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Forward

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Table of Contents

Chapter 8: Resumé

CHAPTER 1: INTRODUCTION

Of all parts of the violin, which one is the most important for the instrument's tone and playability? Though it is impossible to isolate one element from the complicated resonating system of the violin as "most important", the bridge is worthy of consideration. It seems unlikely that a virtuoso violinist would cut through the legs of his instrument's bridge in order to improve his instrument's playing performance, yet that is exactly what 60-80 percent of American bassists do by installing bridge height adjusters on their instruments.

The idea for this project arose when I brought my newly acquired bass, complete with adjusters, back to Vienna from the U.S. An Austrian colleague of mine, seeing such exotic equipment for the first time, asked if they have a negative effect on the sound, and this was a question I could not answer, especially since I had not known the instrument without adjusters. Other questions sprung up, and I became interested in whether they actually *do* make a difference, and if so, what that difference is. What influence the various materials of available adjusters may have on the sound, and why bridge height adjusters are so prevalent elsewhere but not in Vienna?

With the help of a questionnaire sent by e-mail, I was able to contact bassists around the world for their opinions and knowledge on the subject. Their answers indicated that knowledge on bridge height adjusters has up until now been based primarily on trial-and-error and hearsay. The responses provided enough information to define some goals for the new scientific research this project represents.

The following chapter presents an introduction to the topic of double bass bridge height adjusters with an overview of the bridge, the special string height problems of the double bass, and the types of bridge height adjusters currently in use. A detailed analysis of the e-mail survey responses gives an impression of use and knowledge of bridge height adjusters today, and helps to explain why adjusters are most commonly found in North America.

Chapter 3 introduces methods used in this research and the tools used to execute them, including the anechoic chamber, electronic equipment, and software for analyzing recorded sound samples. The special problems of the recording process were solved in interesting ways and are also documented.

Chapter 4 elucidates the specific tests on the tonal effects caused by bridge height adjusters which answer the following questions:

1. Do bridge height adjusters affect the sound of the double bass compared to a bridge with solid feet?
2. If so, how?
3. Are there acoustical differences to be heard between various adjuster models?
4. Do bridge height adjusters affect the pizzicato characteristics of the bass, and if so in what way?

These questions were answered with the help of overtone spectrum analysis, sound intensity statistics, and a listening test survey.

Chapter 5 summarizes the conclusions based on the tests and suggestions for further study on this topic.

Chapter 6 contains the bibliography, literature references, and the listing of bassists who participated in the e-mail survey, and the following Addenda in Chapter 7 contains documentation of the tests, as well as a few other things.

CHAPTER 2: ON THE BRIDGE, DOUBLE BASS AND STRING HEIGHT

2.1 The Bridge

The bridge is a general term for the part of an instrument upon which strings rest and through which vibrations are transmitted to the soundboard and resonating body of the instrument. Bridges are found on violins, viols, fretted instruments, and even within the pianoforte.

History

Woodfield[1] writes that a kind of bridge on stringed instruments as early as 2,500 BC in ancient Egypt. Theories on the origin of the modern violin lead back to the *rebec* or *rebab*, single-stringed instruments that found their way to Europe from Arabia by the Middle Ages. The development of the *vihuela da mano*, a Spanish instrument with several strings, is important in considering the history of the violin bridge. Like a guitar, the early vihuela had a flat bridge and was plucked. Iconographic evidence suggests this instrument was bowed also, in which case it must be assumed that only homophonic chords were playable. As time progressed and musical composition techniques of the 13th and 14th centuries developed, the need for an instrument capable of bowing melodies arose. This need, combined with the vihuela's arrival in renaissance Italy, gave rise to a new instrument, the viol.

Unlike its predecessor, the viol featured a high, rounded bridge which enabled single strings to be bowed. The viol achieved a great amount of success and was played throughout Europe by the time the violin came into use in the 16th century.

A new instrument, the structure of the violin was distinguished by its typical external characteristics: a rounded back, "violin corners" at the c-bouts, "f"-shaped soundholes, and by a new type of bridge and its position near the center of the table between the soundholes. The bridge itself has since undergone changes to meet the demands of new tonal tastes.

Construction

The construction of the bridge depends on the instrument in question. The bridge of a piano is made of hardwood and connects the vibrating strings supported by a metal frame to the softwood soundboard. A guitar's bridge is flat and anchors the strings at a fixed point on the table of the instrument. Unlike the previous instruments, the bridge of the violin family is held in place solely by the tension and downward pressure of the strings, with the strings anchored by the tailpiece. The fact that the violin bridge is removable without altering or damaging the instrument's substance creates an interesting situation, namely the possibility to make reversible changes to an instrument's tone by altering the bridge. Through the years, standards of bridge construction evolved to their present form.

Material

Bridges of modern violin family instruments are carved from blanks sawn or split from a maple log. There are various criteria for judging the quality of maple for bridges, but density and hardness are among the most sought after factors. Slow growing Bosnian

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[1] Woodfield, "The Early History of the Viol", Chapter 1

Maple from a tree up to 100 years old could be considered the ideal origin of fine bridge wood. The wood's color, as well as the striations (Markstreifen) perpendicular to the yearly rings, are signs to judge wood quality. Maple must be properly seasoned for a number of years before being used, though stock which is aged too long may be brittle and too hard to work[2]. Commercially available bridge blanks are most often sawn from the log to reduce waste of the precious raw material, though split blanks are preferred[3]. Splitting follows the natural structure of the wood and results in a straighter, stronger bridge which also reportedly sounds better.

Shape

Fig. 1 Illustrated are some of the various profiles of modern maple bridges: Violoncello, ¾ violin, violin (uncut blanks) and double bass (five string).

Function

With instruments of the violin family, the bridge is found near the center of the sounding plate between the "f" holes, and is held in place solely by the tension and downward pressure of the strings. The bridge serves many structural and acoustical functions simultaneously.

The bridge supports the strings. Its upper contour is shaped specially to fit the fingerboard and body of a specific instrument, and the shape must accommodate comfortable bowing on all four (or five, on some basses) strings with maximum clearance of the corpus. A precisely fitted bridge is cut to exactly match the surface of the table under the feet, providing a stable resting place for the pressure of the strings and a good contact for the transmission of vibrations.

The acoustic function of the bridge is still under study. The relationship of the bridge to the soundpost and bassbar inside the instrument has an essential effect on the acoustical qualities of the instrument. The asymmetrical configuration of the violin's bridge, bassbar and soundpost was invented and refined in sixteenth century Italy, where luthiers intuitively and through trial and error made acoustical and technical advances that have yet to be fully understood[4]. Energy (vibrations) applied to the bridge through the strings is transferred through the legs and feet into the instrument. The table, bass

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[2] The Strad, Nov. 1979, Aubert Bridges

[3] Weisshaar and Shipman, Violin Restoration

[4] Carleen Maley Hutchins, Research Papers in Acoustics (1993), pp.3

bar and soundpost, and consequently the back and remaining body of the instrument vibrate, and these vibrations, together with the vibrations of the resonating chamber, are radiated through the air into the surrounding space.

The violin bridge has been the subject of extensive scientific study since the late 19th century. The experimenter Giltay (1916) describes the first studies specifically on the bridge, starting with Apian-Bennewitz (1892) in his book, Bow Instruments, Their Form and Construction. Stroboscopic photographs (Minnaert and Vlam, 1937) and more recent computerized studies reveal that the bridge has several modes of vibration in different planes, depending on to the frequency being played, including horizontal rocking, vertical fluctuation, other resonances at higher frequencies (see H.A. Müller: The Function of the Violin Bridge, 1979).[5]

Research has also shown that the bridge not only functions as a transmitter of vibrations, but also as a sound filter which can be manipulated by trimming to enhance desired frequencies and reduce undesirable ones in the violin's overtone palette. With skill a master luthier can trim a raw bridge to achieve the desired acoustical qualities suited to the individual violin and its player[6].

While violins, cellos and violas have been the subject of numerous important acoustical studies, scientific writing on the double bass is difficult to find. While it may be assumed that many of the principles learned about violins apply generally to all violin instruments, the double bass surely has special characteristics worth researching. Perhaps it is the instrument's subservient role in traditional repertoire has limited general interest its acoustical character. Like the viola, the dimensions and model types of the double bass are not standardized like those of the violin, which makes the acoustical qualities of each individual instrument harder to generalize. Flat-back, round-back, D-neck , Eb-neck, mensur variance of more than ten centimeters, rib depth, etc. are all structural dimension variables which make it difficult to research and define universal characteristics of the double bass. It is also clear that experimenting with basses is physically more difficult than with its smaller cousins. The instrument's dimensions and frequency range often require different equipment than for violins and violas, where a cello may just fit. Working with basses in any form simply requires more space and muscle power, added inconveniences that makes working with violins much more attractive.

2.2..The Need for Bridge Height Adjustment

Stringed instruments need periodic string height adjustment, when the fingerboard is dressed, when buzzing occurs, or when the strings are or uncomfortable to play, for example. This adjustment most often means having a new bridge fitted, especially in cases where the height is too low. It is also possible to raise to the string by gluing parchment onto the bridge under it, but this is obviously effective only within a very small range. Still these changes are needed relatively seldom since they are proportional to the slow wearing of the fingerboard, seldom major renovations to an instrument an instrument, and other relatively rare occurences. Climatic conditions change seasonally, daily, and during the day, and these changes play a relatively small role in the amount the string height fluctuates with violins and violas. The volume of wood in double

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[5] Carleen Maley Hutchins, Research Papers in Acoustics (1993), pp.3

[6] Rogers, O.E. and Masino, T.R. (1992)

basses exposed to climatic change leads to a more drastic fluctuation in string height. The following comments on bass string adjustment are a summation of information from instrument makers and bassists who responded to an internet survey, and common traditional knowledge among bassists[7].

2.3..Double bass string height adjustment

Double bass string height is dramatically affected from season to season, especially in North America. The large dimensions of the instrument result in a proportional fluctuation that is enormous compared with violins, violas and even violoncellos. It is traditionally recognized that swelling and shrinking of the softwood table due to changing moisture content influences string height. Recent information shows that the heel of the neck is also affected by humidity and causes the angle of the neck to fluctuate[8]. Travelling to auditions or being on tour in regions where conditions can widely vary make playing difficult; strings become either too high or low for ideal playability. Respondents to the e-mail survey answering from Canada to Texas claim that some possibility of changing string height is absolutely necessary to maintain the playability of their instruments throughout the year.

Bass players also need to adjust to various styles quickly. Classical repertoire includes orchestral, solo and chamber music, all of which may require different string height. The “set-up” for orchestral playing is oriented towards power and response, with high string action and tension, while chamber bassists may prefer a warmer, blending tone with somewhat lower tension and action. Solo playing demands a brilliant sound with high tension but low action for technical passages in thumb position. Many players frequently switch between styles using the same instrument.

The double bass also lends itself to styles outside the Classical realm such as jazz and popular music. Jazz playing is dominated by pizzicato style, most often amplified, where acoustical volume and “bowability” of the instrument are secondary to sustain and the “twangy” sound of extremely low string action. Bassists increasingly find themselves playing in a variety of styles, as western art music of the last four centuries blends with contemporary popular and multi-cultural forms. It is not unusual for a bassist to have symphonic rehearsals during the day only to play a “gig” at a hotel or the local jazz club the same evening in a different style, and often a single instrument must meet the demands of these diverse styles.

There are several other uses for string height adjustment in playing double bass. For example, a player can try a variety of heights to find which one works the best before deciding on a “permanent” set-up for a particular instrument. Alteration to the angle of the strings allows the player to experiment with string tension and downward pressure on the table, which is recognized to have a great influence on the sound[9]. One bassist suggests that bridge adjusting machines may even improve the overall tone of some instruments by “loosening up the sound”[10]. Another respondent has lowered string action to relieve left hand stress during a heavy work schedule. Finally, it is beneficial

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[7] See “Internet Survey” below for details

[8] Micheal Kosman** March, 1998 (**denotes telephone conversation)

[9] Hans Sturm*4 Feb. 98

[10] William Vaughn,** 15 March 98

for players and teachers to easily adjust string height on school instruments, since these basses are serviced less regularly by luthiers and are played by a variety of pupils[11].

2.4 Methods of string height adjustment

The traditional solution to climate-related string height fluctuation is to have two or more bridges cut appropriately for each season. Famed soloist Gary Karr may be the best known proponent of this method. The second bridge must be accompanied by a matching soundpost which is also fitted to the changing distance between the table and the back of the instrument, and insertion of the soundpost should be performed by a qualified luthier. Players performing this operation themselves risk damaging table if they install an ill-fitted post. Aside from the inconvenience and expense of semi-annual trips to the violin maker's shop, it is questionable whether a sensitive instrument will respond equally well during all periods of transition. Still, many respondents to the e-mail questionnaire agreed that there is no substitute for a well-fitting bridge with solid legs for tone quality, regardless of inconvenience and expense.

Respondents also mentioned another way of increasing or decreasing the height of the double bass bridge: to place splints of wood, or bridge jacks, between the bridge feet and table. It has been suggested that softwood is superior to maple because of "flexibility". This method would seem an inexpensive alternative to having one or more bridges cut for the instrument But seen from the violin maker's perspective, bridge jacks represent an unprofessional solution to the problem of bridge height adjustment because if they are made to fit, they cost as much time as making a new bridge!

Several references to a Canadian bass maker's new bass neck[12] adjuster remind one of machines found in violoncellos and basses of the 18th and 19th centuries. It is found in the neck joint and uses a key inserted in the heel of the neck to raise and lower the fingerboard relative to the strings without altering their pitch. The author has seen a Stadlmann cello dated 1776 with its original screw adjuster assembly still functional, and these machines were apparently standard equipment on cellos and basses in Vienna at that time. Giovanni Bottesini reportedly possessed an instrument with a removable neck to ease transportation difficulties, and a bass with such a mechanism allows temporary disassembly since the neck is not glued in place. The modern version locates the adjuster at the upper block, which is „structurally important, but not vital to vibrations" instead of at the bridge, "the most 'live' place for vibrations", [13] and theoretically preserves the true vibration transfer into the table of the bass. This design reportedly has the blessing of outspoken bridge- adjuster opponent Gary Karr, who is against interrupting sensitive solid bridge feet with adjusting machines. Critics of this design find it „amazingly complicated" and structurally unsound. Furthermore, the experience of one luthier has shown that the improvement in sound created by a solid neck joint "far exceeds any loss of sound quality that might be the result of the comparatively innocuous bridge height adjuster".[14] Though a system for varying the fingerboard's angle seems interesting, the most commonly used method of string action adjustment is found on the bridge itself.

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[11] Henry Boehm, 10 Feb 98

[12] Jim Hamm

[13] Greg Sheldon*, 9 Feb. 1998 (*denotes e-mail response)

[14] Henry Boehm, 10 Feb.1998*

2.5..The Wheel-and-Axle Bridge Height Adjuster

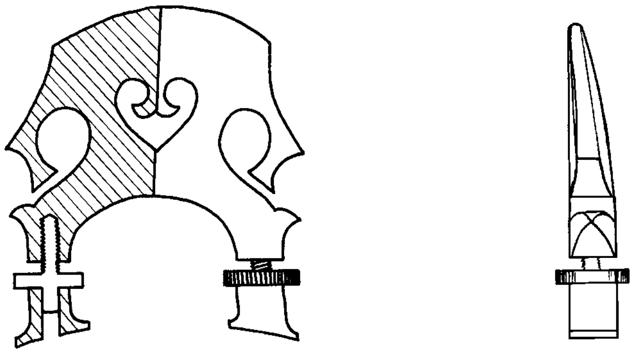

Fig. 2 Technical frontal and side view of bass bridge fitted with bridge height adjusters, with cutaway of bridge foot at left.

The string height adjusters discussed in this paper are constructed of metal, plastic, or wood and have a shaft fixed through the center point of a flat wheel. One end of the shaft is threaded to screw into a vertically drilled hole in each bridge foot. The other end of the shaft rotates freely in the unthreaded portion of the hole, the foot being sawn horizontally to make way for the wheel. By turning the wheel, the threaded portion of the bridge moves vertically toward or away from the table, thereby increasing or decreasing the height of the strings.

Origins

The idea of screw-type bridge height adjusters for stringed instruments may have first been realized on fretted instruments. Mandolins and guitars apparently used the method of changing the string action by the mid-20th Century. Through developments by New York bass makers in the 1960´s such as Chuck Trager, Samuel Kolstein, and Lou DiLeon, bridge adjusters were in common use by the following decade.[15] Today an estimated 60-80% of U.S. bassists use wheel-type bridge adjusters.

Fig. 3 Modern jazz guitar bridge, left, and, exploded view, right

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[15] Lou DiLeon, 15 Feb.1998**

Types

Fig. 4 Aluminum standard, brass standard, aluminum Boehm, polyamide Boehm and maple DiLeone models (lignum vitae Kolstein not shown)

Many types of adjusters are commercially available, varying in material from woods like maple, ebony, cocobolo and lignum vitae to metals like brass and aluminum. Dimensions range from a shaft ¼“ (6.4 mm) to 3/8“ (10.7mm) in diameter and 1 ½“ (41.7mm) to 1 7/8“ (55.5mm) long, and a wheel from 1“ (28.5mm) to 1 5/8“ (39.5mm) in diameter. Exact measurements of tested adjusters are listed below.

Type name and material/code name	Weight	Wheel diameter	Axle diameter/ length
Massive Bridge/ NO	-	-	-
Aluminum Standard/ AS	11.5g	28mm	6mm/ 42mm
Brass Standard / BS	34.6g	28mm	6mm/ 42mm
Aluminum Boehm/ AB	17.3g	32mm	8mm/ 45mm
Polyamide Boehm/ PB	9g	32mm	8mm/ 45mm
Maple DiLeone/ MD	7.8g	39mm	11mm/ 48mm
Lignum Vitae Kolstein/ LK	10.2g	35mm	11mm/ 55mm

Other ideas for materials mentioned in the preliminary research such as steel, nylon and carbon fiber composite led us to create a new bridge height adjuster. Alexander Meyer of IWK created a plastic version of the Boehm model from polyamide stock turned on the workshop lathe.

Use in North America

My information on bridge height adjuster use is drawn from survey of bassists conducted in February 1998, and from conversations on the telephone (see Chapter 7 for documentation). The majority of respondents live and work in North America, so I used their responses to represent current opinions and usage there.

2.6 Internet Survey

Who was contacted.

With the help of the Internet, the following questions were sent to bassists on the e-mail address list of the International Society of Bassists (ISB), which is the leading organization of professional, student and amateur bassists in the world.

The survey was written with four questions:

What are the playing advantages of wheel/ screw bridge adjusters?

What effect on the sound of a bass does the mounting of such adjusters cause?

Do you find the use of such adjusters necessary, helpful, unnecessary, or detrimental to bass playing?

