MAGMAG

June 2015

A Larrivee guitar, hand-built in Canada

Editorial

Christopher Stanbury, BMus MMus FLCM AIOA

Hello and welcome to the sixth issue of MAG MAG, the newsletter of the Institute of Acoustics' Musical Acoustics Group.

After a hiatus of some months, I'm very glad to say that the MAG MAG is now back 'in tune', with this issue including two very interesting articles from MAG contributors.

This month's technical article has kindly been produced by Wiliam Roberts, summarising an investigation into the resonant properties of the classical guitar. I'm sure you will find it a most interesting read.

This issue also contains a report of a recent MAG visit to Liverpool, specifically the home of one of England's finest organ builders - Henry Willis and Sons.

The MAG organised a number of visits and conferences during the year. For details of our forthcoming events, please see the final page of this newsletter.

Last year was a time of special celebration for the IOA, as it marked the institute's fortieth anniversary.

To mark the occasion, the IOA organised a special Acoustics 2014 conference, which the MAG contributed to. Michael Wright writes a brief overview in this issue and provides the abstracts of the presentations made at the event.

Until next time, I hope this MAG MAG proves interesting and look forward to seeing you at a conference soon!

Important Notice

The **Musical Acoustics Group Annual General Meeting** will be held at 12:30hrs on Thursday 9 July 2015 at Kingston University, Galsworthy Building, Penrhyn Road Campus, Kingston upon Thames, Surrey KT1 2EE.

It is important that all members of the Musical Acoustics Group are aware of the activities of its Management Committee and all members are invited to attend. Musical Acoustics is an important aspect of the Institute and there is a longstanding need to improve its awareness among many acousticians.

Corporate and Non-corporate members of the Institute who would be interested in standing for election on to the Management Committee are welcome to seek nomination at the forthcoming AGM.

Investigating Resonant Properties of an Acoustic Guitar

Wiliam Roberts, Cardiff University

One of the goals of the musical acoustics group at Cardiff University is to find out what type of changes to the construction or design of a guitar leads to perceivable differences in the radiated sound from the instrument. Using this information, we hope that guitar makers will have better control over the sound from their instruments. As part of my PhD work at Cardiff, I went about trying to find perceivable differences in the vibrational and acoustical behaviour of a classical guitar.

The method I used was the following. First, a computer model was written based on equations that describe the vibrational and acoustical properties of a guitar. For the model to produce an accurate synthesis of the sound pressure from a guitar a range of specialist measurements had to be made on a real instrument. Then the model was used in listening tests that measure the smallest perceivable changes to the parameters of the model.

As the reader is probably well aware, the strings of a guitar generate musical vibrations that the listener wants to hear. But the strings do not radiate sound very well and so their vibrations are coupled to a more efficient sound radiator, which comes in the form of the guitar body.

The measurements needed to model the strings are quite basic; these include the mass, length and damping of the strings. Modelling the vibration and radiation of the body of the instrument on the other hand is much more challenging.

Measuring the mechanical response of the guitar body reveals a series of peaks that represent the body's resonances. This measurement is made on the bridge of the instrument because this is where the strings excite the resonances of the body. An impact hammer that has a built-in force transducer is used to supply and measure an input force, and the resulting vibration of the body is measured using a small accelerometer or laser vibrometer. An impact hammer and accelerometer are shown in Figure 1. After converting the acceleration signal from the accelerometer into velocity, we divide the velocity of the body's vibration by the input force to give the desired form of the mechanical response.

Each peak in the mechanical response is modelled mathematically as a damped oscillator and so has three parameters; resonance frequency, amplitude and damping factor. Figure 2 shows how we can adjust these three parameters to change the shape of the modelled response in order to fit the measurements. After fitting each peak, the responses of the damped oscillators are summed together to fit the mechanical response of the guitar's body.

To model the radiated sound from the instrument the guitar's sound pressure response must also be fitted. This measurement is similar to the mechanical response but instead of measuring the vibration of the body we measure the sound pressure using a microphone. The sound pressure was modelled by allowing each resonance to radiate as a monopole and dipole sources, (see video for more information).

