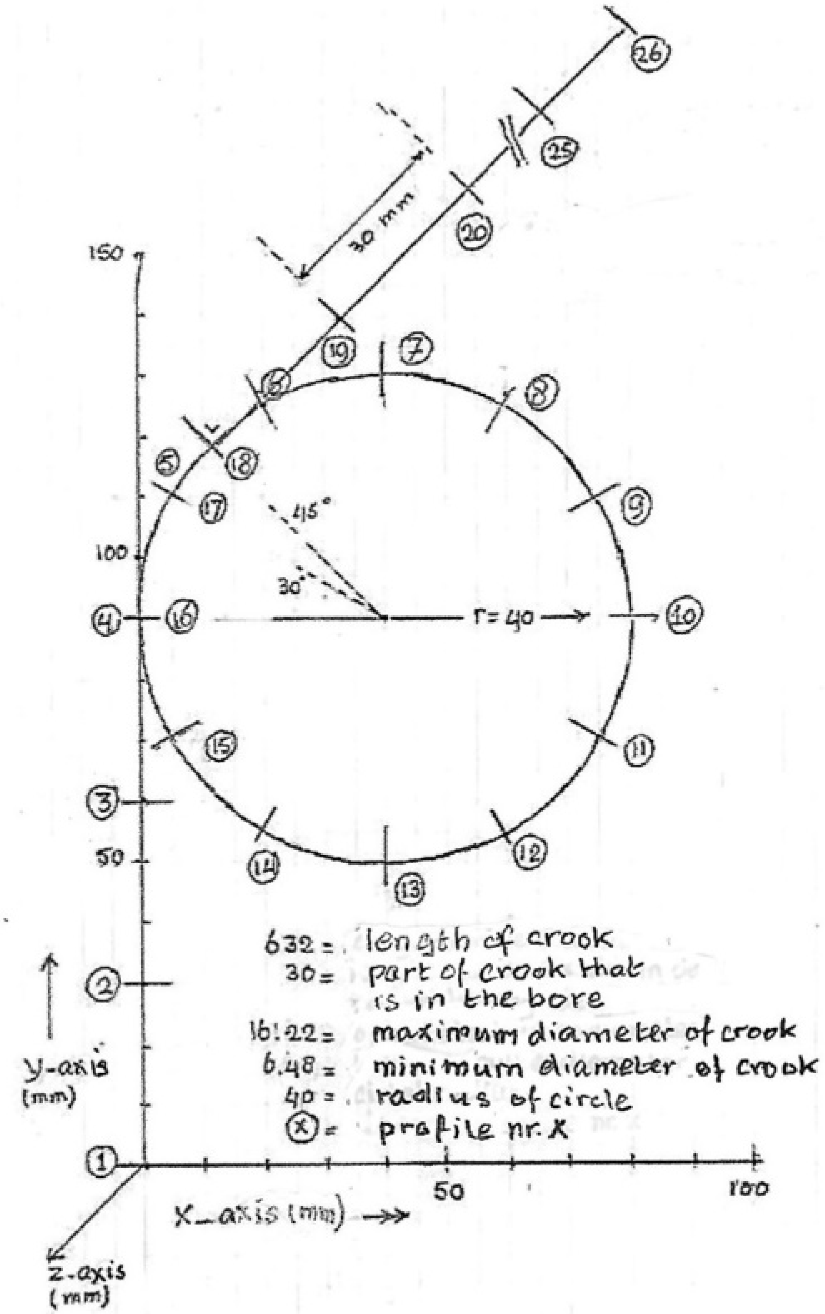
Other method and material

It is quite complicated to make a conical Es. Amateurs do not usually achieve a flawless result. On the other hand, buying an Es is costly. In my experience a 3D printed Es is a good alternative acoustically, visually and financially.

How can it be done? A step by step plan is given below.

Step 1: Make a drawing of the centre line of the Es, scale 1:1

First you make a drawing of the centre line of the Es. The line should have the same length as the crook whose dimensions you know. If you put a mark on the centre line every 30 mm, you can imagine at each mark two circles square and centred on the centre line: the inner and outer profile of the crook. If you know the measurements of the narrowest and widest profiles at each end of the crook, the reduction of the profile sizes from bottom to mouth piece can be calculated, assuming that this reduction is linear over the length of the crook. As you will notice from the drawing below, my crook goes up under an angle of 45 degrees, whereas the original[i] ends horizontally. That is a choice determined by the (expected) playability of the instrument.



