Mutual benefits of collaborations between instrument makers, musicians and acousticians

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Effective collaboration between instrument makers, musicians and acousticians can be of great benefit to all parties, leading to improved instrument designs, greater understanding of an instrument's playing characteristics, and an improved knowledge of the physical processes that occur within an instrument. As a working relationship develops between an instrument maker, a musician and an acoustician, the trust that builds up can facilitate increasingly more detailed investigations. Through a series of case studies involving brass and woodwind instruments, this paper charts the development of several maker/player/acoustician collaborations, showing how they have evolved over the years and highlighting the benefits experienced by all the different partners involved.

1 Introduction

Most traditional, non-electronic musical instruments have evolved over the centuries to their present day forms through the artistry and know-how of makers. However, with the growth of the field of musical acoustics over the past 100 years or so, the potential of science to influence musical instrument design has gradually increased.

It is becoming more and more evident that interaction between instrument makers and acousticians can be of great mutual benefit. Acousticians can tap into the vast experience and knowledge of makers, accumulated and passed down over the centuries, regarding the nuances and idiosyncrasies of given instruments. Meanwhile, acousticians can apply scientific principles to determine and suggest adjustments that a maker could make to an instrument's design in order to achieve a particular playing outcome. The inclusion of musicians (either professional or amateur) in such collaborative work helps to ensure that the end result has a direct musical benefit. It also provides the opportunity for players to provide valuable feedback and influence the direction of the work.

In this paper, case studies are presented which detail the development of several maker/player/acoustician collaborations that the author has been involved in. The case studies demonstrate how the nurturing of such collaborations has enabled more and more sophisticated investigations to be developed over a period of time.

2 Howarth of London collaboration

The author (DS) has been collaborating with woodwind makers Howarth of London Ltd (HoL) since the mid 1990s. Projects have been varied and have focused on both bassoon and oboe related investigations.

2.1 Bassoon crook project

In 1997, shortly after DS completed his PhD work on acoustic pulse reflectometry, one of the HoL instrument manufacturing staff (William Ring) contacted the Edinburgh University Acoustics Group regarding the possibility of using the technique to measure the internal profiles of a selection of bassoon crooks. At that time, HoL had an interest in bassoon crooks and had noted that Heckel crooks from the early 20^{th} century appeared to have a wider bore profile than later crooks both by Heckel and other manufacturers. Initial reflectometry measurements were made by DS which seemed to provide evidence to back up this hypothesis (see Figure 1) [1].

When DS moved to the Open University in 1998, he continued the bassoon crook work, directing a series of listening tests in conjunction with the Edinburgh Group. The psychoacoustical tests revealed that listeners could certainly distinguish differences in the timbres of notes produced using different crooks. However, it was not possible to correlate these differences with variations in bore profile [2,3].

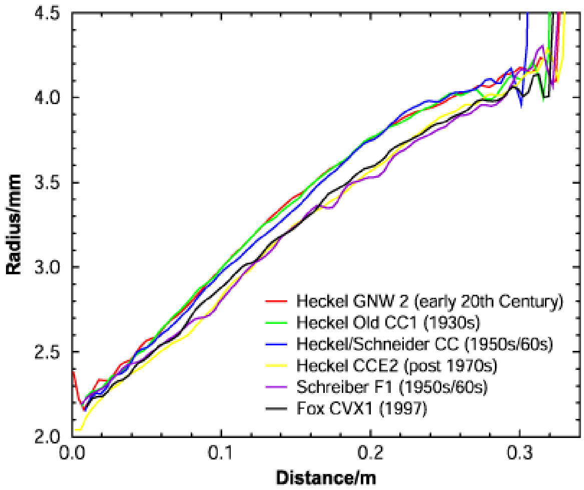

Figure 1: Bore profiles of six bassoon crooks.

Following the listening tests, funding was secured to continue the bassoon crook work. HoL played a major role in helping to gain this funding by committing (i) to provide crooks for measurement throughout the project and (ii) to participate in regular meetings to discuss findings and to guide the direction of the research. In addition, HoL facilitated the input of the world-renowned professional bassoonist William Waterhouse (WW), sadly now deceased. WW provided very useful observations from the musician's perspective and also loaned a number of historical crooks from his own personal collection.