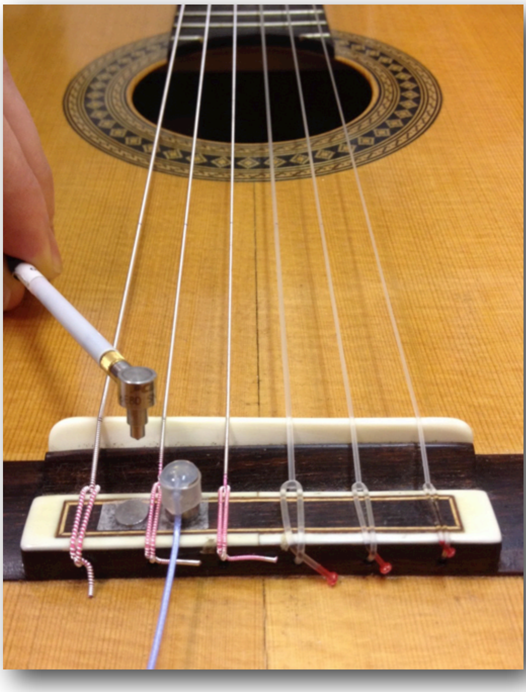


Figure 1: To measure the mechanical response of the guitar body a small steel disk and accelerometer are attached to the bridge using double sided tape. The steel disk provides a good contact between the impact hammer (shown in the picture) and the bridge, as well as protecting the wood from the hammer tip.

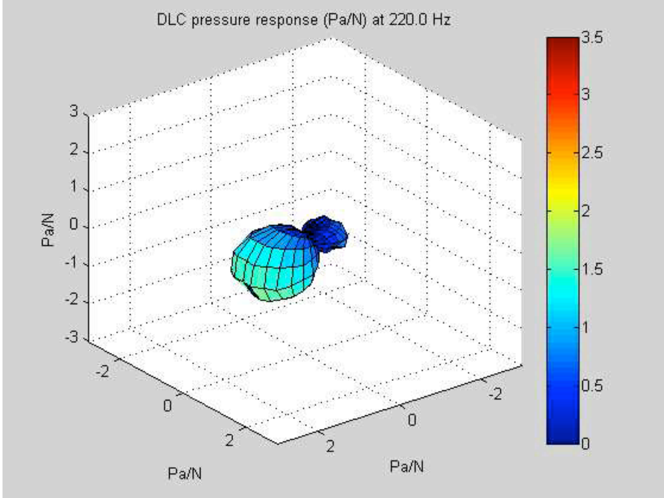
It is essential to model the low-frequency region (below about 500 Hz) of the mechanical and pressure responses of the guitar body accurately. Above this range a cruder approach was implemented using randomly chosen numbers from specific distributions for the model parameters. This method was used to model the radiated sound from a guitar pluck up to 5 kHz.

To measure the smallest perceivable differences in the guitar model we needed to carry out some listening tests. The most popular type of listening test for this job is an adaptive test. An example of such a test is one where the listener is presented with a series of trials, and in each trial the listener hears three stimuli; two are the same and one is different due to a change in a parameter of the model. The task of the listener is to identify the 'odd one out'.

At the start of the test the task is straightforward and the difference is obvious, but as the listener correctly identifies the 'odd one out' the difference gets smaller and the task becomes more difficult. If the listener answers incorrectly the task becomes easier. This process is repeated for about 5-10 minutes as the test homes in on the smallest difference that the listener can hear.

The results from one set of listening tests showed that we are about three times more sensitive to changes to the resonances of the guitar body in the range 0-400 Hz than in the range 400-5000 Hz. Another set of tests showed that monopole radiation is about six times more influential over the total radiated sound from a classical guitar than dipole radiation.

Through this research a clearer picture of our sensitivity to the various parameters of the model is beginning to emerge. This will hopefully be useful to instrument makers by directing their focus and priorities towards controlling those parameters to which our ears are most sensitive.



This video shows the sound pressure-field of guitar 'DLC' from 220 Hz at the start of the clip to 240 Hz at the end. At 220 Hz this guitar radiates sound predominantly as a dipole sound source, but the radiation pattern soon morphs into a monopole shape and reaches a maximum sound pressure at around 230 Hz. Special thanks to Ian Perry for the video.