Finally, I invited my colleagues to make any further comments on bridge height adjusters. Over 300 questionnaires were sent to musician members with an e-mail address.

Who replied

Of the thirty-two bassists on the ISB mailing list who replied to the survey, many were in fact the biggest names in bass playing in the United States: Harold Robinson, Barry Green, Larry Hurst, and others. Mr. Robinson teaches at the Curtis Institute of Music in Philadelphia, and is so convinced of bridge height adjusters that he practically requires them on his students' instruments. Mr. Green summed up the mystery surrounding bridge height adjusters by saying, "I've heard metal is good... wood is good...etc." Mr. Hurst, a leading professor of double bass in Indiana, offered interesting stories, especially about the use of a string-height-adjuster used by Anselm Fortier in the neck of his bass earlier this century. Many free-lance musicians and students also offered their opinions on bridge height adjusters. They cited reasons for using bridge adjusters that apply to their situation: for travelling into different climates for auditions, and for adjusting height for "gigs" of different styles. Two of the respondents were luthiers, Barry Kolstein of Long Island and Henry Boehm of Illinois, who both designed and sell their own model of bridge height adjuster. Both of these models were tested in this project. Americans and Canadians were by far most numerous among respondents, though two answers from both England and Germany (one from an American), and single answers came from Australia, Brazil, and Italy. Most bassists replying from outside of North America said they do not use bridge height adjusters themselves, but know of them.

What they said

What are the playing advantages of wheel/ screw bridge adjusters?

There were about six reasons people use bridge height adjusters, according to the responses. The most popular reason for using adjusters was to adjust to variable climate conditions. Almost all of those who mentioned a reason for installing them said they do so to offset weather-related fluctuations in string height. About a third of all respondents said that style changes create a need for adjusters. Switching between jazz, orchestral playing or chamber music is simplified by having bridge height adjusters. One sixth mentioned the advantages of bridge height adjusters while travelling, most often involving changing climatic conditions involved. One bassist finds them useful for practicing solo repertoire while on orchestral tour[16]. Another sixth of the respondents mentioned that bridge height adjusters are a means of experimenting with bridge height. This varies not only the playing situation for the left hand, but also the "field of tension" applied to the table of the instrument. Adjustment of school instruments was mentioned by one respondent. One person said bridge height adjusters can be used to balance differences between brands or gauges of strings.

What effect on the sound of a bass does the mounting of such adjusters cause?

Opinions varied widely on this question. This question addresses the acoustical difference bridge height adjusters make compared to the massive bridge under the same tension conditions. The majority of players who enjoy the convenience bridge height adjusters find the sound effect negligible. In contrast, the few who wrote who don't use them said they felt some loss of sound must occur. Interestingly, not one response claimed to have heard an actual difference in sound before and after mounting adjusters, nor to believe strongly one way or the other based on observation of the sound. Most opinions on sound were founded on personal reasons and preferences, and "what they had heard" form colleagues on the subject.

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[16] Harold Robinson, 2 Feb 98

Do you find the use of such adjusters necessary, helpful, unnecessary, or detrimental to bass playing?

Respondents addressed this question as follows:

necessary	10	31%
helpful	10	31%
unnecessary	3	11%
detrimental	8	24%

Many of the reasons why players find adjusters necessary or helpful have been mentioned above. Those finding advantages outweighing disadvantages of adjusters used phrases like “no great affect” or “no significant damping of sound” to characterize the disadvantage of adjusters.

The most common reason why adjusters are found detrimental is that they affect the sound in a negative, or at least unnatural, way. One colleague wrote that bridge height adjusters may cause permanent damage by putting an uneven pressure on the table, and another warns of improperly installed adjusters which cause damage in a variety of ways. Two players said they were going back to a solid bridge as soon as they could because they were unsatisfied.

Additional Comments: Materials and Models

There was a great range of opinions on ideal material for a wheel-and-axle adjuster.

Adjuster Material	**Was preferred by...**
Wood	10
Metal (Aluminum)	3
None (solid bridge)	3

Though many conflicting opinions and arguments were cited, wood was the most desirable material mentioned by bassists. Ebony adjusters are reported to be aesthetically pleasing, easier to use because of their larger dimensions, and organic-sounding compared to metal models. Ebony models have the disadvantage that they break easily and are relatively expensive. A model in Lignum Vitae was reported by its designer to be convenient to use because it is “self-lubricating ”,and tougher than ebony[17]. Maple was mentioned less often but seems the logical choice to one respondent since the bridge is of the same material[18]. Whether instinctively, empirically or aesthetically, players seem to prefer “wood in contact with wood”.

Metal adjusters, most often aluminum, are controversial. While some bassists reported that aluminum “deadens the sound” or adds a “metallic” character to the tone, others wrote that this material’s lightness and stiffness is ideal for the transmission of vibrations through the bridge to the table[19]. One luthier referred to the “evil” of steel, aluminum and brass adjusters, while another source reported that aluminum possesses

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[17] B. Kolstein*, 4 Feb. 1998

[18] L. DiLeone, 15 Feb.** 1998

[19] H. Boehm,* Feb. 1998

the “most efficient transmitting density” for the purpose. The report that the smaller aluminum adjusters are difficult or even “painful” to turn because of their smaller dimensions is contrasted by praises of their durability and lower cost.

But there appears to be no controversy about the beauty of aluminum adjusters: no respondent finds aluminum aesthetically superior to other materials. A second luthier uses aluminum for his adjusters, but makes his model in a larger dimension for ease of use and anodizes the metal in black to enhance their appearance. He also notes that with proper installation and a little lubrication of graphite powder, there is no reason why an aluminum adjuster should be difficult to use. It is interesting to note that though wood adjusters are preferred by most respondents, aluminum is in fact more widely used.

Plastics were hardly mentioned as a material. One respondent reported that plastic, such as nylon, “mutes the sound”[20].

Use in Europe

It is remarkable that the wheel bridge adjuster is so prevalent in North America while being virtually unknown in Continental Europe. Is humidity more stable in Europe, resulting in less seasonal difference in string action? Are players there less likely to change playing styles quickly?

It seems there are several factors involved. European players simply don’t need to adjust their strings as often. Changes in climate are more extreme in North America, and American bassists travel further and more often to areas of different climate with their own instruments. Orchestral musicians in Europe are supplied with an instrument to use at work for which the orchestra is responsible, while American bassists most often play in the symphony hall and elsewhere their own instrument and are themselves responsible for their bass‘ playing condition.

Many European bassists are unfamiliar with bridge height adjusters, and aren’t aware that adjusters could solve their string-height problems. Here in Vienna, one still sees bridge jacks under the feet of a bridge that is too low, yet there is no luthier that can install adjusters here. Attitudes toward basses and bass playing are also important factors in the discrepancy. Aside from the responsibility for their own instrument’s playing condition, American bassists may be more willing to try something new than their European colleagues, which has led to widespread use of wheel bridge adjusters over the last twenty years. Europeans seem more tradition-bound and less willing to risk impairing the sound of their instrument. It would be interesting to study the introduction of various instrument developments now in common use, such as the violin chin rest, cello and bass end pin, and the more recent violin shoulder rest, comparing origins and the rate of acceptance of innovations in Europe and North America to make projections about future use of bridge adjusters in Europe.

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[20] Barry Green*, 2 Feb 98

CHAPTER 3: METHODS AND EXPERIMENT PROCEDURE

3.1 Experiment Procedure

This acoustical study is based on the sound analysis of a double bass configured for modern orchestral playing, fitted with bridge height adjusters as described in Chapter 2. The aims of the recording methods are as follows:

to select a broad range of tones and musical samples for testing throughout the range of the instrument

to eliminate as many external factors as possible during the recording session that may interfere with the analysis of adjuster characteristics

to effectively record the resulting data for later analysis within time limits

The recorded material will be analyzed with the following aims in mind:

to objectively determine if BHAs alter sound and if so to define in what way

to compare the acoustical and technical characteristics of various models in a variety of practical playing situations

3.2 Recording Procedure

Overview:

A bassist played selected tasks in an anechoic chamber. The recordings were analyzed using digital sound analysis.

Anechoic Chamber

The recordings took place in a sound-absorbing chamber at the IWK[21].

Recording Apparatus

Fig. 5 Audio Center at IWK. Among the equipment shown are the Audio-PC (lower left), S_Tools-PC, video monitor (upper right) for viewing subject inside anechoic chamber during recording mixer, R-DAT recorder and amplifier (middle column). Also shown are microphones to record comments outside the chamber and to communicate with the test player.

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[21] See IWK literature for documentation

Fig. 6 Test player, instrument and equipment inside anechoic chamber. Note the sound-absorbing wall and floor of the chamber. The instrument is stabilized in its position while the player sits comfortably. The musical samples, or tasks, are seen at upper right. The amplifier for the accelerometer, digital thermometer and metronome (white background, l-r) and pitch meter (on stool facing player) are shown. Video camera, microphones and barometer not shown.

Recording methods were chosen from those available at IWK to serve two purposes: for the digital sound analysis for use in a comparative listening test questionnaire for subjective reaction to data. The entire session was planned for one day to keep factors consistent throughout the recording phase. The overall "sound" of the test instrument with its various adjusters was recorded by one microphone (AKG C414) at a distance of 2 meters onto one of the four tape tracks. A second microphone near the player recorded his voice for reference and the sound of the instrument from the player's perspective. A third track recorded the measurements of an accelerometer (Brüel & Kjear Type 4374) affixed to the bridge itself. To offer data about how the bridge height adjuster affects continuity of vibrations through the body of the bridge, this measurement device was placed in three different positions during three consecutive test rounds of the same adjuster model (only one such accelerometer was available). (These consecutive rounds have the added advantage of offering data to compare accuracy and similarity of the player's work.) A fourth track recorded the test personnel's commentary outside the anechoic chamber.

Test Instrument

Fig. 7 "Bertha", the test instrument, shown with Kolstein model installed

The test instrument is a professional quality double bass over 100 years old and of unknown origin. The existing bridge used in the first rounds of recording was subsequently cut to fit the various bridge height adjusters. In order to minimize error due to temperature or humidity fluctuations, the test instrument remained in the anechoic chamber for the duration of the test phase. It was monitored before each recording round using a checklist to ensure that factors such as soundpost position, exact height of the newly installed bridge, and the angle of the bass table to the microphone remained constant. The bass itself was placed between a marked position at the endpin and the pegbox was placed in a special holding device lined with foam rubber.

Player

A live player played tasks for this test. The player is a member of one of Vienna‘s major symphonic orchestras and a classmate of mine. Intonation of closed notes was consistently checked by using a pitch meter calibrated to A=443hz before each recorded example. The player‘s position was marked by a fixed seat in the anechoic chamber.

Musical Samples

Choosing the sample tones to be played was a compromise between thoroughness and time limitation. The musical samples we recorded were chosen with several criteria in mind:

1. to limit recorded material while including necessary samples, and
2. to contain samples over the range of the instrument.

A detailed table of tasks and a copy of test samples used in the recordings is listed below.

Task Table

Sample Type (dynamic)	**Task Number**	**Note or Musical Sample**	**Approximate Length in Seconds**
Arco over the range of the bass (forte)			
	01	Contra E (ca.41 Hz)	15
	02	Large C (ca.65 Hz)	15
	03	Large F (ca. 87 Hz)	15
	04	Large B (ca.123 Hz)	15
	05	small d (ca. ca.146 Hz)	15
	06	small a (ca. 220 Hz)	15
	07	d 1 (ca. 293 Hz)	15
Open String Pizzicato (forte)			
	08	Contra E (ca.41 Hz)	15
	09	Contra A (ca. 110 Hz)	15
	10	Large D (ca.73 Hz)	15
	11	Large G (ca.98 Hz)	15
(open harmonic)	12	small g (ca. ca.196 Hz)	15
Arco, Open Strings (pianissimo)			
	13	Contra A (ca. 110 Hz)	3
	14	Large D (ca.73 Hz)	3
	15	Large G (ca.98 Hz)	3
	16	small g (ca. ca.196 Hz)	3
Arco, Open Strings (fortissimo)			
	17	Contra A (ca. 110 Hz)	3
	18	Large D (ca.73 Hz)	3
	19	Large G (ca.98 Hz)	3
	20	small g (ca. ca.196 Hz)	3
Musical Phrase (forte)	21	Dittersdorf Concerto in E, first bar of solo	5
Musical Phrase (mezzo forte)	22	Schubert Arpeggione Sonata, first bar of solo	5

The **first seven samples** are designed to show bowed response in a middle dynamic over almost three octaves. Closed notes were included to represent the practical playing situation. To account for variable loudness caused by the live player, each tone was recorded four consecutive times, in a crescendo from *mf-f* , to be selected later into a group of samples similar in characteristics and suitable for caparison. The **next five tones** were to be played **pizzicato** "as loudly as possible without extraneous noise". Open strings and an harmonic tone at a high dynamic level were chosen to show the special characteristics of how bridge height adjusters affect pizzicato notes. We were especially interested in the decay time of these samples. The next **eight samples** were played in extreme dynamics, Numbers 13-16, *p*, Numbers 17-20, *ff*. Recording the open strings played as softly and loudly as possible may yield information about the dynamic potential of various adjusters. The **final two samples** were chosen to show the effect of bridge height adjusters in a musical context. Because the test is after all a musical one, two phrases from the standard repertoire were recorded at the end of each round. These samples are necessary for a possible listening test questionnaire.

Problems with Adjuster Installation- the Plan

To ensure that qualities of the bridge itself remained constant throughout the recording phase, the same bridge was used for all test rounds. Normally, a bridge will be fitted only once with a certain size bridge height adjuster and be set aside or discarded with those. Installing a series of bridge height adjusters successively in one bridge required planning and precision. Of the six models to be tested, only two are identical in size. Consequently, four rounds of refitting were required during the recording sessions. Though the first adjusters are relatively small, the largest model mounted last left little margin for error due to its length and axle diameter.

Description of Adjuster Installation

After recording the first round with massive bridge feet, the bridge was carefully removed from the instrument and taken to a violin shop with a lathe appropriate for the first drilling and cutting, which will serve as the basis for all subsequent work. So the center of the bridge foot in both the X and Z axis (see illustration) was established and marked for drilling on the lathe. A small block of cardboard was spot-glued to each leg and filed to compensate for this particular bridge's angle for straight drilling while clamped in place on the lathe. A pilot hole of three mm was drilled into one leg by sliding the platform of the lathe toward the drill bit, which was marked with white chalk at the proper depth. Because the leg becomes narrower in the Z axis, the maximum drill diameter of 23/64" (9.1mm) must be drilled exactly in the center of each leg. After the successful drilling of the pilot hole, the drill bit was replaced with a 3/16" (5.2mm) bit, the leg redrilled, and the process repeated on the second leg. These holes will accommodate tapping the first ¼" NC 20 (= tap size: ¼" (6.2mm) diameter, 20 threads per inch (254mm)) threads.

The lathe is also equipped with a precision 200mm table saw. After establishing the distance of the perpendicular cut from the foot of the bridge by adding a small margin to the longest adjuster axle, a line was drawn on both legs exactly perpendicular to its centerline. It is crucial to proper adjuster installation that the surface upon which the adjuster wheel rests is flat and at right angles to the axle. The pieces of cardboard remained in place to provide a flat plane for perfect sawing at right angles. A 6 mm portion of each leg was removed using the saw to accommodate the wheel of the adjusters.

The bridge feet, now separated, were drilled to their final diameter of ¼" to make room for the unthreaded bottom portion of the adjuster axle. This done, the bridge was returned to the lab, where the upper portion of the bridge was clamped in a vise at the workshop and the existing holes were tapped by hand with ¼" NC 20 threads. The first adjusters were installed, and the bridge carefully returned to playing position where the next round of recordings could begin.

The following installations of subsequent models was simpler than the initial cutting and drilling and could be performed in the workshop of IWK. Since the previous holes needed only be increased in diameter, this was done by hand using a hand-held drill shank and incrementally increasing drill bit size until the proper diameter was achieved. The workshop vise functioned well for tapping new threads.

With the new adjusters in place, the position of both bridge feet was exactly re-established before the next recording round.

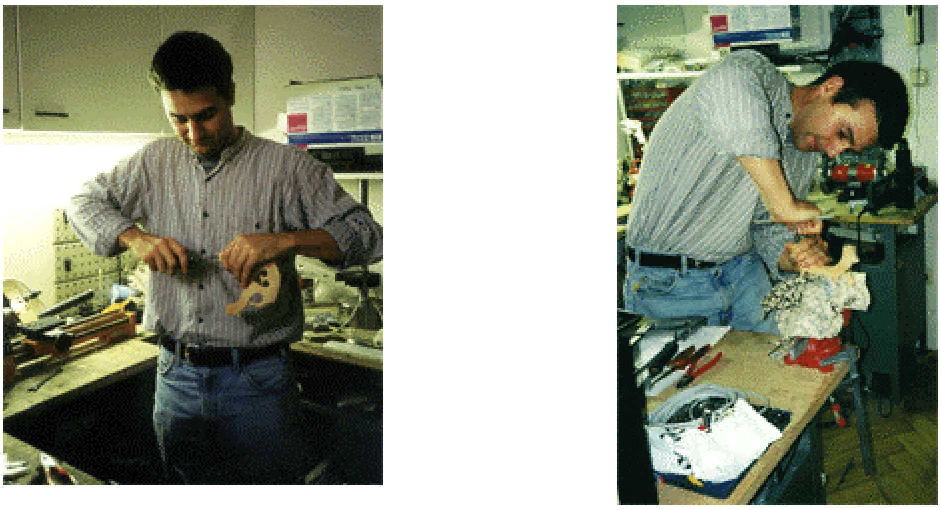


Fig. 8 Preparing cut bridge leg for tapping, left, and tapping bridge, right

Samples were recorded onto Fostex in thirteen rounds

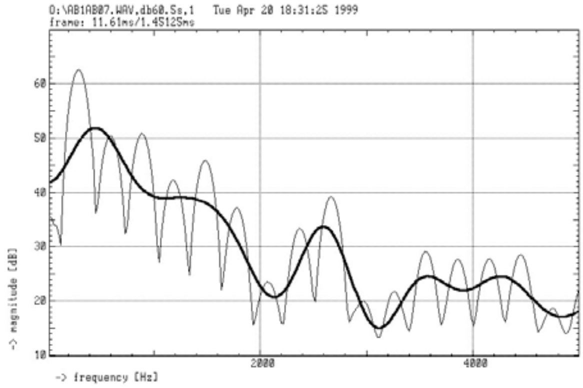
The first three rounds with the massive bridge started at 10:10 AM on October 9, 1998, and took approximately 15 minutes each to record. The type of adjuster, test number, accelerometer position number, time, tape number, and track number, as well as the time I.D. of each sample, were noted on the Recording Protocol (illus). Before each round the checklist was completed (illus). With a longer break to fit the first set of adjusters, the next round of recordings began at 1:15 P.M. The process continued until about 5:00 P.M., when the last round was completed. In all, 120 minutes of samples were recorded onto two Fostex tapes.

