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BRASS WIND INSTRUMENT QUALITY MEASURED AND EVALUATED BY A NEW COMPUTER SYSTEM

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SUMMARY

For the player of brass wind instruments, instrument quality is mainly defined by three parameters: intonation, responsiveness and timber. The problem is, that there exists no direct relationship between such "player defined" quality criteria and the data obtained by physical measurements. This paper presents methods how to get results which are in accordance with practical playing experience and highly confirmed by professional players. Data acquisition and processing is done with a new developed software under Windows using a DSP-based PC-workstation.

INTRODUCTION

For the audience the definition of musical instrument quality is commonly reduced to the quality of the radiated sound in the far field. The listener can only valuate the sound of the instrument produced by the player. Quite different is the situation for the player himself, the quality of an instrument includes some more important aspects as there are: RESPONSIVENESS. Means: how easy it is for the player to produce a note with the instrument. Usually these values vary with the dynamic level and the frequency of the played note.

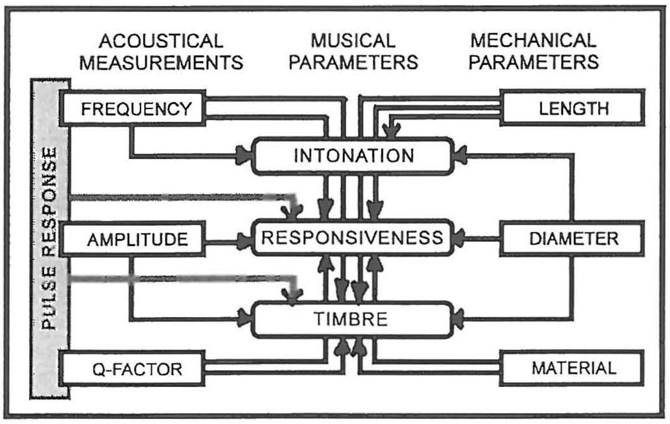
INTONATION. Means: how good do the notes -offered by the instrument- correspond with the equally tempered scale; an important criterium of quality of wind instruments.

TIMBRE. Easy to measure by using FFT algorithms. The assessment however depends on the purpose (classical music, jazz, etc.) and the individual imagination of a "beautiful timbre".

Beside these three main criteria the kind of action of the valves (influences the microstructure of a slur) can be an important criterium of selection by the player. For form´s sake it should be mentioned, that subjective aesthetic aspects like the design and colour of an instrument or the used material can sometimes highly influence the evaluation of quality by the player. Since our approach is the measurement and evaluation of objective quality criteria, such aesthetic aspects are not a subject of our interest, that´s up to each player himself.

RELATIONSHIP BETWEEN PLAYER DEFINED QUALITY AND ACOUSTICAL PARAMETERS

The problem is that we have to deal with quality criteria defined by musicians and expressed in their own terminology. There exists (beside the intonation) no monocausal relationship between such player defined criteria and the data obtained by acoustical measurements. The complex relationship between musical quality parameters, mechanical parameters of the instrument and the data of acoustical measurements shows the schema below. As it can be seen, the player defined quality criteria can be calculated using the data of input impedance and pulse response measurement. General information about the acoustics of brasses, particularly about the relationship between input impedance data and playable notes of an instrument are given in [1], more details about the measurement arrangement and the conception of the used hard- and software can be found in [2]. To get useful data the measurement of input impedance has to be done in the plain of the player´s lips inside the mouthpiece.