Video available here: https://youtu.be/I0XObjH6OL0

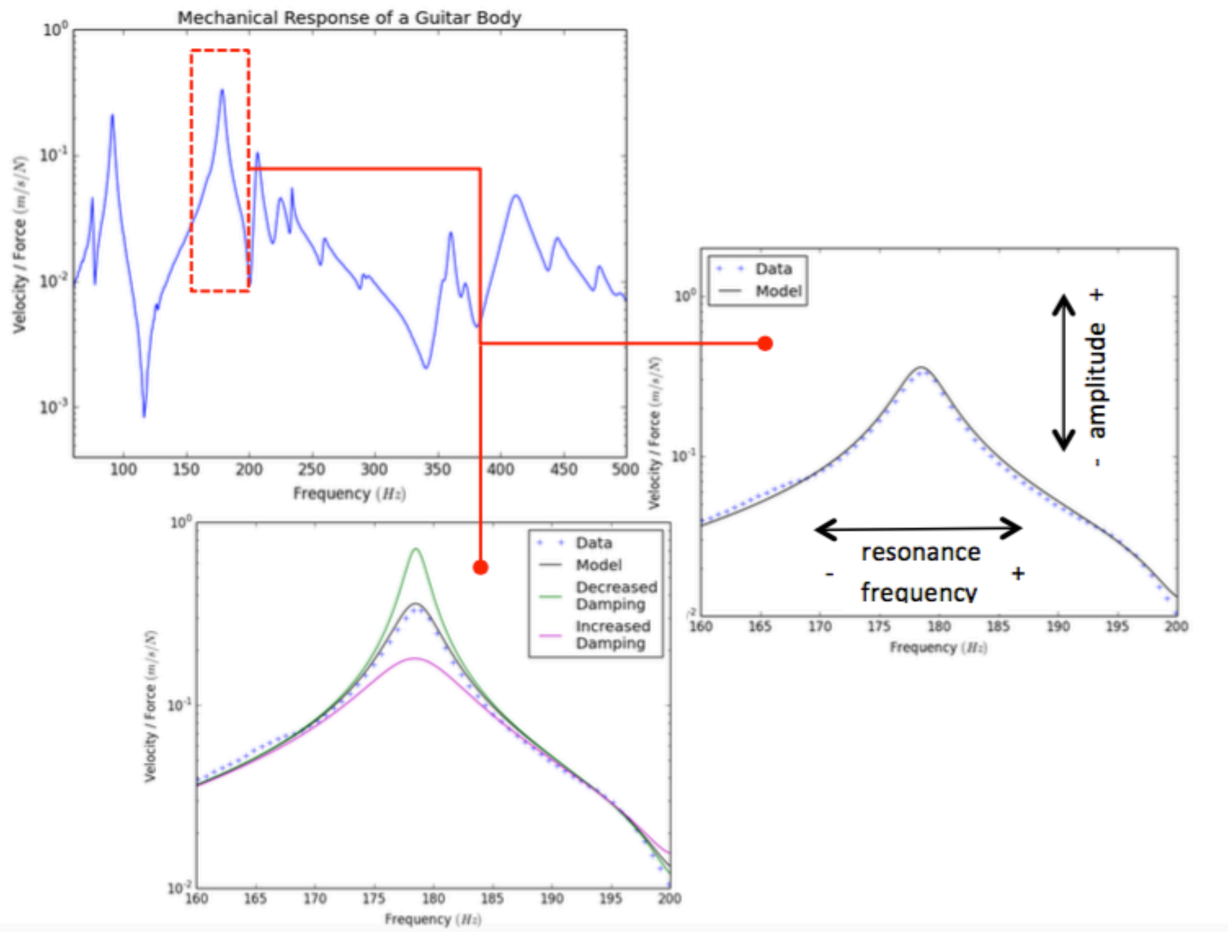


Figure 2 - This diagram demonstrates how the three parameters are adjusted to fit a single peak in the measured mechanical response of the guitar body. The resonance frequency shifts the peak left or right, the amplitude moves the peak up or down and the damping changes the shape of the peak by making it sharper of flatter.