Sound recordings transferred to IWK server using Soundforge HDR

In the following weeks, each sample was saved under its own code name. To accommodate S_Tools, each file was named with a maximum of eight characters. The File name is necessary to identify each individual sample recording and includes a code for the adjuster type, recording round number, microphone number (track number) and sample number. (see Task Table for code name key). *Soundforge* is a standard program for processing sound information in a variety of ways. It was used to convert the digital information on the Fostex tape to individual soundfiles of each sample through HD recording, and these sound files were then saved into a common folder on the server databank at IWK. While processing the samples, excess material recorded between the samples was trimmed away and unacceptable versions of the musical samples (there were several takes of each) were sorted out. Since Soundforge operates in stereo files, it was necessary to record the three tracks of each sample onto two separate files, one for the stereo microphones (a,b), and one for the accelerometer (c). Nearly 600 files were saved onto the server in all.

3.3 Analysis Method

The following is an example of an FFT.



For details of the sound analysis using FFT spectrum images, RMS pizzicato sustain tests, and the listening test, Chapter 4.

CHAPTER 4: SOUND ANALYSIS

After the sound files were recorded, processed and stored into the memory banks of the IWK server, the sound analysis could begin.

Listening to the Sound Examples

To get an impression of tonal characteristics of the various bridge height adjusters, many informal listening sessions were made. After preliminary trials of single tones, I listened systematically to samples 01-07 among all variables, additionally including a separate recording of the massive bridge variable as a comparison control for each task. Using the Massive Bridge as a basis for comparing bridge height adjusters, the following is a summary of the impression the variables made. This overview gives a guide for what to look for on the following FFT spectrum diagrams.

1. Aluminum Standard was consistently rated throughout the range of the bass as sounding “brighter” and “louder” than a bridge without adjusters. In the upper registers I described the sound as “brighter”, yet “thinner” and more “nasal” than a massive bridge.

2. The Brass Standard was less consistent in tone color depending on the frequency range played. The lower notes compared well with the massive bridge, and sounded “louder”, more “focused”, and “rounder” (better tonally balanced) than its aluminum counterpart. The brass model sounded increasingly “mid-range” and “less round” from Large B (on the G string, ca.123 Hz) upwards, and ultimately very “thin” and “nasal” in the high range.

3. The second aluminum model, the Aluminum Boehm, generally shared the characteristics with the Aluminum Standard model, but sounded less “nasal” and more “round” , though not as loud as the Standard. With the exception of the lowest tones, the Aluminum Boehm sounded “brighter” and more “present” than the massive bridge while still remaining very similar to it in the lower registers.

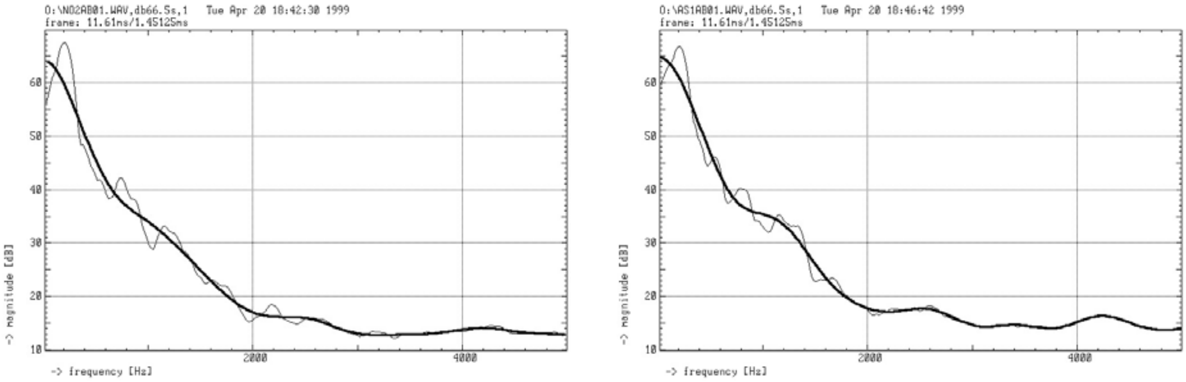
4. The model we created for the project, the Polyamide Boehm, only started sounding distinct from the massive bridge in the middle range, but there and upwards, the difference was pronounced. From Large B, the tone sounded “brighter” and “more direct” than the massive bridge but “nasal” and “less full”. I also remarked in my notes that Polyamide Boehm has a “larger dynamic range” and is “more penetrating” than other models in the top register, but sounds like it’s “in a box” (an odd, nasal timbre) in the middle range.

5. The two wood models, Maple DiLeone and Lignum Vitae Kolstein, showed very similar sound characteristics, especially in the lower register. The first two tones, the open E and large C on the A string, were very similar to a bridge without adjusters, but slightly “more focused” sounding and with “less fundamental”. I was surprised to find that both types sounded equally “darker” than the massive bridge in the lower-middle range (F=ca.87 Hz, and B), while the Kolstein model became more “nasal” and “dampened” in the higher registers. Maple DiLeone remained “similar in color” to the massive bridge on the high notes.

4.2 FFT Spectrums

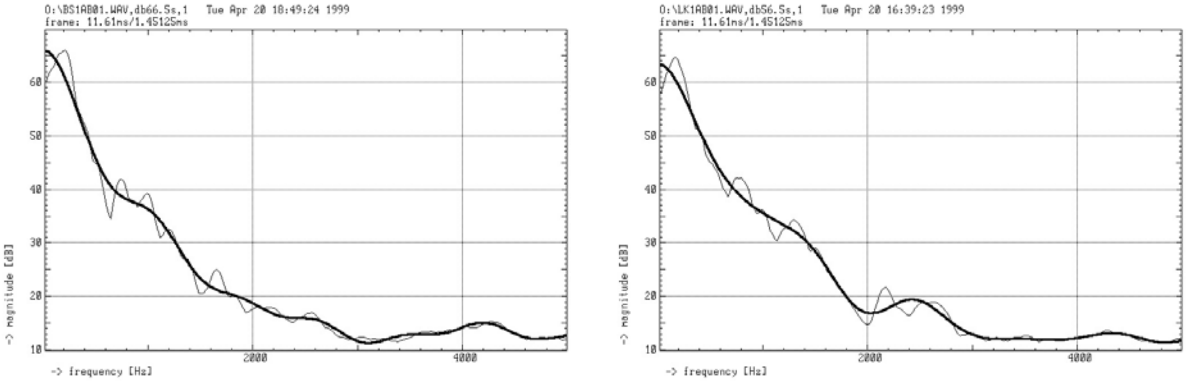
Three bowed tasks (Contra E, Large B, and D 1) are analyzed in the following text using FFT diagrams created in S_Tools.

Contra E (ca. 41 Hz)



Massive Bridge

Aluminum Standard



Brass Standard

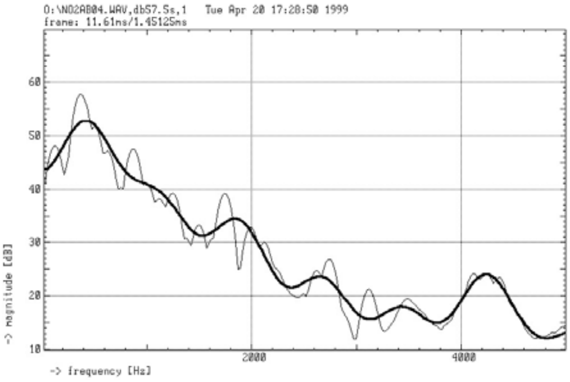
Lignum Vitae Kolstein

Fig. 9 Comparison of FFT spectrums: massive bridge, aluminum standard, brass standard, and lignum vitae Kolstein

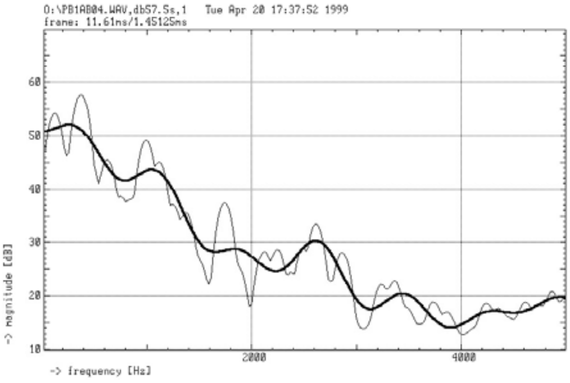
Comparing control task FFTs (separate recordings of the same variable) and listening to the sound files corresponding to the curves during my work showed a somewhat large margin of variation in graphic depictions of double bas tones, and I found that diagrams such as those shown above may be misleading if not interpreted with caution and in combination with other data. In spite of some inconsistencies, the diagrams that were created with S_Tools clearly show some general tonal tendencies of bridge height adjusters.

The figure above shows diagrams representing the overtone spectrum of Contra E (thin line on graph). The bold line is a cepstrum (a smoothed mean curve) with 40 coefficients. A 500ms (1/2 second) section of similar sound intensity was analyzed. It was not always possible to isolate a sample with a similar dynamic level since the player or the adjusters themselves influenced the recorded decibel level. For example, each task above has an average intensity of 66dB except the lignum vitae Kolstein, which was much less intense and showed a maximum of 56 dB. The relatively straight fall of Massive Bridge is characteristic for all ranges: the massive bridge has the most even distribution and decline of overtones of all variables. The Aluminum Standard shows a characteristic typical of all bridge height adjusters: a peak in the frequency range around 1200 Hz at the bass bridge's resonant frequency[22]. Such regions in the spectrum are significant because they are perceived by the listener as another tone color and indicate the tone color character of the individual adjuster type. The Brass Standard shows a curve slightly steeper than the massive bridge, a gentle peak around 1000 Hz (lower than the aluminum) and somewhat lower dB in the high range between 3-5 kHz. The curve of the wood Kolstein model is not as even as the massive bridge's, but very similar in spite of the difference in dB. The peak around 2.3 kHz could explain why this model sounds "more present" on the open E string. The largest difference to be seen among these four examples is between the Massive Bridge and the aluminum standard model. The stronger resonance at 1200 Hz of the latter probably indicates why it sounds "louder" and "more focused" than the solid bridge on this note.

Large B (ca. 123 Hz)



Massive Bridge Aluminum Boehm



Polyamide Boehm Maple DiLeone

Fig. 5 Comparison of FFT spectrums: massive bridge, aluminum Boehm, polyamide Boehm, and maple DiLeone

Here, the massive bridge shows a less steady curve than on Contra E (Massive Bridge Comparison sample's curve is more even- see Addenda Chapter 7). The listening test I made called the two samples "identical" from sound in spite of the optical difference. In spite of the peaks, the overall slope between 500 and 4000 Hz is more even than the examples of the other adjuster models that follow. The greater intensity between 3-4 kHz on the curve of the aluminum Boehm model shows why it sounds "more present" than the massive bridge at this frequency. This curve also shows the peak typical of adjusters at 1200 Hz. After viewing many such graphs, I can well imagine how the curve of Polyamide Boehm corresponds to a sound "like in a box", with an uneven distribution of partials and a weaker fundamental. The fundamental of the Maple

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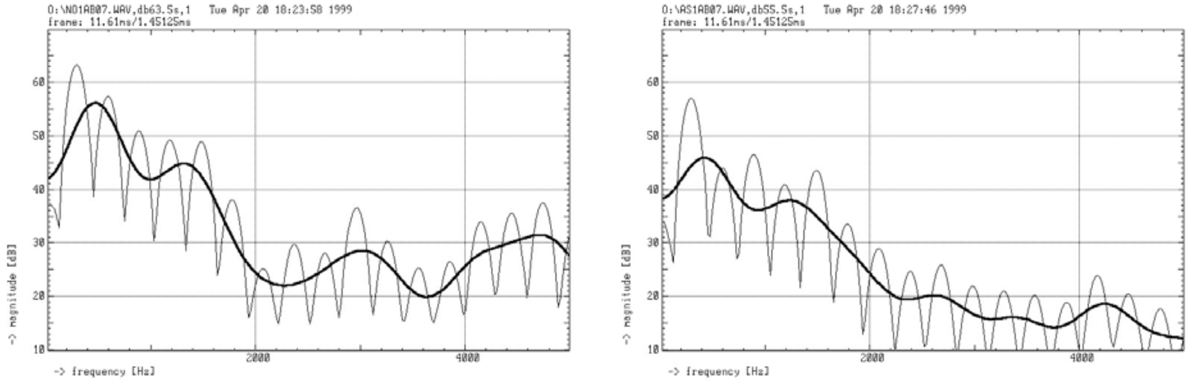
[22] Meyer, J. Akustik, und Musikalische Aufführungspraxis, 1995. Pp. 84

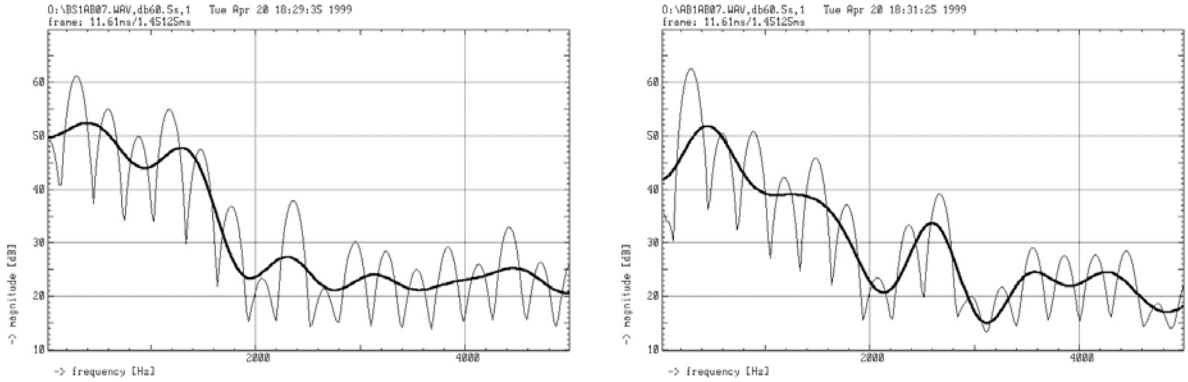
DiLeone model is similarly diffuse in comparison with the compact peak of the massive bridge, but the maple model still has a more even curve than the plastic one. The pronounced troughs of Maple DiLeone at 800 and 1800 Hz probably show why it sounds “darker” than the massive bridge on this note.

D 1 (ca. 293 Hz)



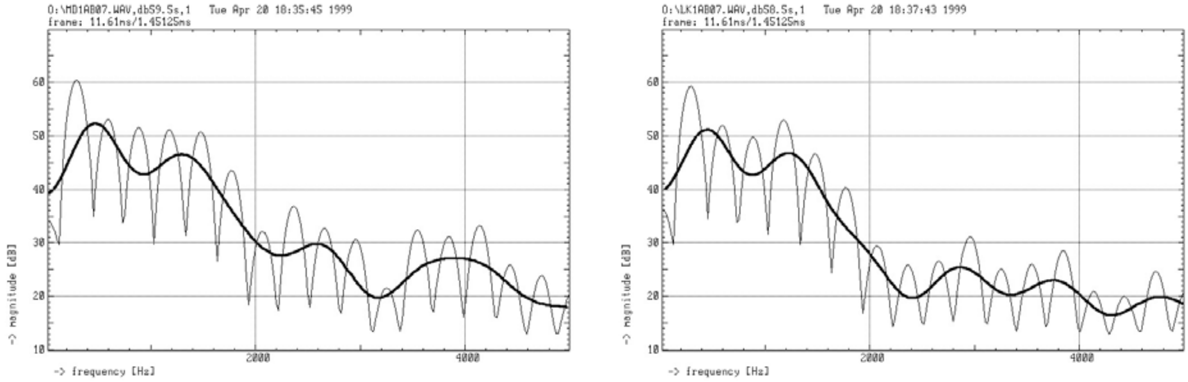
Massive Bridge

Aluminum Standard



Brass Standard

Aluminum Boehm



Maple DiLeone

Lignum Vitae Kolstein

Fig. 6 Comparison of FFT spectrums: massive bridge, aluminum standard, brass standard, aluminum Boehm, maple DiLeone, and lignum vitae Kolstein

This was the highest tone on the list of tasks. The Massive Bridge curve was consistent in both samples (see Chapter 7) and characterized by four peaks between 250 Hz (mean) and 4.8 kHz. The “thin” sound of the Aluminum Standard model can be seen in that the fundamental peak at 250 Hz (293Hz, to be exact) is weaker, and the higher frequencies also fall off significantly. The Aluminum Boehm model shows a stronger fundamental and richer overtones above 2 kHz, including a sharp peak at around 2700 Hz, which support the observation that this model sounds “brighter” than the massive bridge but “rounder” than the standard model. The two wood models show a very similar curve to the Massive Bridge, especially in the case of the maple model. Lignum Vitae’s lack of strong peaks above 4 kHz probably shows why it sounds “slightly more dampened” than the solid bridge.

Conclusions of FFT Analysis

In summary, a subjective listening test and a broad analysis of FFT spectrums represented by the examples below have led to the following generalizations about bridge height adjusters’ sound characteristics:

1. Massive Bridge- bridge height adjusters generally sound brighter than the massive bridge, with the exception of the brass model in the lower range and the wood models in the lower-middle range. The massive bridge is richer in fundamental and has more even overtone distribution throughout the range of the instrument than any adjuster model, but may lack brightness or focus in comparison.

2. Aluminum Standard- sounds consistently brighter, more nasal and louder than the massive bridge, but sounds thinner and weaker in the very high positions.

3. Brass Standard- sounds full and focused in the low registers, but quickly loses overtones in the middle range of the bass and sounds thinner than the aluminum standard from there on.

4. Aluminum Boehm- is somewhere between the sound of the aluminum standard and the massive bridge, sounding similar to a solid bridge in the low register, brighter and focused in the middle and high positions, yet rounder and less loud than the aluminum standard.

5. Polyamide Boehm- the least consistent one of all variables, it is distinguished with an uneven palette of tone colors and a weak fundamental above the middle range.

6. Maple DiLeone- is closest overall to the massive bridge in bowed tones.

7. Lignum Vitae Kolstein- almost as close in tone, though somewhat more muted. Like the maple model, it sounds more focused but less fundamental in the lowest frequencies and darker in the middle range. The lignum vitae Kolstein loses overtones in the higher registers.