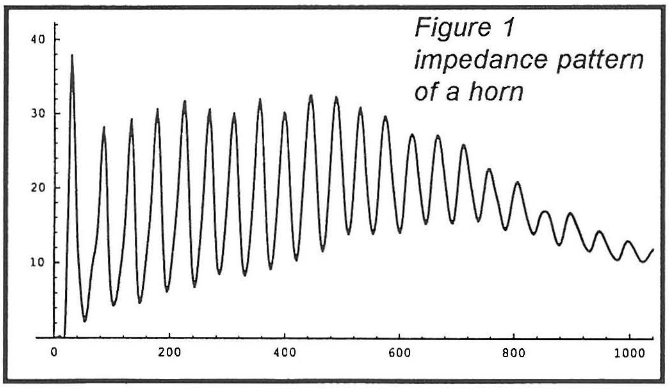


Figure 1
impedance pattern of a horn

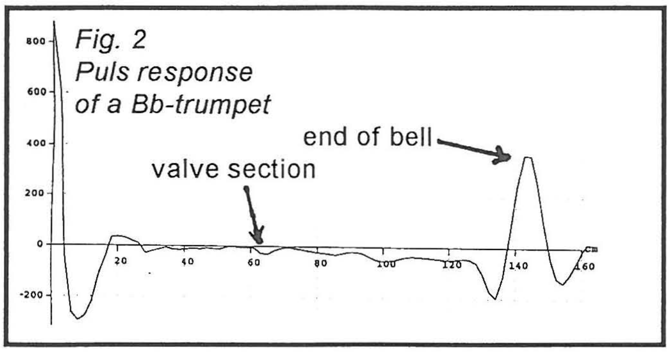


Fig. 2
Puls response of a Bb-trumpet

As the peaks of such an impedance pattern (Fig.1) mark the frequencies of the playable notes of the instrument, the deviation due to the equally tempered scale is easy to calculate. Measurements in the frequency domain like impedance measurements give already good informations on the intonation characteristic, but no direct information on parameters which are helpful to calculate values for the responsiveness, like the settling time of the instrument, its response or effects caused by unwanted reflections inside the tube. These transient phenomena are an important part of the acoustical behaviour of a brass instrument and highly influence the „playing feeling" of the musician. Therefore measurements in the "time domain" have to be done. A combination of both measurements can provide with a sufficient quantity of data as a base material for subsequent processing.

As a realisation with an exactly defined short pulse (Dirac-pulse) causes high efforts of technical resources, we decided to calculate the pulse response of the instrument by processing the data of impedance measurement. An example is given in Fig. 2.

THE PROBLEM OF OBJECTIVE AND SUBJECTIVE QUALITY

Trying to verify the results of calculated intonation error and responsiveness by comparing the calculated values with the subjective assessment by players a new phenomenon occurs, which is well known by instrument makers because of their highly dependence on the valuation of their instruments by professional players: whilst player one is very impressed of the outstanding quality of an instrument, player two locates the same instrument only in the mid- or lower range of a quality scale (needless to say, that nearly all professional players are convinced, that their expert opinion has to be taken as an objective „factual statement"). Who is right, player one or two? The solution of the problem: both are right! A wind instrument has only **one objective quality** but may have two or **more subjective qualities**. It is caused by the fact that the player and the instrument forms (from the physical point of view) a control loop. On the one hand the produced sound primary depends on the vibration characteristics of the individual player´s lips, on the other hand the lip vibrations (=excitation spectrum) are influenced by the impedance characteristics of the instrument. Within this system, the player is represented by its excitation spectrum.

INTONATION

1. Objective intonation error. For the calculation of intonation error due to the equally tempered scale, the frequencies corresponding to the impedance peaks are determined (the peaks 1, 7, 11,13 are not included into this process). After that the pitch (a^1= xxx Hz) is determined, where the sum of the deviation of the found frequencies due to the equally tempered scale is a minimum. Finally the deviation of each playable note (=impedance peak) from the reference pitch -determined in step two- is calculated and displayed in "cent".

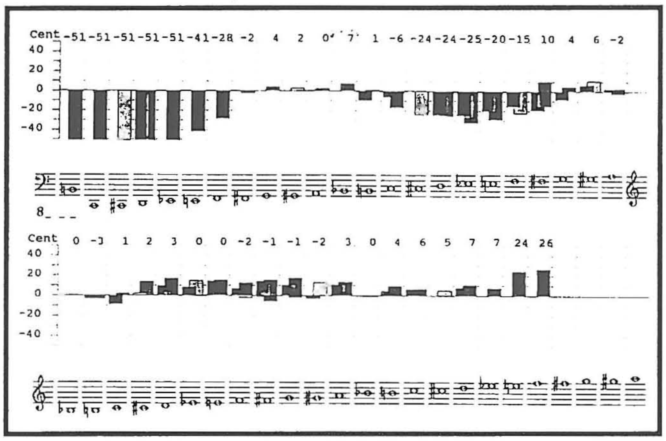


Fig. 3: Objective intonation of a horn. The bars indicate the deviation due to the tempered scale (color print).