MAG Event Report: visit to Henry Willis, Organ Builders

25 February 2015 - Dr Edgar Brown

Around 20 members of the Musical Acoustics Group visited the Liverpool workshops of the renowned organ builders Henry Willis & Sons Ltd. This old-established firm was founded in the 19th century by Henry - "Father" - Willis who rose to fame by his organ built for the 1851 Exhibition at the Crystal Palace. The firm, renowned for the tonal excellence and workmanship of its instruments, built organs for many cathedrals and churches - including St Paul's in London and the Anglican Cathedral in Liverpool. It also built many concert organs, notably Alexandra Palace (London) and St George's Hall (Liverpool). After being headed by four generations of the Willis family - all "Henrys" - the firm's managing director is now Mr David Wyld. After a move from premises at Petersfield in Hampshire, the factory is now located in Liverpool.

David Wyld with demonstration pipe

Mr Wyld welcomed us all and led us on a tour of the workshops. First of all, we were introduced to the traditional crafts of pipe-making. The organ is a conglomeration of hundreds - or thousands - of separate musical instruments; its pipes. Each pipe is designed and made by the builder to produce a musical note of a certain *pitch, loudness* and *tone quality* entirely unique to itself. The majority of pipes in most organs are *Flue* Pipes; they operate on the same principle as the recorder, except lacking the side finger holes. Moreover, most are made of *"Metal"*. This metal is an alloy of lead and tin in various proportions with a small admixture of other metals. The alloy must have the necessary mechanical strength that the pipes made from it don't collapse under their own weight; also it must be soft enough to be cut with a sharp knife in "voicing" operations. David Wyld dispelled some of the mystique surrounding the production of the metal sheets for pipe-making!

We then saw the casting bench; a long horizontal apparatus of cast-iron with a narrow open-topped box at one end. This box could be filled with molten metal and then moved dexterously along the bench allowing the metal to escape from a carefully adjusted slot at the rear of the box. A sheet of metal would be deposited on the cloth-covered surface of the cast iron and allowed to cool. At least, that was the theory! "It's not as simple as that!" We were told that temperature and several other factors were critical in making a good "cast" (they'd even got an electronic thermometer - how un-sixteenth century!) David told us that several spoilt sheets were the usual preamble for getting a production run of good ones (throw the spoilt ones back in the melting pot) and enough would be produced at a single cast to cover future expected needs. Practical point in using this medieval piece of kit: boots must be protected against spillage! Get molten metal through the lace-holes and you're in A& E!

We now moved to a larger workshop where the number of benches indicated the degree of activity in pipe-making which took place in a normal working day. David showed us the set of metal pieces cut from the flat metal sheet according to the pattern for a particular pipe. There was the *foot*, about to be rolled into a cone; the *languid*, a circular plate, the same diameter as the pipe, but with a piece cut away forming a chord of the circle - this corresponded to the "block" in a recorder. In assembling the pipe, the languid was first to be soldered to the foot. Finally the *body*, the cylindrical (or sometimes inwardly tapered) part of the pipe would be soldered-on above the foot. The top of the foot and the bottom of the body would be pressed inwards to conform to the straight part of the languid. These would form the *lips* of the pipe. The *mouth* would be cut into the upper lip - its critical dimensions to be determined in the *voicing* operation; the narrow gap left between the lower lip and the edge of the languid, forming the *wind way*, - another critical dimension would be adjusted later. David showed us a complete pipe -"one that he'd made earlier"- to demonstrate the tonal effects of various adjustments, easily made with a sharp knife on the soft metal. Blowing the pipe gave a characteristic "organ-like"(Diapason) tone of pitch around middle-C. A significant dimension in achieving this tone-quality was the ratio of pipe diameter to "speaking length" (distance form languid to outer open end) , or *scale.* A smaller scale would have produced a more "stringy" tone; a larger scale a more "fluty" one. Now for adjustments. Cutting a short narrow slot near the open end of the pipe "hardened" the tone. Fitting a short tinplate extension, sprung onto the end of the body provided a length adjustment for tuning as well as modifying the effect of a slot. Increasing the height of the mouth made the tone more fluty. Cutting the body shorter, while, of course, raising the pitch also made the tone more fluty by virtue of increasing the scale. Controlling the "starting-up" noises at the beginning of a note were effected by *nicking* - cutting an evenly-spaced series of small v-shaped notches in the edge of the languid and also possibly the inner surface of the lower lip. (What happened to our grossly mutilated exhibit pipe? Into the melting pot! Nothing's wasted!) Looking back at some acoustic theory, we would recognise the tonal effects as variations in the admixture of harmonic overtones present in addition to the "fundamental" - or "keyboard-name"of the note.