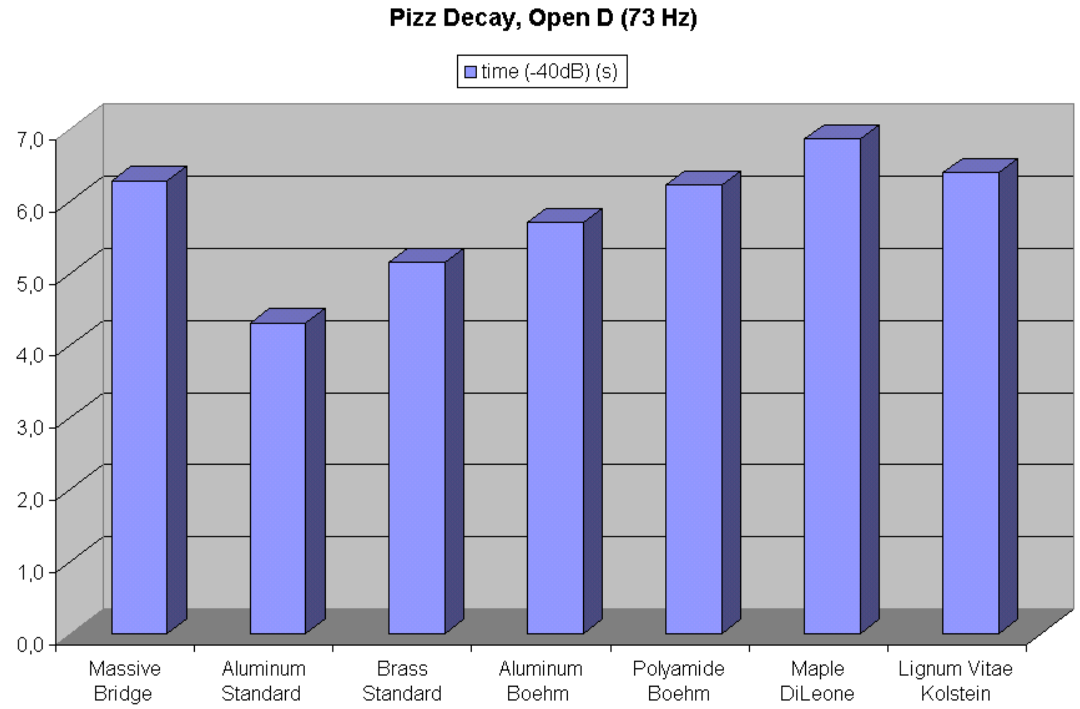
4.3 RMS Pizzicato Decay Time

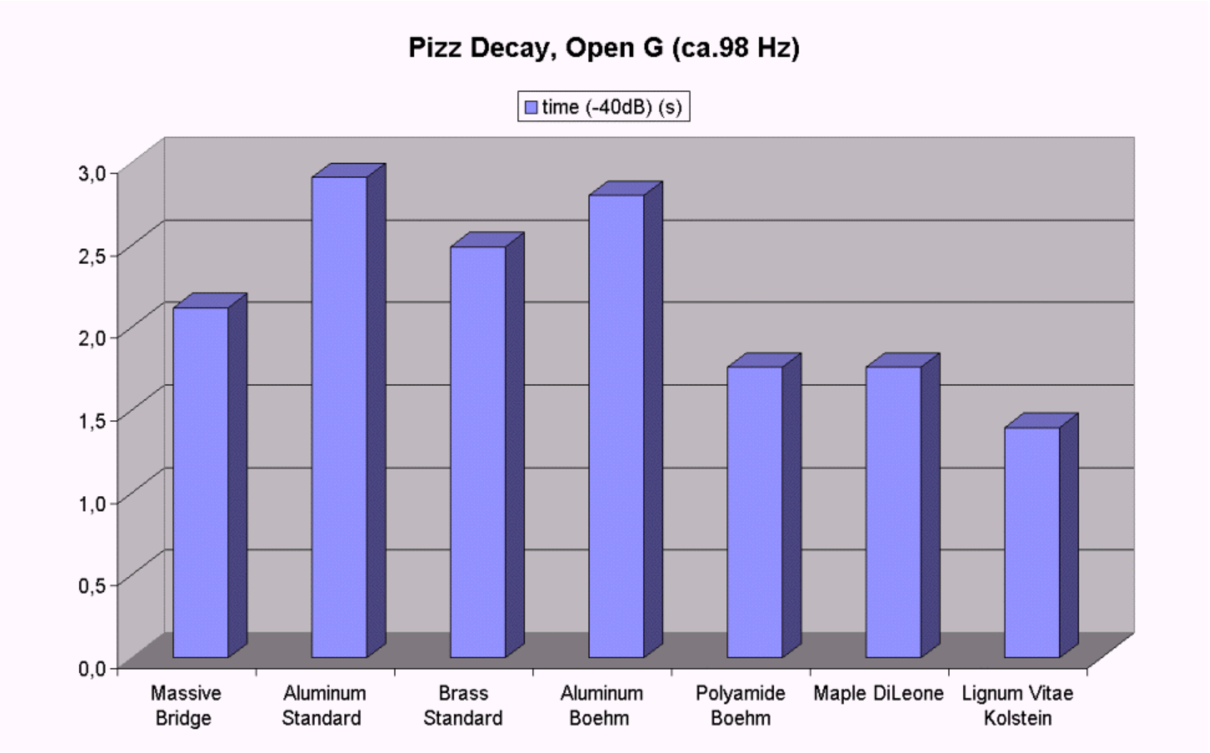
The characteristics of plucked notes are of special interest to bassists. Not only the foundation of jazz and popular bass style, pizzicato is also a specialty of the bass in orchestral ensembles because of its resonance and sustain. Background information leading to this study indicated that bridge height adjusters have an effect an pizzicato notes, leading to an examination of how adjusters affect sustain.

Two studies were made, both using S_Tools RMS analysis and Microsoft Excel tables. The first was to define the sustain of the various adjusters by the amount of time (t->, in seconds) necessary for a tone's amplitude to fall from maximum loudness (max) to 40 dB below maximum (max-40 dB= 100 times less intense). This results in a single number which can be represented in a bar graph.

Pizzicato Test 1

Bridge variables behaved quite differently depending on which tone was played. Overall there was a maximum difference of 2.8 seconds among adjusters on the D string, whereas the smallest difference was on the E string (.6 seconds). The maximum deviation on the G string was 1.5 seconds, and the octave harmonic showed a difference of 1.8 seconds among the variables. Variance on the A string was 1.1 seconds. No variable, including the massive bridge, showed a consistent tendency to increase or decrease sustain. The diagrams below illustrate the point.

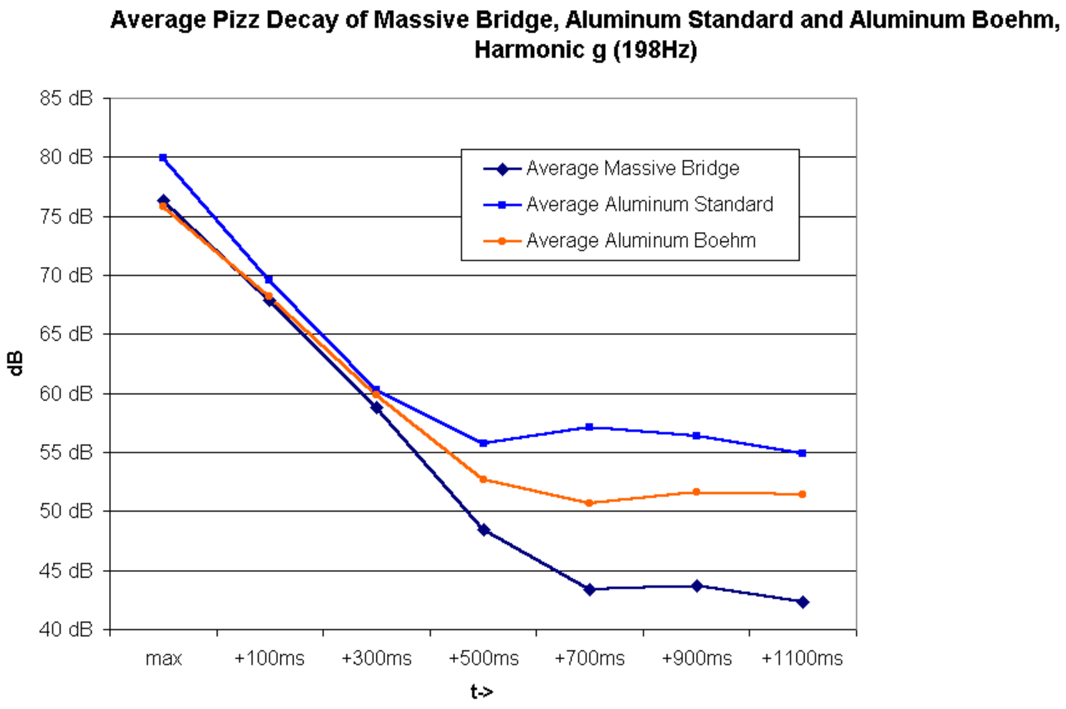


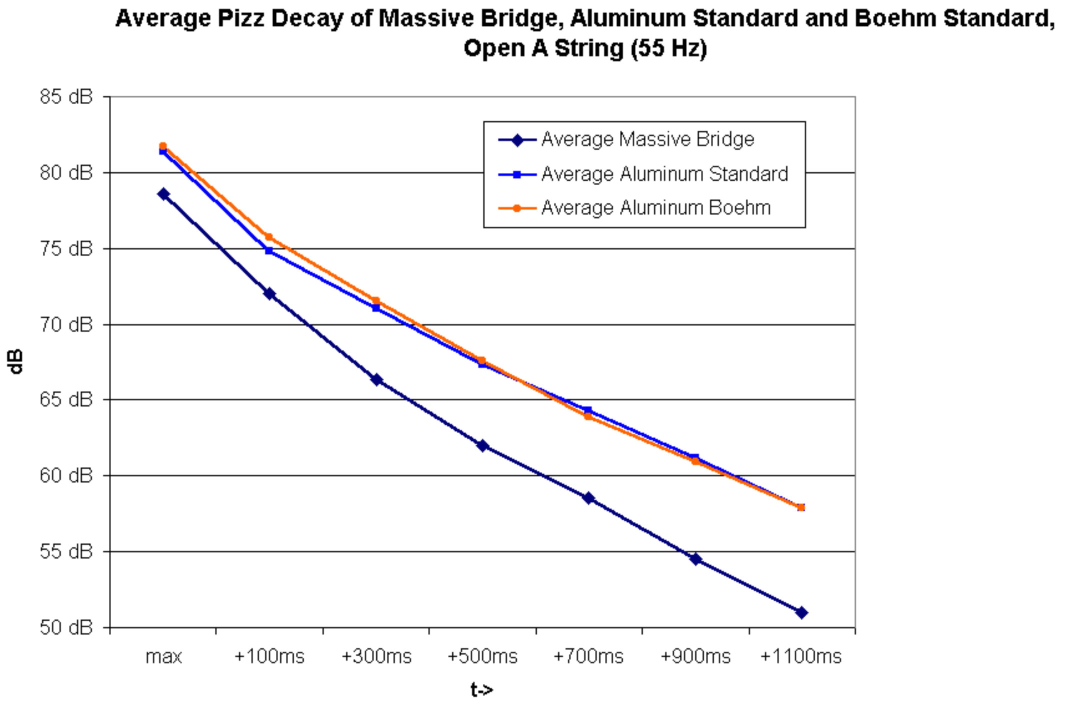


Dia. 1 The above tables show inconsistency in the sustain time of pizzicato notes among bridge height adjuster variables, including the massive bridge.

Pizzicato Test 2

The second test plotted the maximum dB level, dB level after 100ms, and every 200ms until 1100ms. This results in a curve of seven points which are roughly equivalent to the RMS curve of the pizzicato note when plotted on a linear graph. This information was processed with Microsoft Excel, and two examples are shown below.





Again, variables were inconsistent, and it is difficult to generalize about their sustain characteristics. It is interesting, however, to compare the massive bridge with the aluminum adjusters and the wood adjusters (see Chapter 7, Pizzicato Test 2, Metal- and Wood Comparison). The only real tendencies seem to be that the notes A, G and g harmonic vibrate louder and longer with bridge height adjusters within this 1.1 second period.

4.4 Listening Test

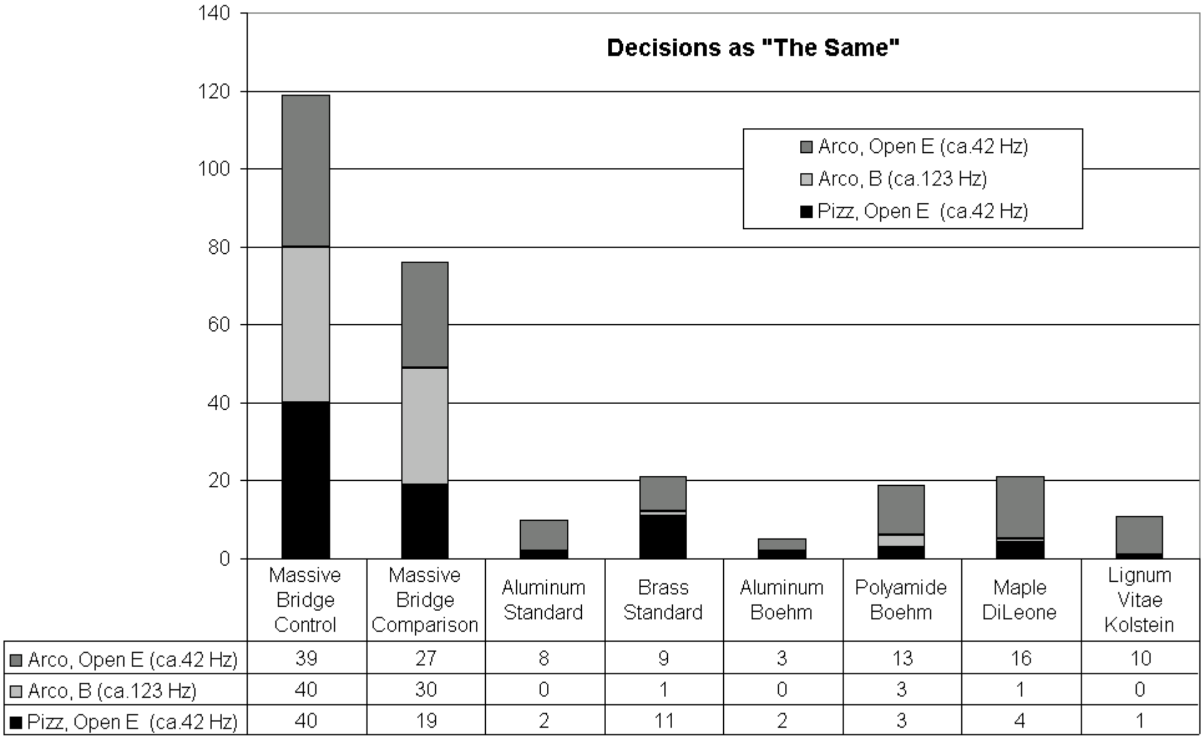
A closed system programmed onto laptop was used for flexible listening tests and exact data processing. Soundcomparison[23] is a program written especially for such tests which presents a written dialogue to a test participant on the monitor screen, plays tone samples from its database through headphones, asks for a decision and records the results. The test parameters were defined, then sound files of three types of tones were selected and stored in the program's databank.

Sound file Selection and Processing

Three types of tones were chosen to be compared: a low pizzicato (contra E, ca.41 Hz), a low bowed tone (contra E, ca.41 Hz), and a medium-range bowed tone (B, ca. 123 Hz). These three tones were extracted from the recordings of all adjuster variables and processed by equalizing volume and eliminating initiation and decay. A second set of separate massive bridge tones was also chosen as a control.

Testing Method

Using *SoundComparison*, candidates were asked to give some personal statistics and introduced to the test. The processed sound excerpts were played in pairs in a specific order which remained the same for each separate test. One series of massive bridge tones was used as a comparison and always present in the pairs. The control pairs played the identical file twice; all other pairs were either a different recording of the same adjuster variable (massive bridge) or different recording *and* variable. Test participants were asked to judge examples as "the same" ("gleich") or "not the same" ("nicht gleich"). 24 pairs (3 tones x 8 variables) were played twice during each test, resulting in 48 judgements per test and 960 judgements in all. Twenty people participated in the test, the majority of whom are music students.



	Massive Bridge Control	Massive Bridge Comparison	Aluminum Standard	Brass Standard	Aluminum Boehm	Polyamide Boehm	Maple DiLeone	Lignum Vitae Kolstein
▨ Arco, Open E (ca.42 Hz)	39	27	8	9	3	13	16	10
□ Arco, B (ca.123 Hz)	40	30	0	1	0	3	1	0
■ Pizz, Open E (ca.42 Hz)	40	19	2	11	2	3	4	1

The bar on the left shows that the identical files were judged by almost all participants (99.16%) to sound the same. The next bar shows results of the massive bridge

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[23] See IWK literature for documentation

comparison between different recordings of the same variable (63.1%). Though there is a large difference between the identical control files in the first bar and the massive bridge comparison in the second column, the closest bridge height adjusters, the maple DiLeone and brass standard models (17.43%), were judged the same significantly less often. Adjusters that were judged the fewest times to sound the same, such as the aluminum Boehm (4.15%), aluminum standard (8.3%) or lignum vitae Kolstein (9.13%) models, sound the least like a massive bridge with these tones.

Bowed tones were found different more often than pizzicato among all adjusters, while the massive bridge comparison remained more or less proportional to the control. Especially noticeable was the arco tone, which was judged the same only 5 times out a possible 240 (2.1%) among all bridge height adjusters compared to the massive bridge, whereas the massive bridge control was the same 30 out of 40 times (75%). The brass standard model came closest to the massive bridge on the arco low E with 27.5% "the same", compared with 47.5% of the control.

Conclusions of the Listening Test

Bridge height adjusters generally make a substantial audible difference in sound compared to a massive bridge. There is tonal variance among models of bridge height adjusters depending on the frequency of the note played. These differences are more audible with bowed tones than with pizzicato.

Of the tones tested, maple DiLeone sounded most like the bridge without adjusters on the low pizzicato, brass standard sounded least different on the low bowed note, and all models sounded significantly different on the mid-range note. The aluminum Boehm model ranked furthest from the massive bridge overall.

CHAPTER 5: CONCLUSIONS

Preliminary research showed that there is no previous literature on the acoustical characteristics of double bass bridge height adjusters.

Local and international surveys showed current tendencies in adjuster use. Between 60-80% of North American bassists use them, while they are practically absent from the European music scene. Wood adjusters are preferred by bassists for tonal and aesthetic reasons, but aluminum models are more commonly used.

Listening tests show that all types of bridge height adjusters cause an audible difference in sound compared to bridge with no adjusters, and that individual models and materials have unique tonal characteristics.

A test was prepared with a massive bridge and six types of bridge height adjusters. Digital analysis shows that bridge height adjusters make a significant difference in pizzicato decay time, but vary irregularly throughout the range of the double bass. FFT and listening to sound examples defined the sound characteristics among the tested variables as follows:

1. Massive Bridge: bridge height adjusters generally sound brighter than the massive bridge, with the exception of the brass model in the lower range and the wood models in the lower-middle range. The massive bridge is richer in fundamental and has more even overtone distribution throughout the range of the instrument than any adjuster model, but may lack brightness or focus in comparison.