Further crook profile measurements were made by Toby Hill under the direction of DS [4]. These measurements suggested that, contrary to previous findings, there are a number of crooks being produced today that have wider bores. Indeed, it was found that there is a comprehensive array of profiles available to the modern day bassoonist. In addition, a series of playing tests were carried out which suggested that there was a slight trend towards bassoonists preferring wider bore crooks, but the results were not statistically conclusive.

The bassoon crook work provided HoL with useful information regarding the geometrical and acoustical properties of both historical and contemporary bassoon crooks. In addition, it provided an interesting topic for DS and other colleagues to investigate through a combination of measurement techniques and psychophysical testing. Perhaps more importantly, though, the work provided a starting point for a long standing collaboration between DS and HoL.

It is also worth noting that other smaller scale collaborations have since arisen, as a direct result of the bassoon crook work with HoL. For example, an investigation into the effect of bending a bassoon crook on its profile and input impedance was carried out with maker

Mathew Dart. Meanwhile, DS recently carried out a series of crook profile measurements with professional bassoonist Damian Brasington who has an interest in making his own bespoke crooks.

2.2 Manufacturing consistency project

The next major DS/HoL collaborative project was concerned with investigating the consistency of musical wind instrument manufacturing. Although the idea for the project came from DS, HoL immediately saw the potential for the research to provide invaluable data regarding their manufacturing processes and to aid their quality control. Moreover, by providing a letter of support committing to provide instruments for testing, HoL once again played an essential role in helping secure the funding for the work.

For the first stage of the project, HoL loaned the Open University Acoustics Group five nominally identical student model oboes to investigate. Under the direction of DS, Adrien Mamou-Mani (AMM) carried out bore profile and input impedance measurements on the instruments. With the help of HoL, he also organized a set of playing tests at the International Double Reed Society conference (held in Birmingham in 2009).

The main findings [5,6] with regard to the student model oboes were that the majority of participants were unable to distinguish between the oboes selected for the playing tests. However, two of the nine oboists that took part were consistently able to distinguish differences between the instruments when playing the note F6, and one player was consistently able to distinguish differences when playing in the lowest register. It was discovered that when the F6 fingering was applied, small but significant differences could be observed in the impedance curves for the instruments (see Figure 2). These variations were shown to be due to differences in the elevation of the C key above the hole. Meanwhile, small variations in bore profile between the instruments were measured (see Figure 3). These were the most likely reason that one player was able to perceive differences between the instruments when playing in the lowest register.

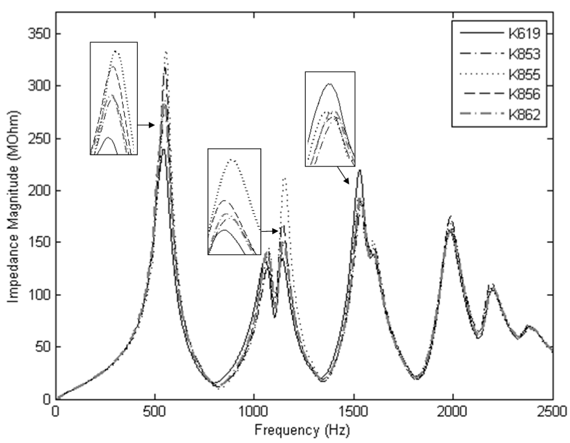

Figure 2: Input impedance magnitude curves for five Howarth student model oboes with F6 fingering applied.

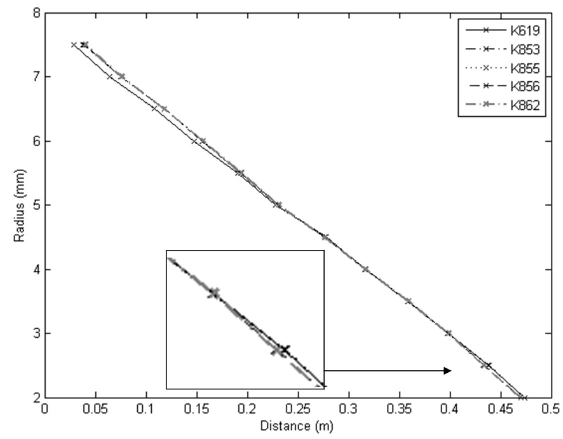

Figure 3: Bore profiles of the bottom and top joints of five Howarth student model oboes.