We were also shown a selection of wooden pipes, mostly of rectangular cross-section, although triangular ones were once a Willis speciality. Their acoustical action is identical with that of metal pipes, except that all air passages must have smooth walls. Failure to ensure this will result in a rough tone - as anyone who has tried to make wooden pipes will testify! Next we saw a Reed Pipe, in which the sound-producing agent was a vibrating brass tongue *(reed)* beating against a slot in the tube *("shallot")* forming the base of the pipe. The reed and shallot were enclosed in an air chamber *(boot)* through which the pipe was blown. All this was similar to a clarinet mouthpiece in the player's mouth. The rest of the pipe consisted of a resonator of suitable form to control the tone. Pipes such as this could constitute the Trumpet stop. As well as the choice of shape of the shallot opening, the critical adjustment of the curve of the reed is vital. Reed voicing is a "black art" quite separate from the voicing of flue pipes.

Now we moved to a workshop where organs began to take shape. Here was a complete soundboard of the traditional

Organ from Stichting Cathedral

"Bar and Slider" form. The pipes were to stand on the soundboard, under which was a series of wooden bars, running from front to back. The space between each pair of bars formed an air channel connected to a key on the player's keyboard. Pressing a key opened a valve *("pallet")* admitting the air *("wind")*. All the pipes for each note on the keyboard were arranged behind each other over their particular air channel. This also ensured that a set of pipes *("rank")*of the same tonal quality for all the notes on the keyboard was brought into a broadside arrangement. The sounding of each rank was controlled by a long valve *("slider"*or *"slide")* interposed between the air channels and the pipe feet. The slider contained holes corresponding to the pipe feet. Pulling the slider in one direction would allow air to enter those pipes for which the keys were pressed down; pushing it the other way would blank off all the pipes of that rank. The position of the slider is determined by the relevant "stop" operated by the organist. (Historically the "stop" was a means of stopping off parts of the brutally noisy organs of the time! Nowadays "stop" is considered generally synonymous with "rank of pipes")

Closely adjacent was a large airy workshop which contained a COMPLETE ORGAN! This was a large three-manual instrument - an original Willis - from Stichting Cathedral, Leiden, The Netherlands. This impressive organ had returned to its "birthplace" for renovation and some enlargement.

Retracing our steps, we saw another complete organ - well separated from its console on the other side of the workshop. This instrument had originally been built by the firm of Hunter - long since amalgamated with Willis. The organ was equipped with electric action, key and stop contacts at the console activating electro-magnetic valves at the organ. For many such organs, the connection would have involved a multi-core cable, containing probably several hundred wires. For a number of years, "time-division-multiplexing" has been possible in which signals from the entire console can be repeatedly sent in rapid sequence along a *single-core* cable. In the present case, even the single cable had been supplanted by *wi-fi* . David's colleague played the organ "radio-controlled" from across the workshop, also demonstrating such electronic tricks as transposition at the touch of a switch and entire control of the instrument from an i-phone! Yes; the real pipe-organ can be just as versatile as the electronic one!

We had all taken part in an extremely informative and enjoyable visit and thanked David Wyld most cordially for his hospitality. May the firm of Henry Willis and Sons continue to flourish under his expert direction!

What is MAG?

The Musical Acoustics Group (MAG) is a special interest group of the UK Institute of Acoustics.

The MAG has a very important part to play in the understanding and research of many aspects of acoustics.

The mission of the MAG is as follows:

- To encourage closer working with professionals in related disciplines such as architects, musical instrument designers and builders, sound engineers, performing musicians and composers, musical education, music in health and wellbeing.
- To be a forum for members and other professionals with an interest in all aspects of musical acoustics.
- To promote a wider understanding of musical acoustics to academics, professionals in all related fields and increase public awareness.
- To hold regular meetings (with access available to related professional disciplines) for the interchange of information and experiences.