2. Aluminum Standard: sounds consistently brighter, more nasal and louder than the massive bridge, but sounds thinner and weaker in the very high positions.

3. Brass Standard: sounds full and focused in the low registers, but quickly loses overtones in the middle range of the bass and sounds thinner than the aluminum standard from there in the middle and high range.

4. Aluminum Boehm: is somewhere between the sound of the aluminum standard and the massive bridge, sounding similar to a solid bridge in the low register, brighter and focused in the middle and high positions, yet rounder and less loud than the aluminum standard.

5. Polyamide Boehm: is the least consistent of all variables, and is distinguished with an uneven palette of tone colors and a weak fundamental above the middle range.

6. Maple DiLeone: is closest overall to the massive bridge sound in bowed tones.

7. Lignum Vitae Kolstein: almost as close in tone, though somewhat more muted. Like the maple model, it sounds more focused but less fundamental in the lowest frequencies and darker in the middle range. The Lignum vitae Kolstein loses overtones in the higher registers, resulting in a more dampened tone.

CHAPTER 6: BIBLIOGRAPHY/SOURCES

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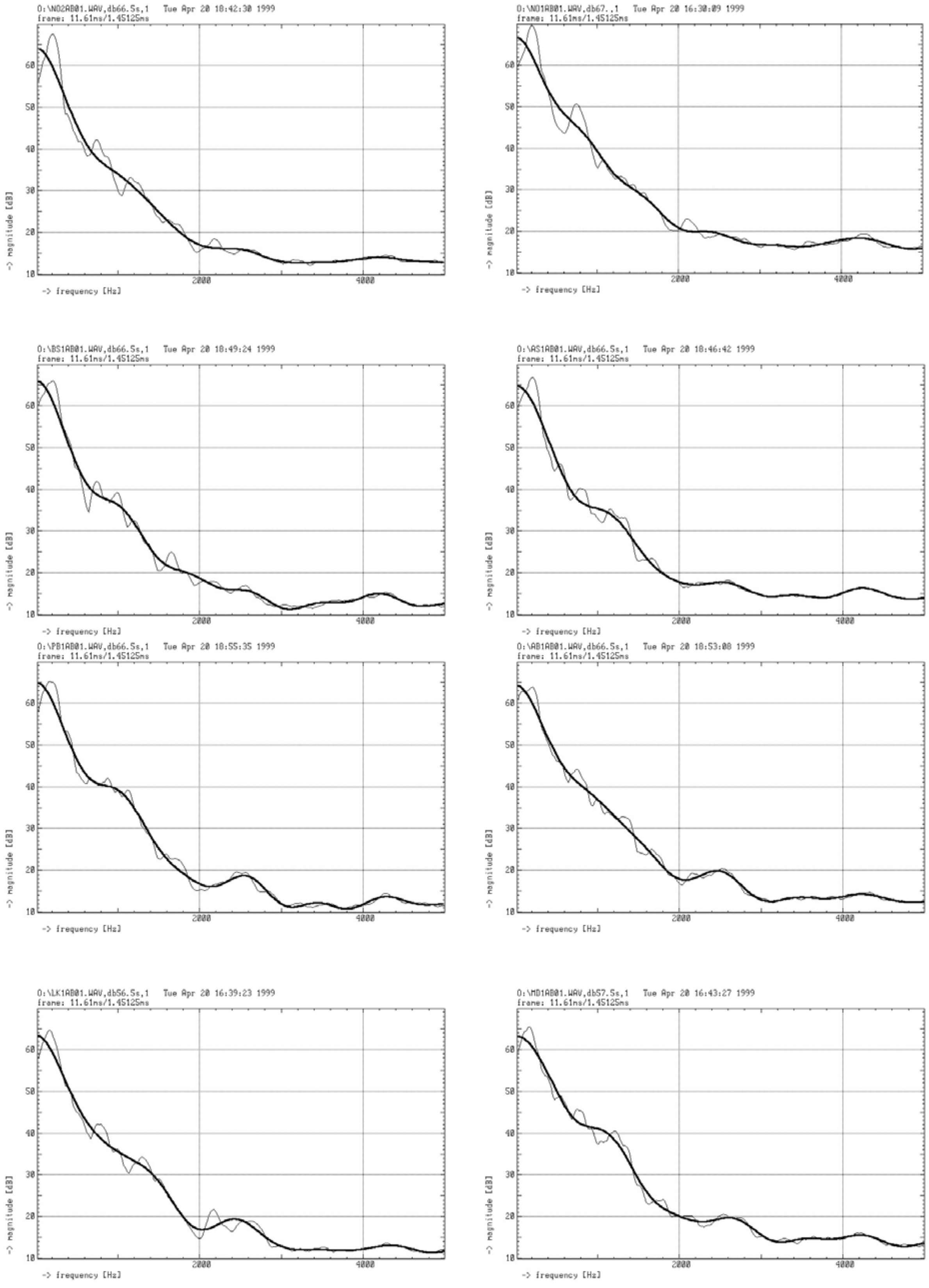
E-MAIL SURVEY QUESTIONNAIRE, FEBRUARY, 1998

Bassist Andrew Brown is writing to you from Vienna, Austria, where I am collecting information for a study on double bass bridge adjusters and how they affect the sound and playability of basses. I value your professional experience, and answers to my specific questions will help lay the groundwork for computerized acoustical tests at the Acoustical Research Center (IWK, Wien), planned for the spring of ´98.

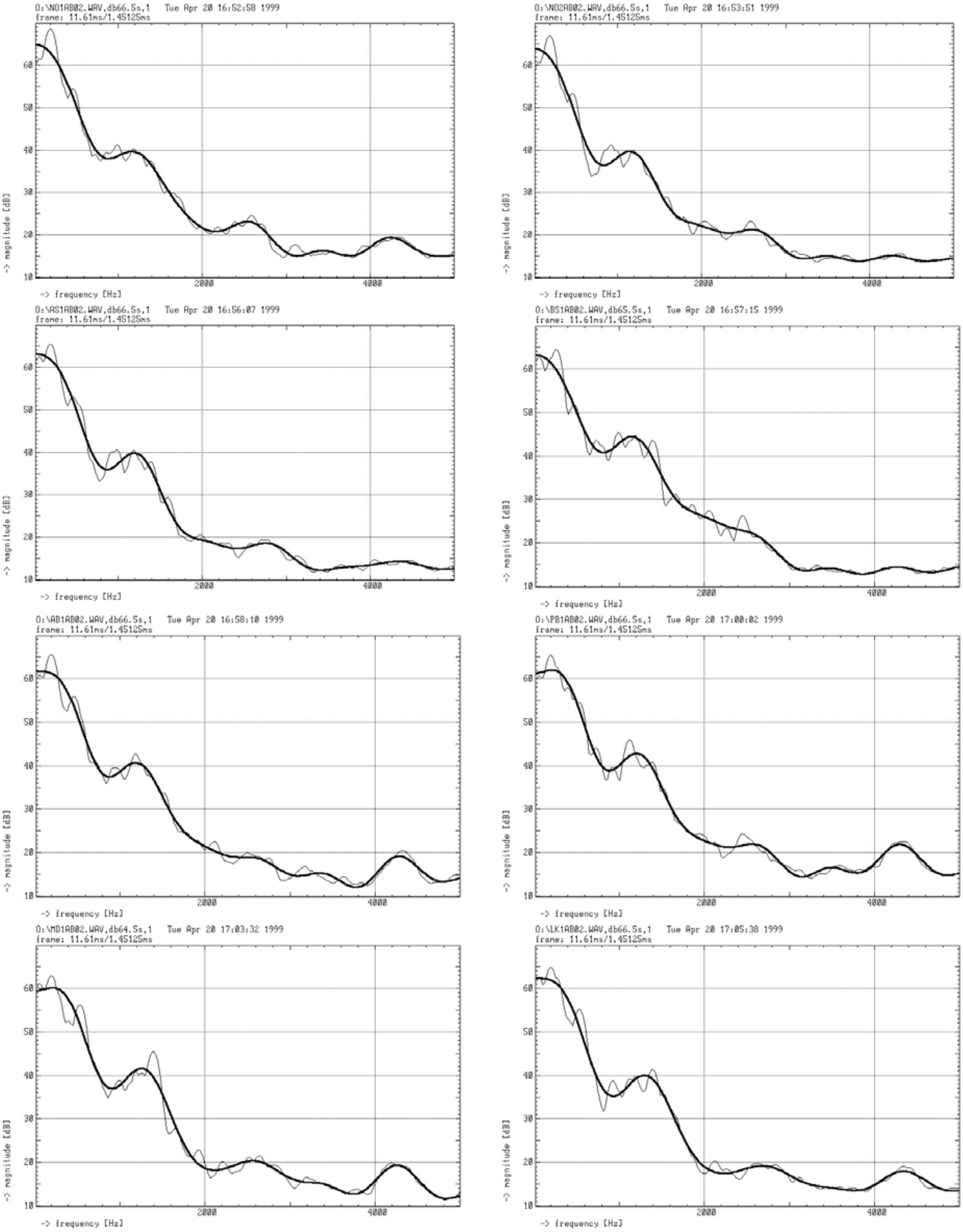
a) What are the playing advantages of wheel/ screw bridge adjusters?
b) What effect on the sound of a bass does the mounting of such adjusters cause?
c) Do you find the use of such adjusters necessary, helpful, unnecessary, or detrimental to bass playing?
d) Any other comments considering the regional, climatic, stylistic, aesthetic aspects of adjusters, or regarding the various available adjuster materials would be relevant to my thesis topic, and tips on existing research would be of much help.

I'm looking forward to sharing my results with you!

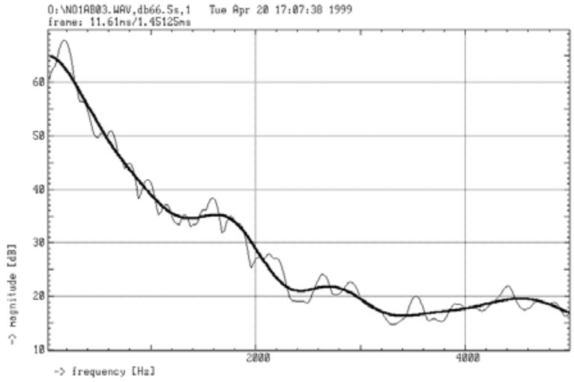
FFT Table 1, Massive bridge, Massive Bridge Comparison, Aluminum Standard, Brass Standard, Aluminum Boehm, Polyamide Boehm, Maple DiLeone, and Lignum Vitae Kohlstein

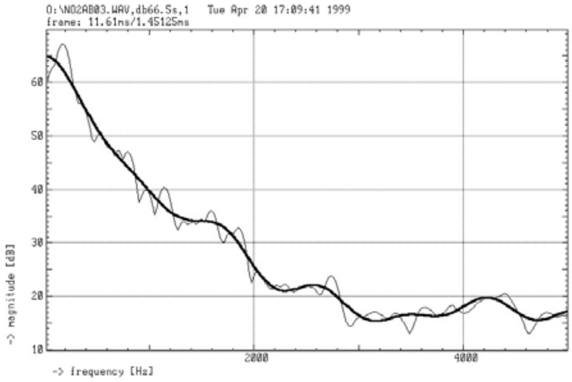


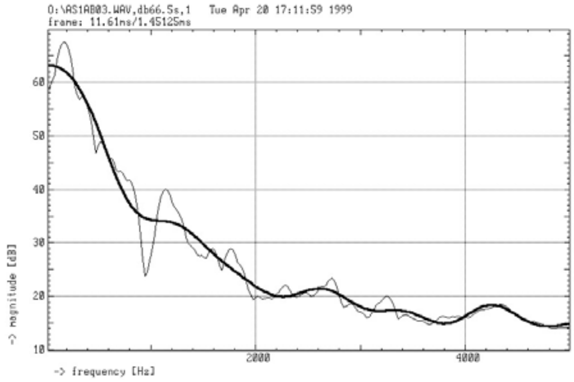
FFT Table 2, Massive bridge, Massive Bridge Comparison, Aluminum Standard, Brass Standard, Aluminum Boehm, Polyamide Boehm, Maple DiLeone, and Lignum Vitae Kohlstein

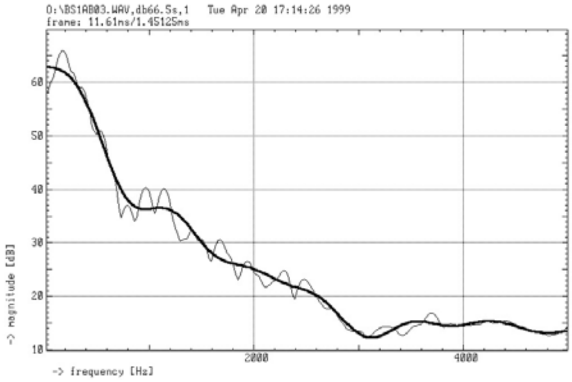


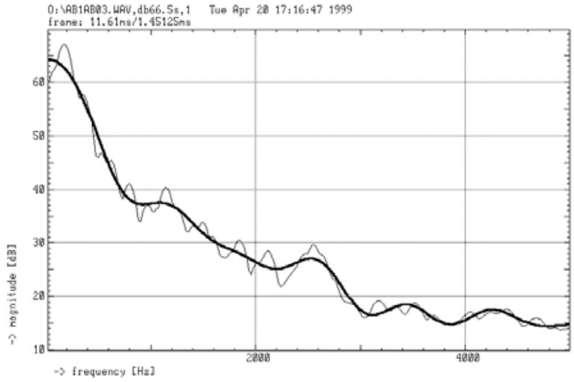
FFT Table 3, Large F (ca.87 Hz), Massive bridge, Massive Bridge Comparison, Aluminum Standard, Brass Standard, Aluminum Boehm, Polyamide Boehm, Maple DiLeone, and Lignum Vitae Kohlstein

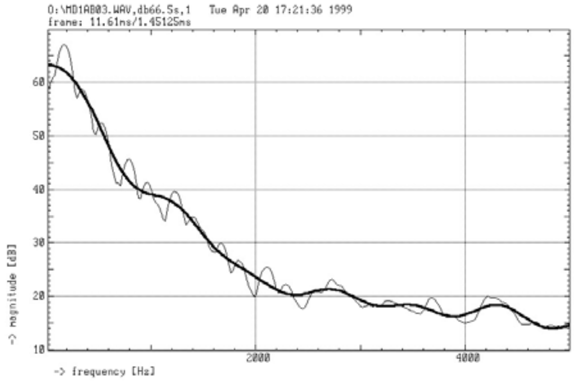


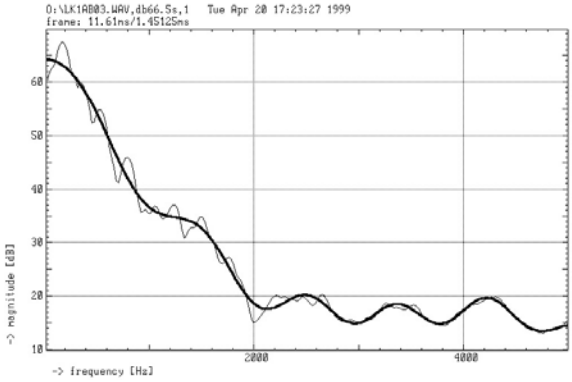




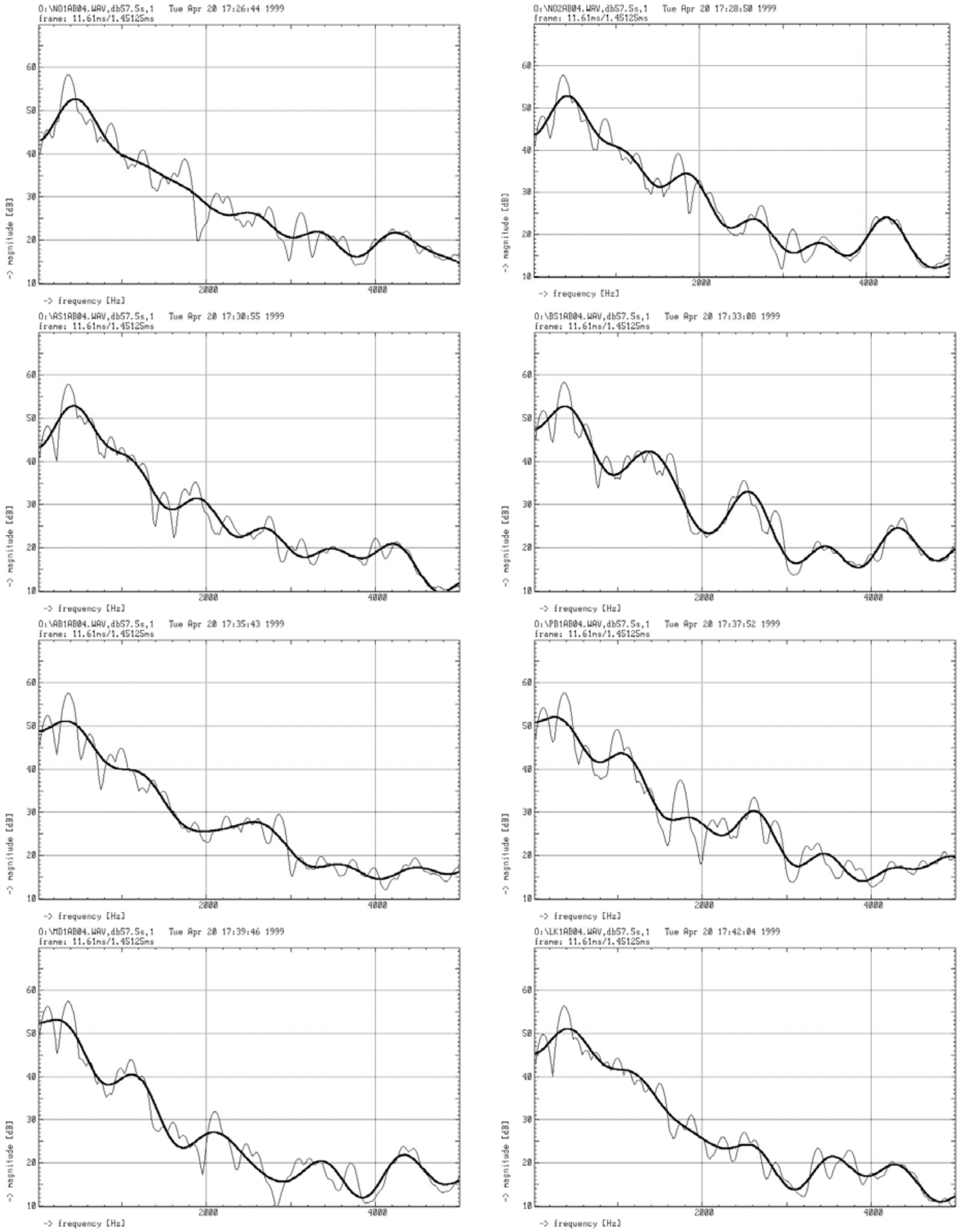




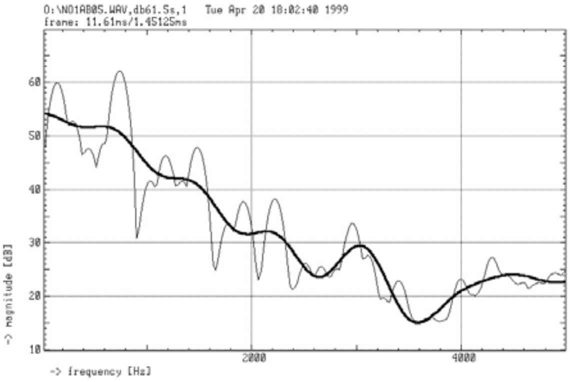


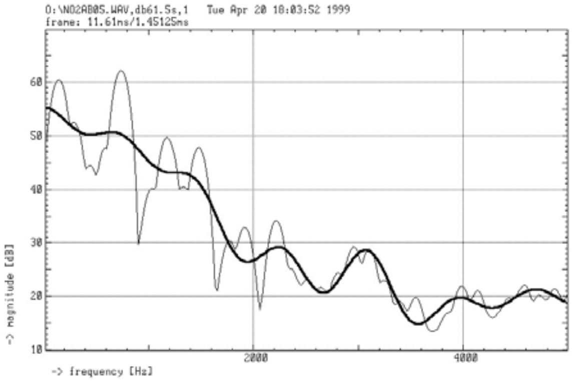


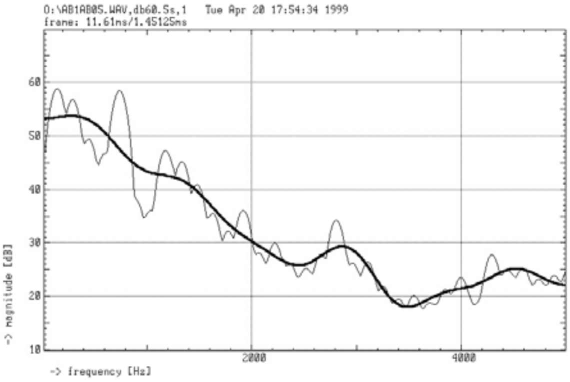
FFT Table 4, Large B (ca.123 Hz), Massive bridge, Massive Bridge Comparison, Aluminum Standard, Brass Standard, Aluminum Boehm, Polyamide Boehm, Maple DiLeone, and Lignum Vitae Kohlstein