Step 2: Calculate x,y and z coordinates, profile sizes and angles with a spreadsheet

The centre line of the crook can be modelled mathematically[ii], in parts. You start with part 1: a straight line extending vertically. Continue with part 2: a circle with a little overlap where the circle evolves into the straight line towards the mouthpiece. Finally, part 3: a straight line running at an angle of 45 degrees. If you have your base data and formulae right, you can easily calculate coordinates, angles and sizes for each part of the model. The following Excel spreadsheet shows the results: the calculated profile angles, x,y and z coordinates, crook length at each profile (to calculate the outside size of the profile) and the size reduction factor relative to profiles 0, 1 and 2. For profile 11 and 25 the applicable formulae also are shown.

A few words about z coordinates: adjacent to the number tables a view of the crook in the xy plane is shown. Profiles 4 and 16 have the same x and y coordinates. However, they have different z coordinates. Profile 4 is on z=0. Profile 16 is closer to the viewer. There should be room between those profiles. The centre of profile 16 should be at z= 0.5* (profile 4 size + profile 16 size) +3 mm (3 mm is chosen the distance between the outer sides of profiles 4 and 16. This z value can be linearly reduced to 0 over profiles 15,14….,4. With all the data calculated, you can make graphs of the crook. These can be used for a final check of your design.

Step 3: Make a 3D model with a design programme[iii]

The next step is to make a 3D model of the crook with a 3D design programme. For the

Calculations - base for the design of a crook for a baroque bass racket

mm		mm	
632	Length of the crook according to the drawing	40,00	Radius of the cicle
30	Part of the crook that is in the bore	251,20	Circumference of the cicle
602	Part of the crook where profiles are reduced	20,93	Length of 1/12 circle segment
16,22	Maximum diameter of the crook	31,40	Length of 1/8 circle segment
6,481	Minimum diameter of the crook	10,47	Length van cirkelsegment 17-18
9,734	Diameter reduction, totally	30,00	Distance between profiles on straigt vertical line
0,016	Reduction of diameter per mm length	19,47	Remaining length near the mouth piece
		21,21	x and y deviation over 30 mm length, under 45 degr angle
		13,77	x and y deviation over remaining length, under 45 degr angle
		16,21	z distance between centre poits of profiles 4 and 16
		1,474	deviation of z coordinate between profile 4 en 16, per profile

Model part	Profile number	Profile angle (degr)	Profile angle (rad)	profile coordinates x	y	z	Length relevant for reduction	Outer diameter	Reduction factor
Part 1	0	0	0,00	0,00	-2,50	0,00	0,00	16,22	1,000
	1	0	0,00	0,00	0,00	0,00	0,00	16,22	1,000
	2	0	0,00	0,00	30,00	0,00	0,00	16,22	1,000
	3	0	0,00	0,00	60,00	0,00	30,00	15,73	0,970
	4	0	0,00	0,00	90,00	0,00	60,00	15,25	0,940
Part 2	5	30	0,52	5,36	110,00	1,47	80,93	14,91	0,919
	6	60	1,05	20,00	124,64	2,95	101,87	14,57	0,898
	7	90	1,57	40,00	130,00	4,42	122,80	14,23	0,878
	8	120	2,09	60,00	124,64	5,90	143,73	13,89	0,857
	9	150	2,62	74,64	110,00	7,37	164,67	13,55	0,836
	10	180	3,14	80,00	90,00	8,84	185,60	13,21	0,815
	11	210	3,67	74,64	70,00	10,32	206,53	12,88	0,794
	12	240	4,19	60,00	55,36	11,79	227,47	12,54	0,773
	13	270	4,71	40,00	50,00	13,27	248,40	12,20	0,752
	[illegible]	[illegible]	[illegible]	[illegible]	55,36	14,74	269,33	11,86	0,731
	[illegible]	[illegible]	[illegible]	[illegible]	70,00	16,21	290,27	11,52	0,711
	16	360	6,28	0,00	90,00	17,69	311,20	11,18	0,690
	17	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	10,84	0,669
	18	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	10,68	0,658
Part 3	19	45	0,79	32,93	139,50	17,69	[illegible]	[illegible]	[illegible]
	20	45	0,79	54,14	160,71	17,69	[illegible]	[illegible]	[illegible]
	21	45	0,79	75,36	181,92	17,69	432,60	9,22	0,569
	22	45	0,79	96,57	203,14	17,69	462,60	8,74	0,539
	23	45	0,79	117,78	224,35	17,69	492,60	8,25	0,509
	24	45	0,79	138,99	245,56	17,69	522,60	7,76	0,479
	25	45	0,79	160,21	266,78	17,69	552,60	7,28	0,449
	26	45	0,79	173,98	280,54	17,69	572,07	6,96	0,430

H4-H4*cos(D31)

F24+H4*sin(D31)