Further information from the chairman, Michael Wright: michaelwright946@btinternet.com

MAG Event Report: IOA 40, NEC Birmingham

Michael Wright

The IOA 40 conference at the NEC Birmingham was well attended. The appearance of Leo Beranek who gave his Keynote Lecture: 'Concert hall design: new findings' was most welcome. Although he passed his 100th birthday last month, he delivered his lecture with great presence. Very few, if any acousticians can claim a career of over 75 years and I have a feeling that his appearance and most interesting findings so clearly presented in an entertaining way will help to ignite further interest in the essential relationship between musical and building acoustics in the design of concert halls. He discussed his expectations of the new Philharmonie de Paris (due to be completed in January 2015). Like the pioneer Berlin, Philharmonie Hall from 1963, is a 'surround hall'.

The Paris hall will have 2,400 seats, almost 200 more than the Berlin Hall! An architect's impression is is shown above. .

Here is his abstract:

The listeners' choices of ten top concert halls based on on-line and interview surveys are presented. The acoustical characteristics of six of the top quality halls are shown. Recent studies are reviewed of (1) the preferences of listeners' for different sound fields; (2) how the clarity of sound varies with positions in a hall; and (3) how musical dynamics are enhanced by hall shape. The growth of sound in a concert hall is analyzed with emphasis on hearing the direct sound clearly. The desirability of early lateral reflections and their dependence on hall shape is stressed. The strength (loudness) of the orchestral sound with emphasis on the degree of seat upholstering and the cubic volume are presented Finally, maximum and minimum dimensions and seating capacities for shoebox-shaped, surround-shaped, and fan-shaped concert halls are proposed.

Why do brass instruments sound brassy?
D M Campbell, University of Edinburgh

Musical wind instruments of the brass family share certain common timbral characteristics which distinguish them from other types of wind instrument. Despite the name commonly given to this family, the timbral behaviour of a brass instrument is not primarily determined by the material of construction of the duct wall, but by nonlinear aspects of the behaviour of the sound generating source and the resonating air column. This talk reviews recent developments in the understanding of these processes and their musical significance.

Developing and evaluating a hybrid wind instrument excited by a loudspeaker - K Buys, D Sharp and R Laney, The Open University

A hybrid wind instrument generates self-sustained sounds via a real-time interaction between a computed physical model of an embouchure and a real acoustic resonator. This concept remains poorly investigated due to the technical demands on the actuator that supplies the calculated mouthpiece signal. A newly proposed prototype has been realized, using a loudspeaker as actuator. We evaluate the resulting self-sustained sounds by mapping their sound descriptors to the input parameters of the physical model of the embouchure. Results are compared with simulations. The largely coherent functioning confirms the usefulness of the device in both musical and research contexts.

A Zhang & J Woodhouse, University of Cambridge

This paper presents an experimental investigation of the motion of a cello bridge in the low- to mid-frequency range, in order to explore variations in the body response to bowing on the four separate strings. Transfer admittance measurements were carried out on one tested cello fitted with a Belgian design bridge. Five points around the bridge plus four points on the top near the bridge feet were excited with an instrumented hammer while the response acceleration was collected at the C string corner of the bridge. The motion of these points at any given frequency can be processed to show the best-fitted rigid-body motion of the bridge, which can be expressed as rotation around an instantaneous centre. This motion centre tends to move from the sound-post bridge foot at low frequencies, then to move towards the bass-bar foot at higher frequencies, and to move back and forth between the two feet of the bridge.

R K Seaton, D Sharp & D N Pim, The Open University

Email: richard.seaton@open.ac.uk – Richard Seaton presented

This paper describes work carried out during the first eighteen months' part-time research towards the award of a PhD from The Open University. The project is researching reasons, other than the music itself, that choirs performing Western music a cappella are not able always to maintain pitch. This paper presents the initial results from a recent survey of choral practitioners. There were two main objectives: firstly, to obtain experiences of pitch drift, whether it happens and if so how it affects the overall performance; secondly, to seek opinions as to the causes and remedies used to overcome the problem. The findings of the survey will be discussed along with ideas for future work, which will be undertaken with selected choirs over an extended period.