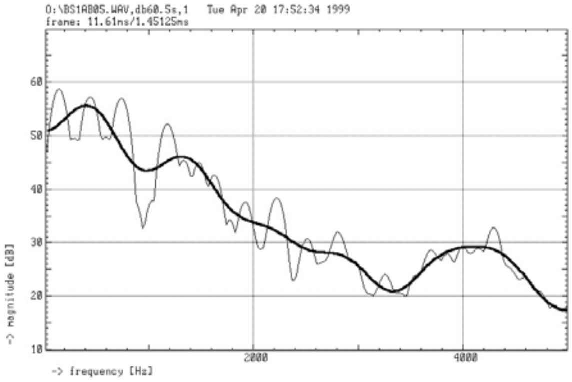


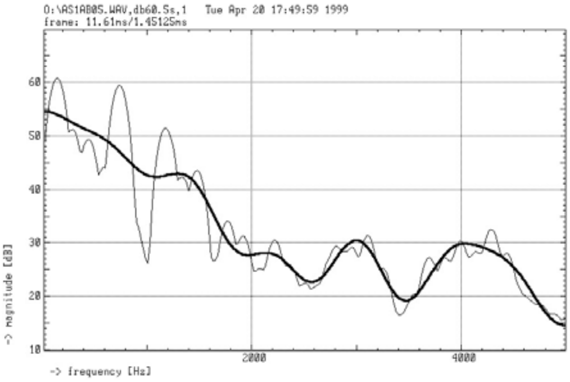
FFT Table 5, Small d (ca.146 Hz), Massive bridge, Massive Bridge Comparison, Aluminum Standard, Brass Standard, Aluminum Boehm, Polyamide Boehm, Maple DiLeone, and Lignum Vitae Kohlstein

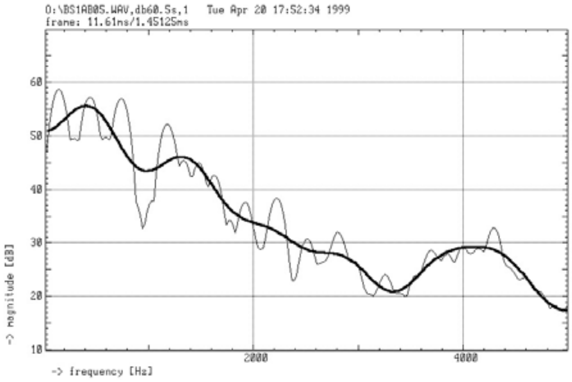


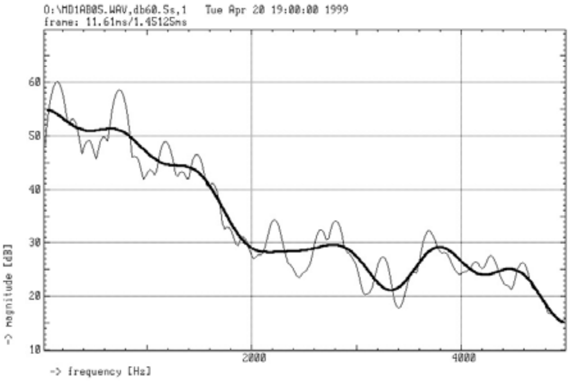


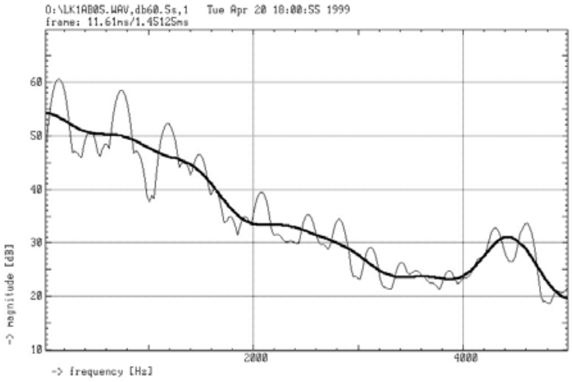




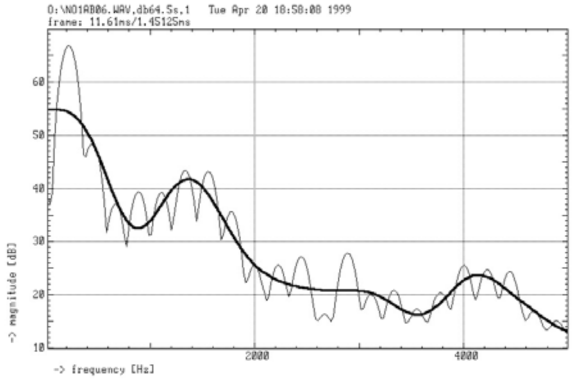


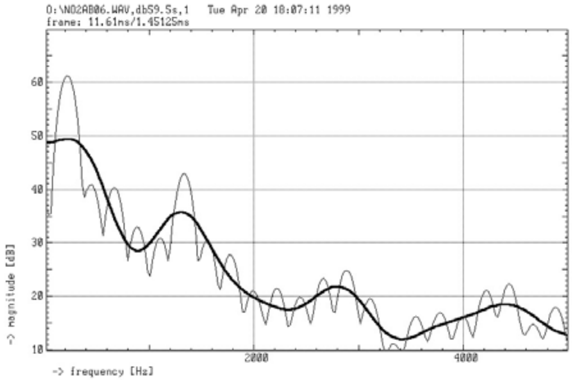


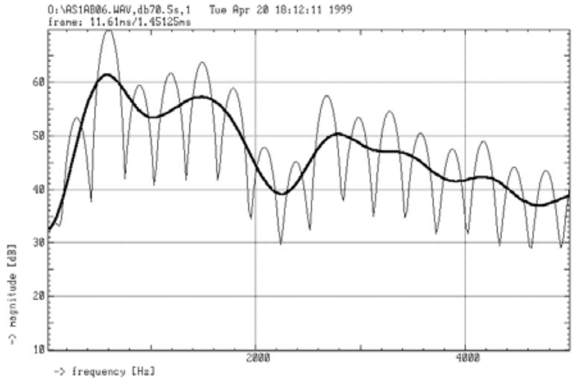


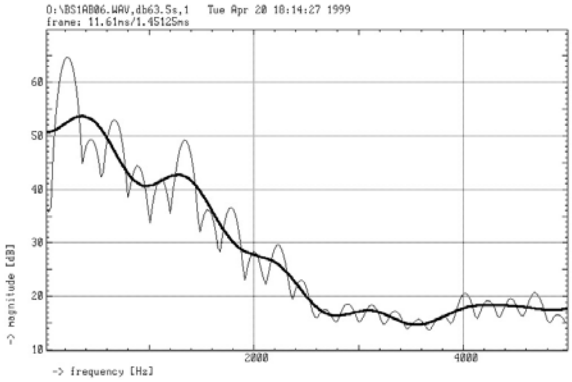


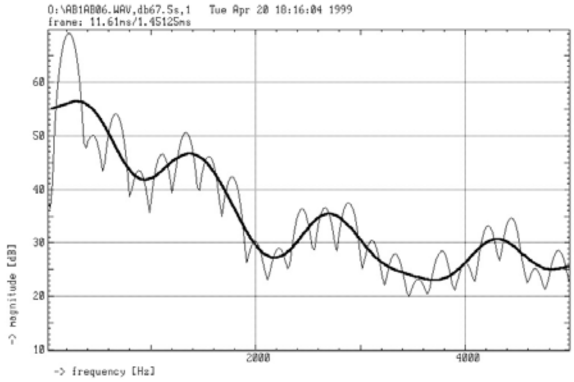
FFT Table 6, Small a, (ca.220 Hz), Massive bridge, Massive Bridge Comparison, Aluminum Standard, Brass Standard, Aluminum Boehm, Polyamide Boehm, Maple DiLeone, and Lignum Vitae Kohlstein

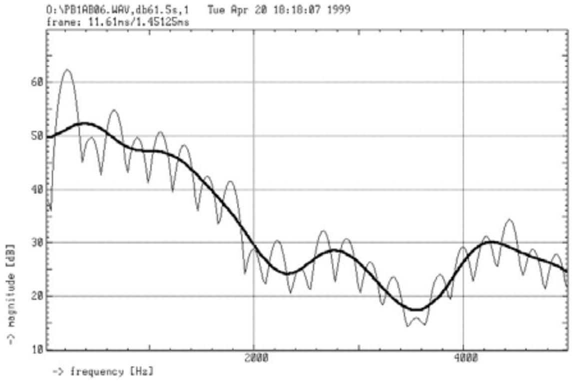


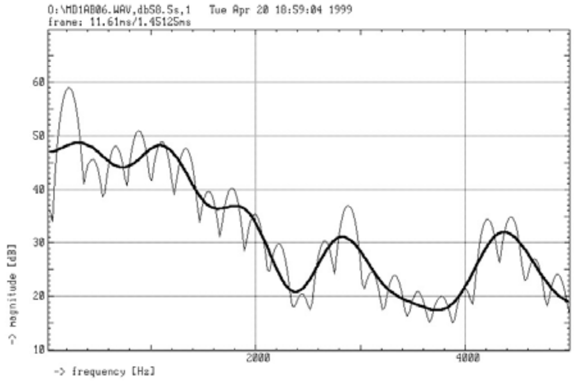


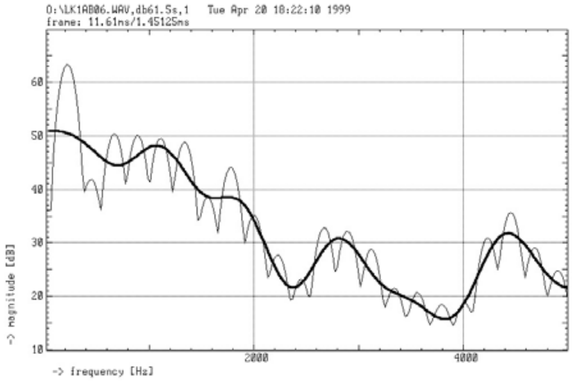




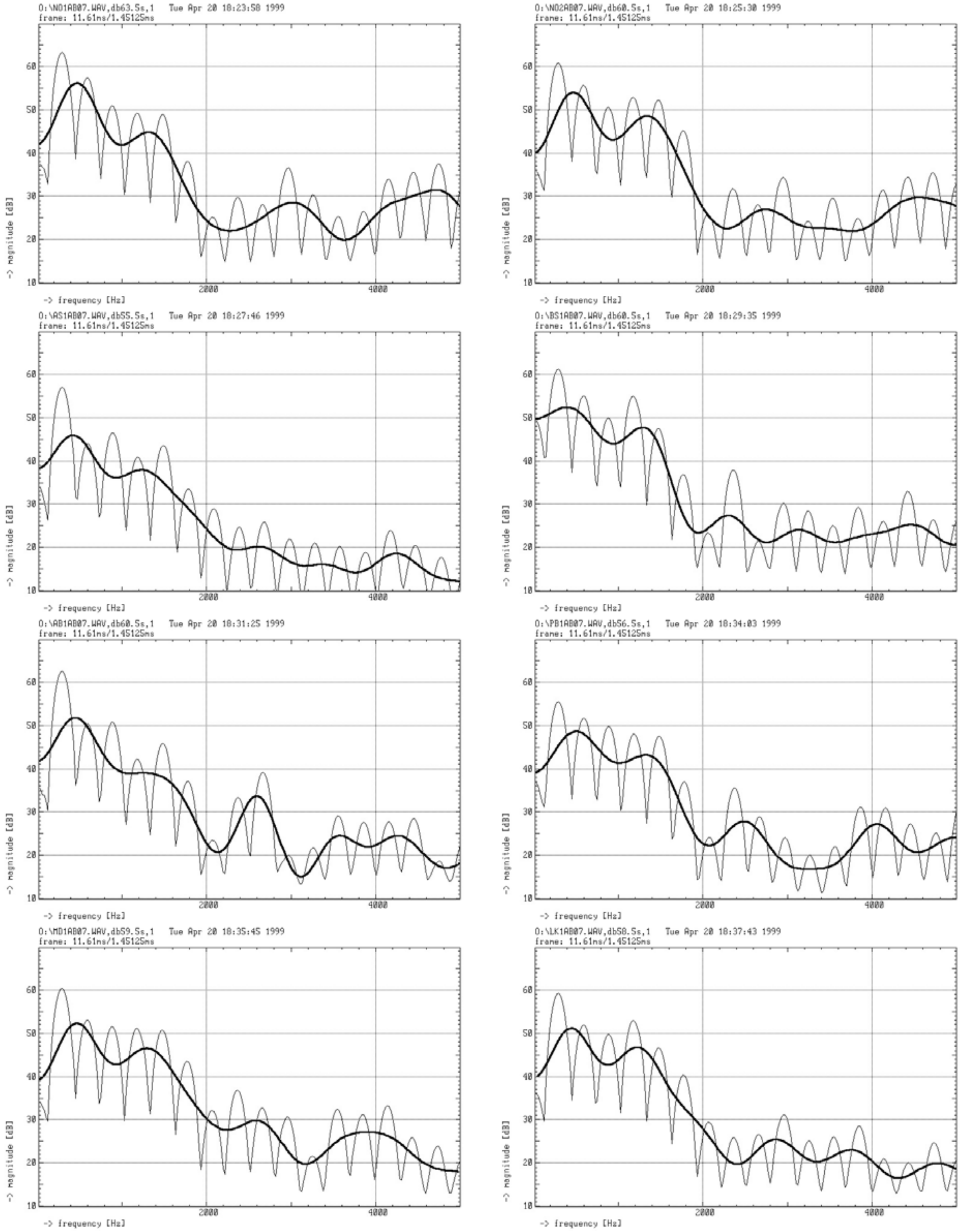








FFT Table 7, d1 (ca.293 Hz), Massive bridge, Massive Bridge Comparison, Aluminum Standard, Brass Standard, Aluminum Boehm, Polyamide Boehm, Maple DiLeone, and Lignum Vitae Kohlstein



Pizzicato Test 1, Data Table 1

pizz forte, open E	Magnitude max (dB)	Magnitude (+100ms) (dB)	time (-40dB) (s)	max - 40dB	diff 100ms
Massive Bridge	77,1 dB	70,4 dB	2,4	37,1 dB	6,7 dB
Aluminum Standard	75,3 dB	71,9 dB	2,5	35,3 dB	3,4 dB
Brass Standard	76,4 dB	70,5 dB	2,4	36,4 dB	5,8 dB
Aluminum Boehm	75,5 dB	69,4 dB	2,7	35,5 dB	6,1 dB
Polyamide Boehm	75,0 dB	69,5 dB	2,7	35,0 dB	5,5 dB
Maple DiLeone	75,1 dB	69,8 dB	2,4	35,1 dB	5,3 dB
Lignum Vitae Kolstein	76,0 dB	70,4 dB	2,1	36,0 dB	5,7 dB
Mittelwert	75,8 dB	70,3 dB	2,4	35,8 dB	5,5 dB
Minimum	75,0 dB	69,4 dB	2,1	35,0 dB	3,4 dB
Maximum	77,1 dB	71,9 dB	2,7	37,1 dB	6,7 dB
Differenz	2,1 dB	2,6 dB	0,6	2,1 dB	3,4 dB

pizz forte, open A	Magnitude max (dB)	Magnitude (+100ms) (dB)	time (-40dB) (s)	max - 40dB	diff 100ms
Massive Bridge	76,0 dB	71,5 dB	1,6	36,0 dB	4,5 dB
Aluminum Standard	80,6 dB	74,1 dB	2,0	40,6 dB	6,5 dB
Brass Standard	80,7 dB	75,9 dB	2,1	40,7 dB	4,8 dB
Aluminum Boehm	82,4 dB	75,9 dB	2,4	42,4 dB	6,5 dB
Polyamide Boehm	79,9 dB	74,5 dB	2,5	39,9 dB	5,5 dB
Maple DiLeone	80,7 dB	75,5 dB	2,7	40,7 dB	5,2 dB
Lignum Vitae Kolstein	80,2 dB	74,9 dB	2,7	40,2 dB	5,3 dB
Mittelwert	80,1 dB	74,6 dB	2,3	40,1 dB	5,5 dB
Minimum	76,0 dB	71,5 dB	1,6	36,0 dB	4,5 dB
Maximum	82,4 dB	75,9 dB	2,7	42,4 dB	6,5 dB
Differenz	6,4 dB	4,4 dB	1,1	6,4 dB	2,0 dB