The information on the variations between the oboes was very useful to HoL. While the differences in the elevation of the C key did not indicate a major issue in terms of manufacturing consistency (as all the keys on the oboe can be easily adjusted by the manufacturer), it was useful to HoL to know that this key in particular was worthy of special attention. Of more interest to HoL though were the tiny variations in bore profile between the instruments. One possible explanation was a gradual build-up of burr on the reamer used to bore out the joints over the course of a manufacturing run. Another possible cause was a variation in the amount of relaxation experienced by the wood of the different joints after the machining had taken place.

Following the work on the student model oboes, attention was turned to a set of HoL professional model oboes with a view to investigating the consistency of their manufacture. Not only did HoL again provide instruments for testing, they also allowed DS and colleagues regular access to a room in their London shop to carry out measurements. Analysis of the data acquired on the professional instruments is still ongoing.

2.3 21st century oboe project

During the course of the manufacturing consistency work, HoL introduced DS and AMM to Chris Redgate (CR), a professional oboist who specializes in exploring the limits of the oboe. CR was working with HoL to develop an oboe with modified keywork to help facilitate the playing of multiphonics, microtones, and notes above the standard playing range of the instrument.

As part of his research, CR had documented numerous fingerings for producing multiphonics on a standard HoL oboe. In conjunction with CR, DS and AMM carried out impedance measurements with these fingerings applied. Analysis of the resultant impedance curves demonstrated why such fingerings enabled the production of multiphonics and also provided information regarding alternative multiphonic fingerings.

In addition, impedance measurements were made on a prototype oboe to investigate potential new register hole positions and sizes. Analysis of the impedance curves, together with CR's observations, gave an indication of the most effective location and size of a new register hole for easing the production of notes higher than the current playing range of the instrument (see Figure 4).

Altogether, the impedance results played a small part in informing the design of the so-called "21st century oboe" (see Figure 5).

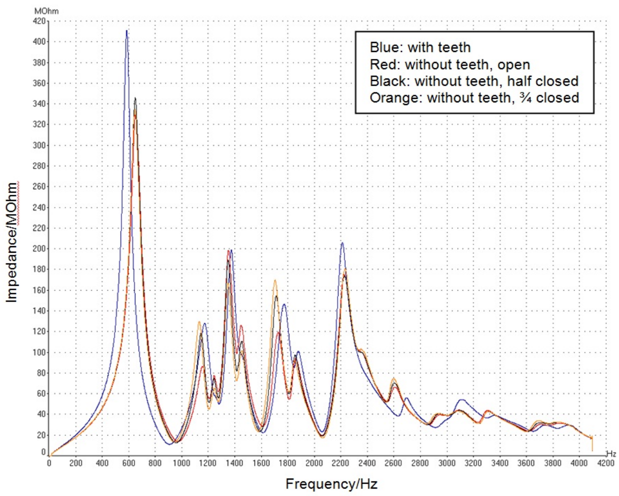

Figure 4: Input impedance magnitude curves for Howarth oboe with standard C7 fingering applied together with different degrees of venting.

Figure 5: 21st century oboe (photograph by kind permission of Howarth of London and Christopher Redgate)

2.4 Additional smaller scale interactions

In addition to the larger projects described in the previous sections, other smaller scale interactions have taken place between DS and HoL over the past decade or so. For example, HoL have previously provided DS with invaluable help in dating and identifying the history of an unknown oboe [7]. Meanwhile, DS has helped HoL with an investigation into the potential for using modern manufacturing technologies in the production of small parts for woodwind instruments. Currently, DS is working with HoL to identify the small physical changes required to optimize certain playing properties of their professional model oboe.

3 Smith-Watkins collaboration

DS has been collaborating with brass instrument makers Smith-Watkins (SW) since the late 1990s. Projects have tended to focus on the development of acoustic pulse reflectometry and the application of the technique to the measurement of brass instruments.