O F Woods, Consultant

Email: owen@melodeonmusic.com Owen Woods will be presenting

In this paper I illustrate some of the problems that occur when trying to use Acoustics and Vibration to further the study musical instruments, but also some of the unique insights that it can give. The objectives of Musicians, Luthiers, Organologists and Acousticians in studying musical instruments are very different and this can give rise to misunderstandings. Luthiers are concerned with the subtlest of changes and take the overall sound generation mechanism for granted. This means that they sometimes miss potentially disruptive innovations. Acousticians tend to look at the big picture before the fine detail and sometimes overlook key and characteristic features. Musicians have another perspective, heavily influenced by their perception not only of how an instrument sounds but how it should sound. Organologists and Ethnomusicologists are interested in the circumstances behind an instrument's production, the history of the instrument, what it meant to the people of the time and so on. Analysing the musical sound of an instrument is valuable and relevant, but it is also highly subjective. It is very difficult to isolate differences in construction and to link them to differences in sound. Investigating the history and social circumstances behind an instrument is also important, but it is difficult to link to the design of the instrument itself. An acoustic analysis is a way of connecting all of these facets of study. I have conducted such an analysis on the Bolivian Charango, a small plucked stringed instrument from the Andes region of Bolivia and Peru. I used *the results of the acoustic analysis to explain the construction by linking the musical sound to the Ethnomusicology; something that would not have been possible without this data. It is a good example of the contribution that Acoustics and Vibration can make to Organology.*

Interactive performance for musicians with hearing impairments using the vibrotactile mode

C. Hopkins, J. Ginsborg#, S. Mate-Cid*, R. Fulford#, G. Seiffert* * Acoustics Research Unit, University of Liverpool,*
 # Royal Northern College of Music

This paper reviews recent research by the authors on the potential for using vibrotactile feedback to facilitate interactive musical performance for deaf musicians. Limits have been established for perceiving musical notes via vibration on the fingertips and feet. This has defined the usable dynamic range and a pitch range that can reliably be perceived. Perception and learning of basic relative pitch was investigated with normal and hearing impaired participants. This indicated a high success rate with and without training which implies that everyone has a basic ability to perceive relative pitch although it is difficult to distinguish intervals smaller than three semitones. With training it has been shown to be possible to achieve significant improvements in the assessment of relative pitch. To promote the research aims of social inclusion and to challenge public perceptions of what is possible with a hearing impairment; public engagement activities have taken place with the deaf community along with a video showing musicians performing using vibrotactile feedback.

The inner part of a guitar frame is meticulously sanded to remove any surface imperfections, despite the fact that the final result will be hidden when the guitar is fully constructed.

Picture on the cover..

The picture on the front cover of this edition of the MAG MAG is of an acoustic guitar built by the Larrivee company of Canada. A family-based firm of artisans, Larrivee guitars are constructed by hand using a process established fifty years ago. http://www.larrivee.com/features/acousticBuildTour.php

FORTHCOMING MAG EVENTS...

2015

9th July *MAG / IOA, Kingston University, Penrhyn Campus, The John Galsworthy Building, Penrhyn Road, Kingston upon Thames, Surrey KT1 2EE*

Hearing Impairment and the Enjoyment and Performance of Music
This meeting is open to all, and is expected to be of interest to members of the Institute of Acoustics, including those working in audiology, music therapy and charities for the hearing-impaired.

Further details from the IOA website conference page.

27-30th September *MAG/Galpin Society Joint Conference, Cambridge*.

Musical Instruments in History and Science
A 3.5-day joint conference which will be held at the University of Cambridge Music Department, West Road Site. This event promises to be very interesting and thanks are due to Owen Woods of the MAG for acting as lead organiser. Further details regarding this event can be found at: http://gsconference2015.wordpress.com .

Last Word..

Lastly, I would warmly welcome any submissions from interested parties or members to be used in the next issue of our newsletter. The subject matter can be entirely up to you, the more diverse the better! Don't forget that, as this publication is published electronically, it is an ideal opportunity to link technical articles with sound recordings, video demonstrations etc and it is my intention to gradually build the MAG MAG's technical content over the next few months.

Please email any articles for publication to christopher.stanbury@btopenworld.com.

Closing date for submissions:
30th August 2015