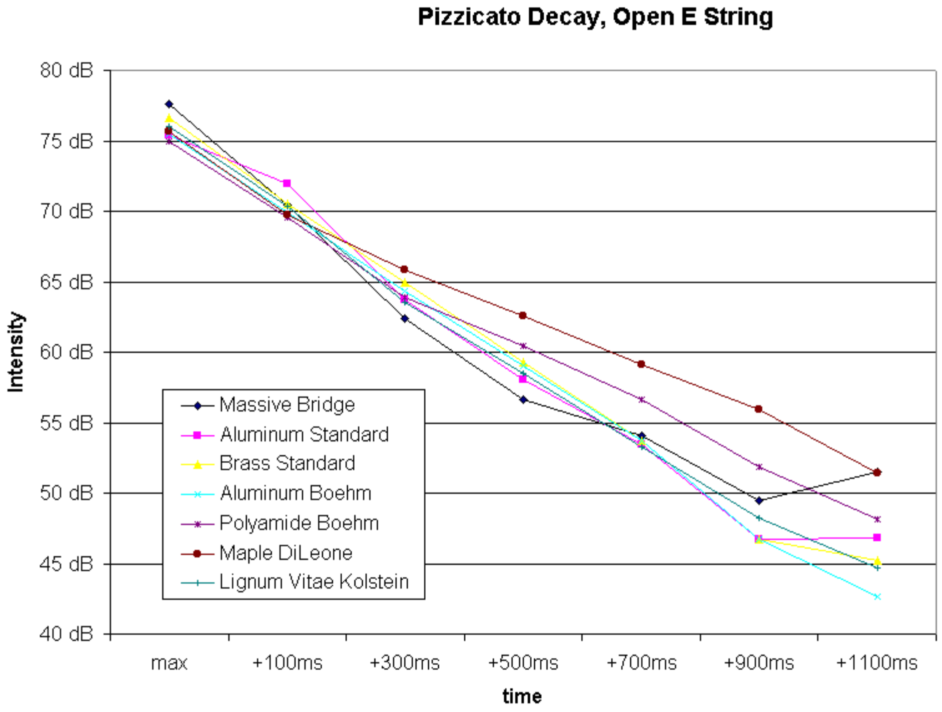
pizz forte, open D	Magnitude max (dB)	Magnitude (+100ms) (dB)	time (-40dB) (s)	max - 40dB	diff 100ms
Massive Bridge	75,0 dB	72,5 dB	6,3	35,0 dB	2,5 dB
Aluminum Standard	80,4 dB	75,1 dB	4,3	40,4 dB	5,3 dB
Brass Standard	77,9 dB	75,0 dB	5,2	37,9 dB	2,9 dB
Aluminum Boehm	79,0 dB	76,1 dB	5,7	39,0 dB	2,9 dB
Polyamide Boehm	75,3 dB	73,3 dB	6,2	35,3 dB	2,0 dB
Maple DiLeone	73,8 dB	70,2 dB	6,9	33,8 dB	3,6 dB
Lignum Vitae Kolstein	75,8 dB	73,0 dB	6,4	35,8 dB	2,8 dB
Mittelwert	76,7 dB	73,6 dB	5,9	36,7 dB	3,1 dB
Minimum	73,8 dB	70,2 dB	4,3	33,8 dB	2,0 dB
Maximum	80,4 dB	76,1 dB	6,9	40,4 dB	5,3 dB
Differenz	6,6 dB	5,9 dB	2,6	6,6 dB	3,3 dB

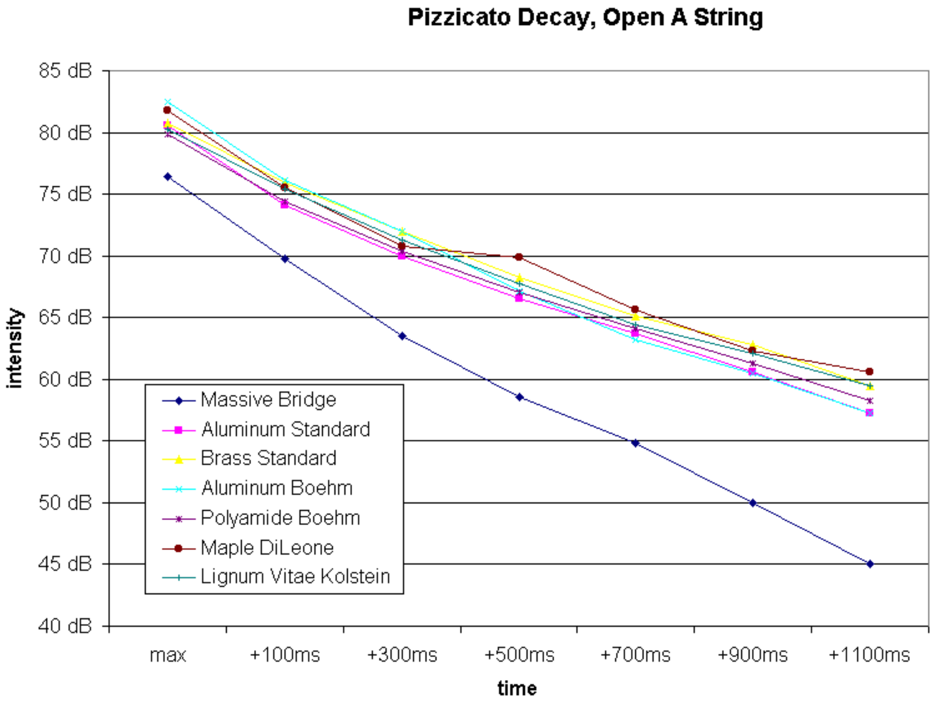
pizz forte,open G	Magnitude max (dB)	Magnitude (+100ms) (dB)	time (-40dB) (s)	max - 40dB	diff 100ms
Massive Bridge	80,8 dB	74,3 dB	2,1	40,8 dB	6,4 dB
Aluminum Standard	82,0 dB	77,2 dB	2,9	42,0 dB	4,8 dB
Brass Standard	81,7 dB	75,2 dB	2,5	41,7 dB	6,5 dB
Aluminum Boehm	80,4 dB	72,8 dB	2,8	40,4 dB	7,6 dB

Polyamide Boehm	80,4 dB	72,9 dB	1,8	*40,4 dB*	7,5 dB
Maple DiLeone	82,4 dB	76,5 dB	1,8	*42,4 dB*	5,9 dB
Lignum Vitae Kolstein	82,8 dB	75,3 dB	1,4	*42,8 dB*	7,5 dB
Average	*81,5 dB*	*74,9 dB*	*2,2*	*41,5 dB*	*6,6 dB*
Minimum	*80,4 dB*	*72,8 dB*	*1,4*	*40,4 dB*	*4,8 dB*
Maximum	*82,8 dB*	*77,2 dB*	*2,9*	*42,8 dB*	*7,6 dB*
Difference	*2,4 dB*	*4,4 dB*	*1,5*	*2,4 dB*	*2,8 dB*

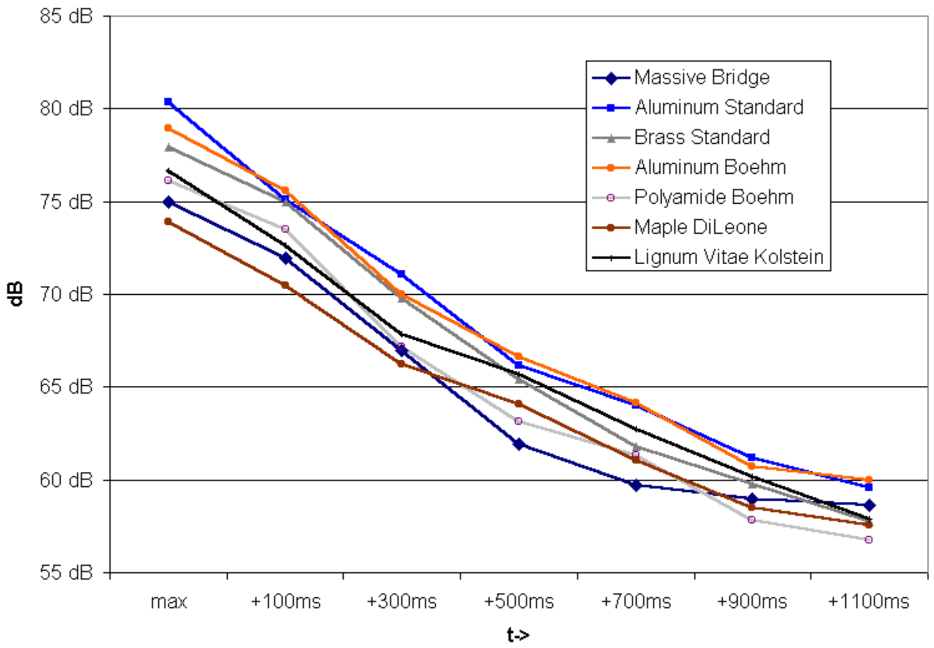
pizz forte, open G harmonic	**Magnitude max (dB)**	**Magnitude (+100ms) (dB)**	**time (-40dB) (s)**	**max - 40dB**	**diff 100ms**
Massive Bridge	76,7 dB	68,2 dB	2,0	*36,7 dB*	8,5 dB
Aluminum Standard	80,0 dB	69,2 dB	3,3	*40,0 dB*	10,7 dB
Brass Standard	79,1 dB	72,4 dB	2,8	*39,1 dB*	6,6 dB
Aluminum Boehm	76,3 dB	70,0 dB	3,0	*36,3 dB*	6,3 dB
Polyamide Boehm	78,1 dB	70,6 dB	1,7	*38,1 dB*	7,5 dB
Maple DiLeone	73,7 dB	68,5 dB	2,2	*33,7 dB*	5,3 dB
Lignum Vitae Kolstein	77,1 dB	68,1 dB	1,5	*37,1 dB*	8,9 dB
Mittelwert	*77,3 dB*	*69,6 dB*	*2,4*	*37,3 dB*	*7,7 dB*
Minimum	*73,7 dB*	*68,1 dB*	*1,5*	*33,7 dB*	*5,3 dB*
Maximum	*80,0 dB*	*72,4 dB*	*3,3*	*40,0 dB*	*10,7 dB*
Differenz	*6,3 dB*	*4,3 dB*	*1,8*	*6,3 dB*	*5,5 dB*

Pizzicato Test 2 (over 1100 ms), All Variables

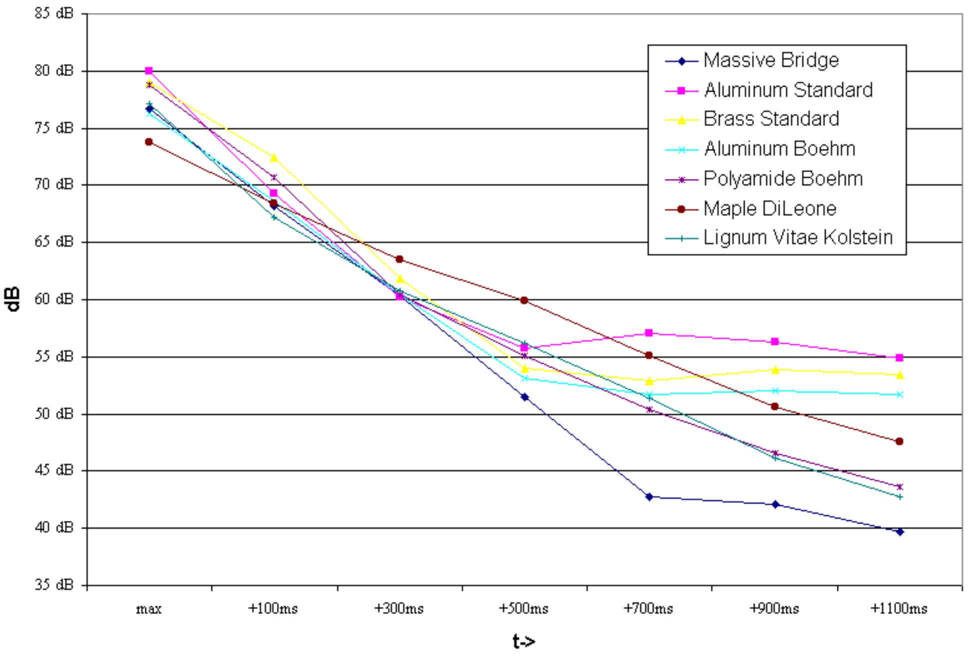


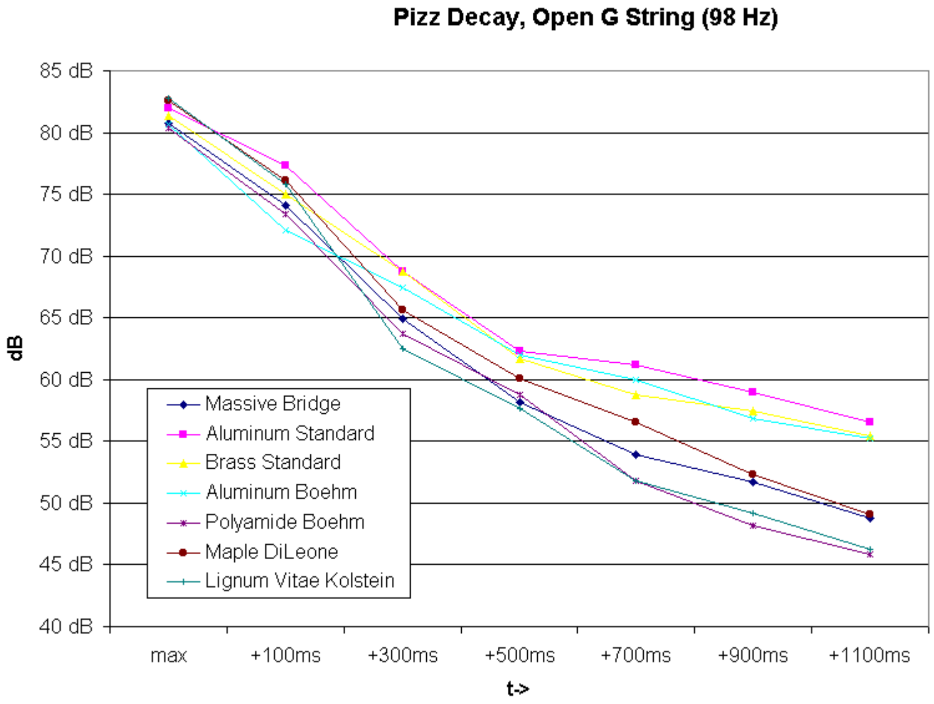


Pizzicato Decay, Open D String (73 Hz)

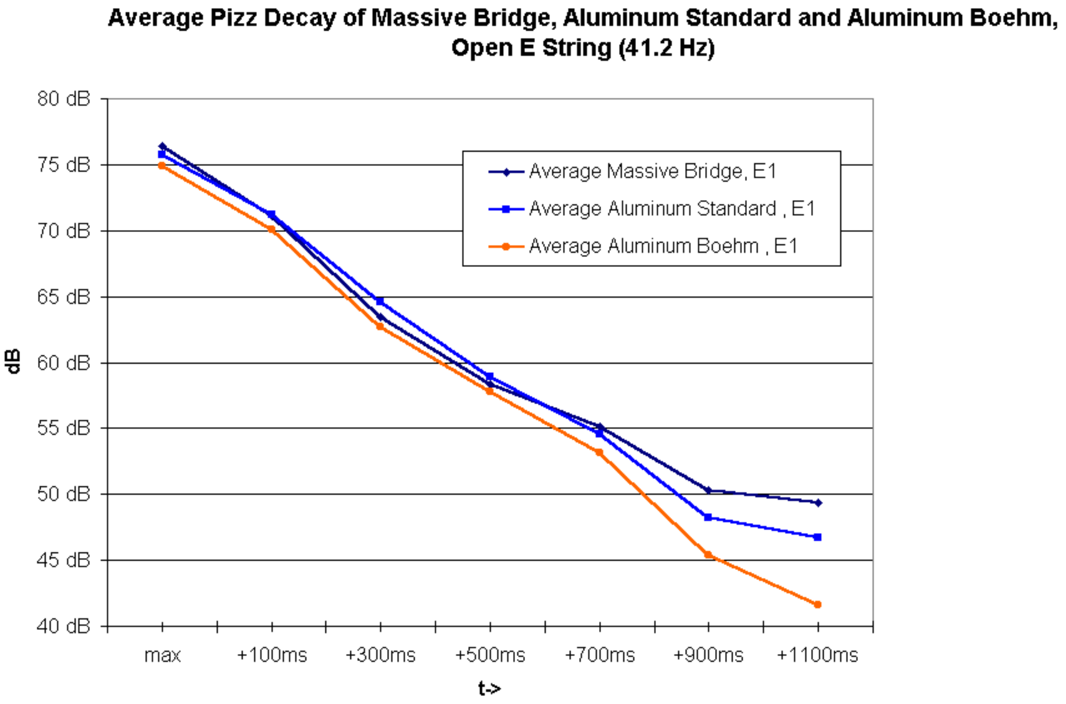


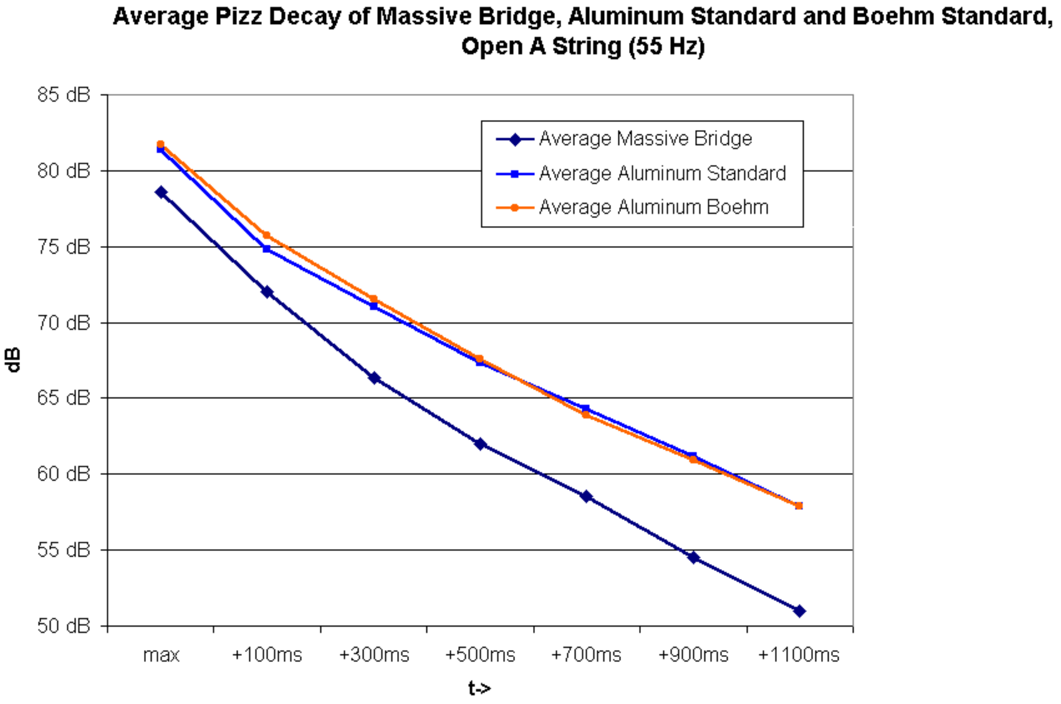
Pizzicato Decay, Open G String Octave Harmonic (196 Hz)