H14+G30

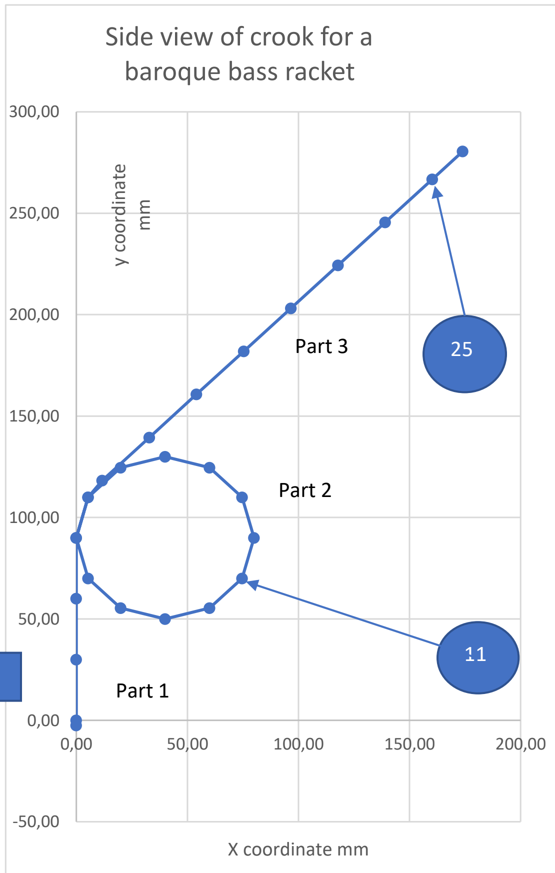
B7-B10*H31

H11+E44

H11+F44

G36

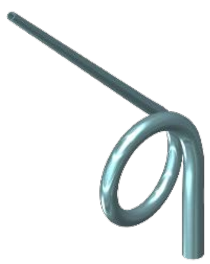
B7-B10*H45



programme I used, only the outside sizes of the profiles were relevant (I shall explain this later). First you put the profile of largest size in the drawing plane. The centre of this profile is on x=y=z=0. Then you copy this profile and move the copy to the next mark point (x, y and z are known), set the angle of the profile and reduce the size. Repeat this another 23 times, using the data from your spreadsheet. This may seem a lot of work, but an experienced user of a design programme can accomplish this task in a little more than an hour. It is important to always start from the profile on x=y=z=0, so profile 1, for the construction of each following profile. Copying other profiles potentially containing an error will adversely affect all following profiles.

Following this method three-dimensional images of subsequent, ever smaller profiles at different angles evolves.

You then connect all the profiles by mouse-clicking them in sequence and using a feature of the programme. The result of this is a massive, transparent, conical staff in the form of the crook design. Remove all profiles and transform the massive crook into a hollow one, by applying a programme feature which allows you the choose the final thickness (my choice: 1 mm). The programme has feature to check and eventually adapt all dimensions before you go printing. The 3D model of the crook is ready.



Step 4: Have your 3D model printed by an industrial manufacturer
I do not have my own 3D printer. I prefer to make use of the services manufactures offer on the internet. A home printer cannot match the quality of industrial printers. You send your 3D-model file (in STL format) to a few manufacturers. Various options are on offer: the type of print process, the type of material (including metals) and various finishes. Manufacturers check the printability of your model and give a price quotation (ex VAT and delivery costs). If you accept an offer, advance payment is required. Delivery is generally within ten working days.

For prototyping I advise the print process Selective Laser Sintering, material nylon, with no finish. This gives a very detailed and strong print result at an affordable price. Costs are important if you want to improve your design by repeatedly printing augmented models. I strongly advise to ask price quotations from a few manufacturers. Their prices for the printing the same object (probably with the same type of industrial printer) can be as much as three times higher from one manufacturer to another.

First impressions of playing
I put the crook in the proper bore of a 3D printed prototype of a baroque bass racket. I could play it with a good quality double reed made by an experienced bassoon player. The sound was surprisingly good according to a few former professional bassoon players. Of course, this is not a scientific judgement.

As the racket has no keys some of the chromatic notes cannot or hardly can be played. My next step is to find out how I can improve this by tuning the instrument using cork stops.

Finally
Please send me an email in case you have any comment or question: ton_pel@hotmail.com

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[i] I used measurements made by Jan Bouterse of a baroque racket with original crook, from the collection Boers, Rijksmuseum, Amsterdam, inventory nr. BK-NM-11430-111;
[ii] If the crook cannot be described mathematically, you can of course apply measured values (without a spreadsheet) or even invented measures if you want to make a unique design;
[iii] Design programmes have nothing to do with programming in the classical sense. Modern design programmes, often available free of charge, are visually strong and can be operated intuitively. For instance, if you want a sphere somewhere, you click on a pull-down menu, select a sphere, input the radius and place it where you want. It is easy to merge different objects into one new object. On YouTube you can find many ‘how to‘ videos explaining programmes like 123D Design, TinkerCad, or SolidEdge.