3.1 Acoustic pulse reflectometry project

In early 1999, together with members of the Edinburgh University Acoustics Group, DS visited Dr Richard Smith (RS), the co-founder of SW. The purpose of the visit was to demonstrate the developments to the acoustic pulse reflectometry technique that had made during DS's PhD work, through measurements on various brass instruments. In fact, as well as being an instrument maker, Richard Smith (RS) is also a physicist and was an early pioneer of the application of reflectometry to the measurement of musical wind instrument bores.

Over the next decade, RS made a number of visits both to the Open University and to Edinburgh University, with the main focus being the setting up of a reflectometer for RS to use as a quality control tool. In particular, a dual source tube reflectometer was developed to enable comparative measurements between two instruments to be made.

During this time, RS was extremely supportive of the reflectometry research, providing several letters of support for funding applications, detailing his commitment to loan instruments and to provide input to the research from the maker's perspective.

3.2 Trumpet/cornet leadpipes project

Developing from the more general reflectometry research, came a more specific project which involved measuring differences in the bore profiles of various trumpet and cornet leadpipes. The leadpipe forms the initial part of the instrument bore and has a significant effect on the musical properties of the overall instrument.

The project (carried out by Jim Buick and Jonathan Kemp of the Edinburgh Group together with input from DS) demonstrated that acoustic pulse reflectometry was capable of measuring differences as small as 0.05 mm in radius between leadpipes. Over the selection of different model leadpipes measured, variations of the order of 0.1mm in bore profile were observed (see Figure 6) [8]. Physical differences of this order produce small but noticeable differences in the sound produced by the overall instrument.

The project was useful, both to DS at the Open University and to the researchers in the Edinburgh Group, in helping to determine the overall accuracy of the reflectometry technique, particularly in establishing the limits of its resolution. The work was useful to RS in that it provided complete bore profiles of a selection of SW leadpipes. It also resulted in significant publicity, both for SW and for the Open University and Edinburgh University acoustics research groups, through a series of interviews on national radio and in the press (see Figure 7).

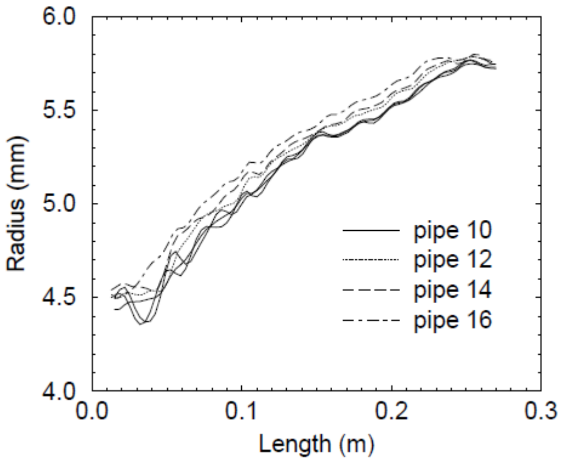

Figure 6: Bore profiles of four trumpet leadpipes in the mandrel I family. Three replicas of pipe 10 are shown.

Figure 7: Articles in Financial Times and Classical Music magazine.

3.3 Additional smaller scale interactions

In addition to the direct collaborations described in the previous sections, RS also provided useful input on a project carried out at the Open University concerned with measuring and investigating the effect of the vibrations induced in the walls of brass instruments during playing.

4 Conclusion

Collaborations between acousticians, makers and musicians help ensure that the research projects have strong links to the requirements of the musical community. The case studies presented in this paper have demonstrated the benefits that can be experienced by all the involved parties.

Of course, not all collaborations flourish in this way. For example, DS started to build up contact with Besson Brass in late 2003 (to the extent that they committed to providing support for a potential research project) only for the company to go out of business a couple of years later. However, it is the experience of the author that such interactions have generally tended to be very fruitful.

Acknowledgments

In addition to the names already mentioned, other researchers/musicians/makers who have been involved in the research discussed in this paper include Murray Campbell, Maarten van Walstijn, Howard Wright, Tom MacGillivray, Emma Gourlay, Jeremy Walsworth, Mike Britton, Rainer Thonnes, Mike Lovatt, Shahram Taherzadeh, Peter Seabrook, James Whitehouse, Aijun Li, Barbara Forbes, Deborah Mairs, Camille Ribot, Thibaut Meurisse, Paulina Kowal and many others besides.

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