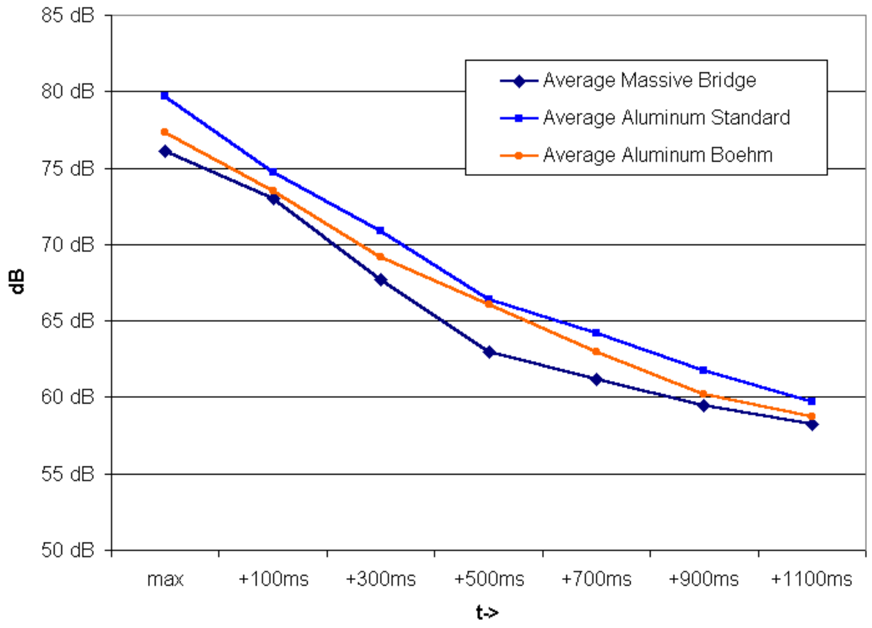

Pizz Decay, Open G String (98 Hz)
85 dB
80 dB
75 dB
70 dB
65 dB
60 dB
55 dB
50 dB
45 dB
40 dB
dB
max
+100ms
+300ms
+500ms
+700ms
+900ms
+1100ms
t->
Massive Bridge
Aluminum Standard
Brass Standard
Aluminum Boehm
Polyamide Boehm
Maple DiLeone
Lignum Vitae Kolstein

Pizzicato Test 2: Comparison of Massive Bridge and Metal Adjusters

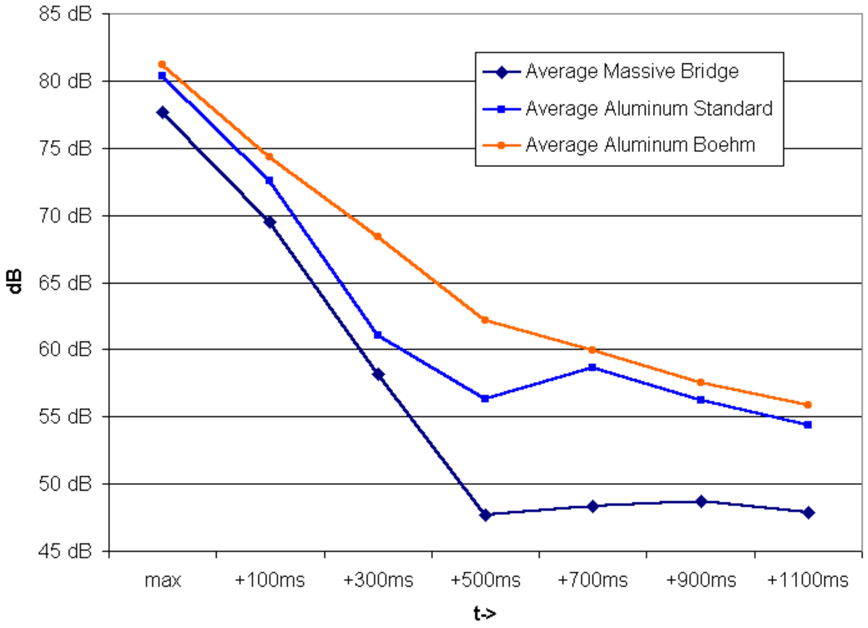




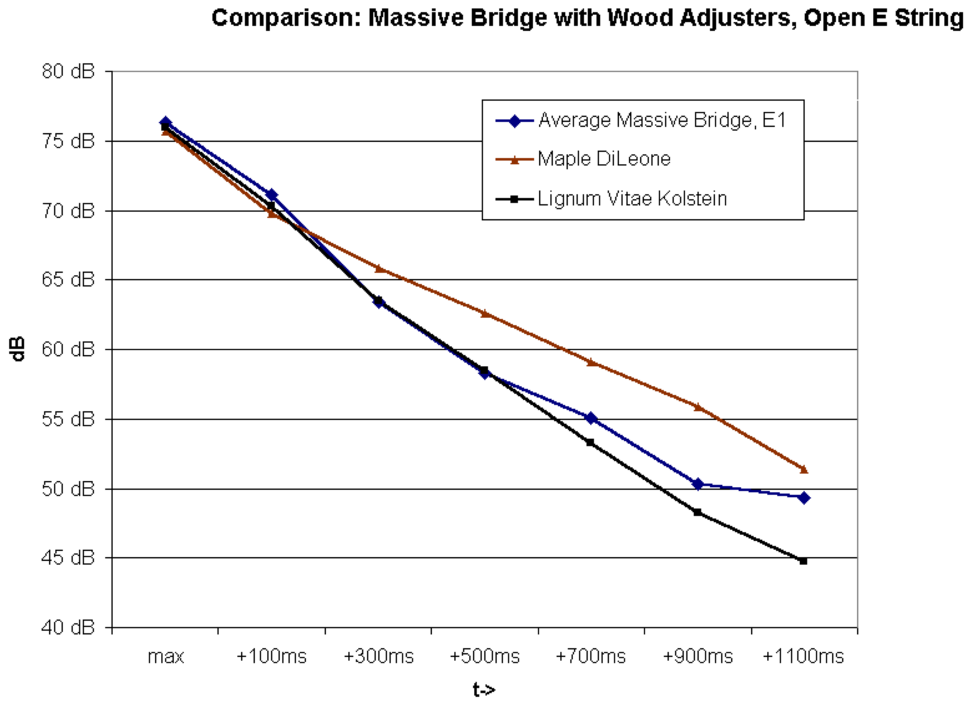
Average Pizz Decay of Massive Bridge, Aluminum Standard and Aluminum Boehm, Open D String (73.4 Hz)

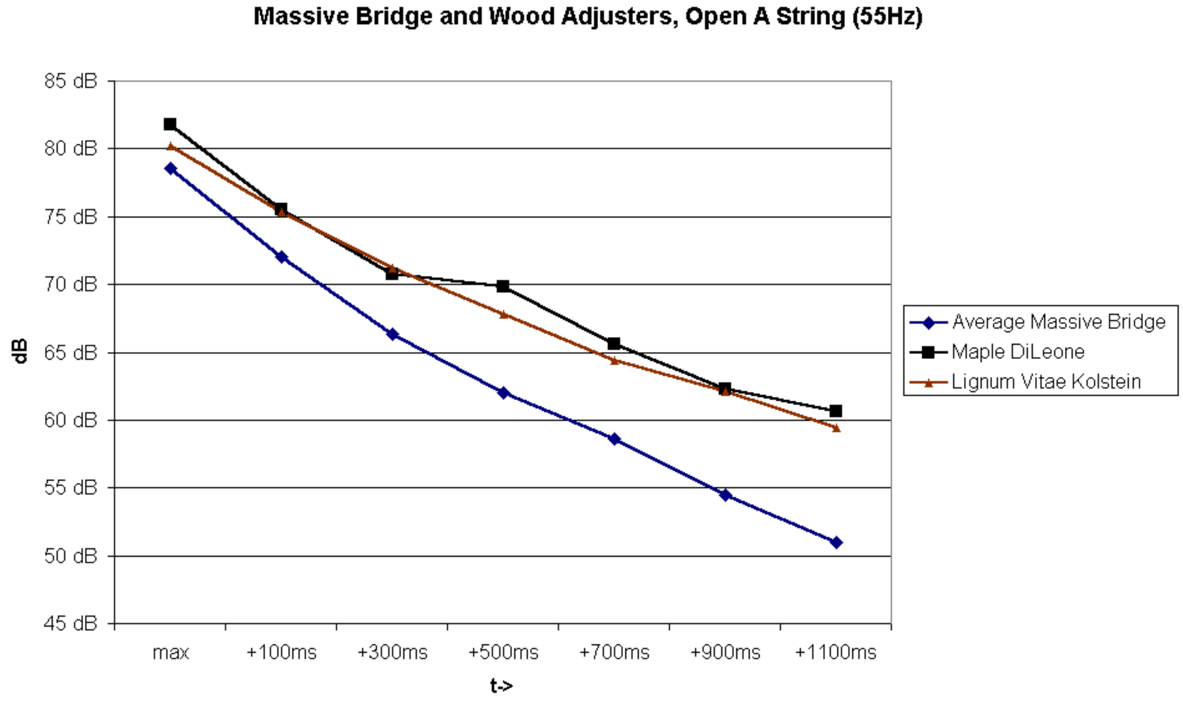


Average Pizz Decay of Massive Bridge, Aluminum Standard and Aluminum Boehm, Open G String (98Hz)

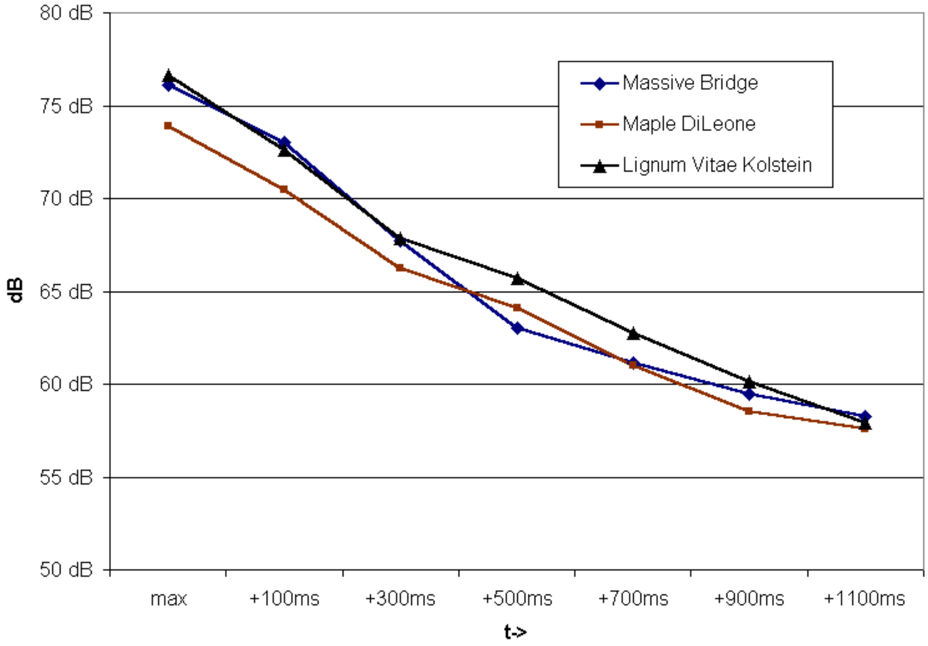


Pizzicato Test 2: Comparison of Massive Bridge and Wooden Adjusters

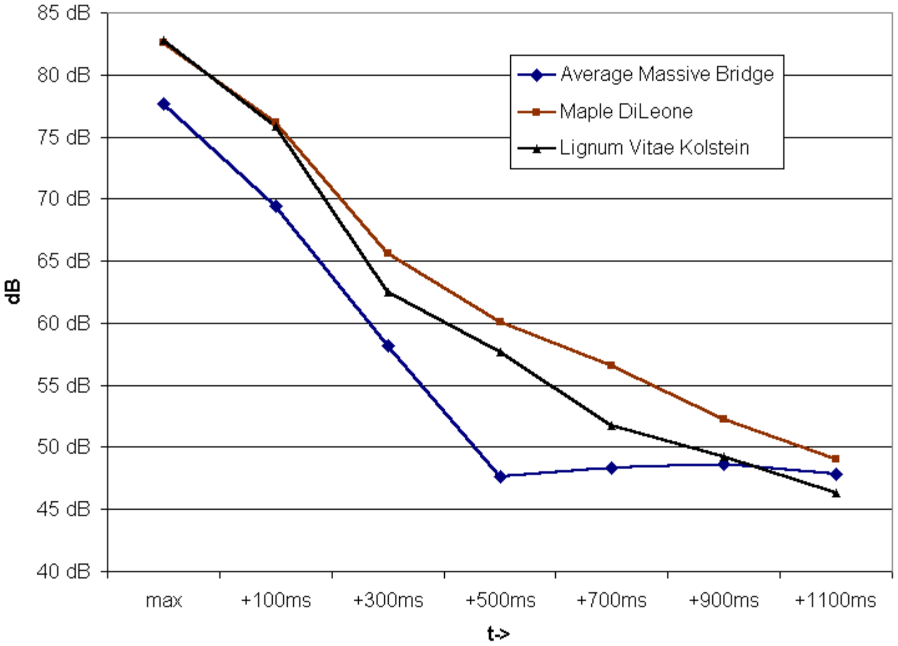




Massive Bridge and Wood Adjusters, Open D String (73.4 Hz)



Massive Bridge and Wood Adjusters, Open G String (98 Hz)



Subjective Findings

In the course of this study I have often been asked, "So, which one of the adjusters is best?" The answer to this question, though not the 'official' goal of this study, is somehow still implied, to which I can only offer my experienced opinion as a researcher and most of all a bassist.

First impressions

My colleague and I noted some differences immediately after changing the adjusters during the recording session. It is unusual that a player has the chance to hear the difference bridge height adjusters can make on the sound one after the other. We remarked simply that the aluminum standard adjusters made the sound possibly "freer" than the massive bridge previously recorded, but the difference caused by the next model inspired more detailed comment. The brass standard model was found by A.R. to be "more structurally sound" (in tone quality) than aluminum, and "less nasal" sounding. I found the sound "more focused in the lower frequencies" but "muted" in the middle range. We recorded no notes for the next adjuster, the aluminum Boehm, but found the following polyamide model "generally weaker, less fundamental", and the "tone less stable". My favorite during the tests was the more eaven-sounding maple model of DiLeone, while the final model, lignum vitae Kolstein seemed "dead" in comparison.

Working with the Kolstein model

It occurred to me only after the test that one parameter was not controlled effectively: the gap between the top surface of the adjuster wheel and the corresponding bridge leg. Since the bridge height remained constant while the thickness of the wheels increased, the gap in the sawn portion of the leg was reduced as the larger adjusters were installed. I believe the vibrating characteristics of the bridge are influenced by this gap and cause it to move more freely as the gap increases. Playing the test instrument with the lignum vitae adjusters after the test was difficult because of low dynamic output and sluggish response. Pizzicato notes "died" immediately, causing me to "hate" the adjusters. But I successfully altered them for a better sound by removing more bridge wood to increase the gap, and by trimming some of the axles from the non-threaded portion. The increase in gap or decrease of mass of the adjusters, or both, improved pizzicato sustain, tone color and response.

Integrity of the instrument

Bridge height adjusters alter the sound of the double bass. During the entire project, I encountered the opinion of purists opposed to bridge height adjusters who argued that they interfere with the natural tone of the instrument. It is clear that the sound is influenced, but think the player may use the differences to his own advantage to create his ideal tonal characteristics. After all, the same bass will probably sound different with each bridge that is cut differently or of a different wood. Players also must be cautious using adjusters because they can damage a double bass, especially if improperly installed. Besides gouging the table if the axle is too long for the drilled hole, adjusters must be perfectly cut and drilled to avoid putting uneven pressure on the table. Since the legs of my test bridge are on a slight angle and not parallel, this pressure has caused visible warping of the table under the treble (sound post) leg of the bridge. I find it urgent to have a new bridge fitted as soon as possible to avoid further trouble.

Recommendations for bridge height adjuster use

To answer the question, “which adjuster is best”, one must first define the desired tone qualities. I listed a few possible categories of the “ideal bass sound”:

1. *A “natural, even tone” throughout the range of the bass*. I think there is no substitute for a massive bridge in this case. My first choice in adjusters for bowed bass in this category would be a maple adjuster with a larger diameter (DiLeone model). The polyamide model would be the worst choice for “warm” and even sound.

2. *A “bright sound with fast response”.* The aluminum standard is the choice here, which showed itself to have more harmonics in bowed tones than the massive bridge. These adjusters are somewhat louder than massive bridge but intensity is inconsistent through the range of the bass and lacking in fundamental.

3. *Long sustain of pizzicato notes.* Again, the aluminum standard is my recommendation, though all metal models have a relatively favorable sustain in the deep regions that jazz players need. The rich overtones of this model combined with its sustain make it ideal for that “twangy” jazz sound. The aluminum Boehm model, being of the same material but a larger dimension, could keep many positive qualities jazz while “toning down” the brilliance somewhat.

4. *A “dark” sound*. Brass sounds strong in low registers and has a similar spectrum to the massive bridge. But while it is rich in the fundamental, overtones and volume become increasingly weak as the frequency increases. For a sound not quite as dark but more even, the massive bridge or maple DiLeone is recommended.

5. *A “soloistic sound”.* If this description means a brilliant sound, than aluminum is the choice. But my experience shows that aluminum can be “thin” or “scratchy” in the high registers. I rather think “robust”, “compact”, “even”, and “overtone” rich are words to describe my ideal solo sound, which are better achieved with a massive bridge. My next choices would be the maple DiLeone or aluminum Boehm.

6. *“General Purpose”.* For the all-around player, I would follow the maxim stated by Lou DiLeone: maple is good for bowing and aluminum is good for jazz. If the player plays both styles, I recommend the aluminum standard model.

Chapter 8: Resumè

Born in January 11, 1969 in Maryland, U.S.A.

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