2. Subjective intonation error. According to the definition of the excitation signal during the measuring procedure, the calculated intonation values are valid only for a sinosidual excitation. As the player excites the instrument with a spectrum including more or less harmonics (depending on the individual physiological setup of his lips and the dynamic level of the played note), not only the impedance peak of the fundamental frequency, but all impedance peaks corresponding with the frequencies of the harmonics of the excitation signal have to be taken under consideration. As the values of the amplitudes of the harmonics commonly are different, their contribution to the "over all value" has to be weighted according to their relative amplitude within the excitation spectrum. The result of such a procedure can be different intonation and responsiveness values for one instrument, depending on the musical dynamic level (*piano, fortissimo*) and the individual player´s lip setup. Numerous tests during the last five years proved the correctness of this method.

RESPONSIVENESS

Musicians commonly differentiate between something like an "over all responsiveness" of an instrument and the responsiveness of each single note. The value of the "over all responsiveness" corresponds with the quotient between the amplitude of the excitation pulse and the response of the bell (Fig.2). The responsiveness of a single note is primary determined by the amplitude of the corresponding peak of the impedance curve and its ratio to the neighboring maxima and minima (Fig.1). Experiments proved that the influence of the Q-factor on the responsiveness values of given instruments seems to be less important.

As the player is represented through his excitation spectrum, values for individual responsiveness can be obtained by using the above described procedure.

TIMBRE

This is the only point where we needed the help of the player. The sound of the instrument (played by the musician) is analyzed by FFT. At present we work on a method for calculating radiated sound spectra by the use of the transfer function of the instrument and standardized or individual excitation spectra.

VALVE ACTION AND MICROSTRUCTURE OF SLURS

Depending on the kind of valve (perinet, rotary) and its location related to the mouthpiece/bell, the transients of slurs can sound like a glissando or they can be seperated by a short noise band. The preference for one of these two valve systems depends on the kind of music to be interpreted and the individual musical taste.

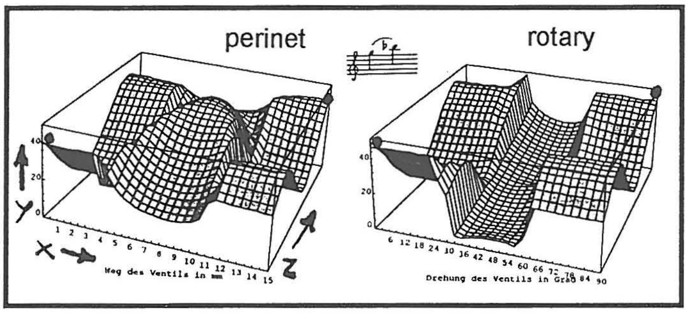


Fig. 4: Difference between Perinet- and Rotary valve. Situation for the player's lips for a slur from g2 to Bb2. (X-axis:Status of the valve from not engaged=left up to engaged=right, Y-axis: impedance, Z-Axis: frequency) Performing a slur, the player has to press down the valve button and simultaneously change the tension of his lips. The starting point (g2) in the graph is located left/front, the target point (Bb2) right/back. The graph shows, that in this particular case the rotary valve produces a short noise band ("break down" of the standing wave system).

In such a way, the kind of valve performance can be determinated without any player.

USED HARD- AND SOFTWARE

For "BIAS" (= Bras Instrument Analyzing System) a DSP-board is plugged into an ordinary PC. An external subsystem contains the ADC/DAC´s, filters and preamplifiers. The instrument is excited by a "multitone" via a special measuring head during a periode of 2 seconds. Microphon 1 is located inside the mouthpiece and picks up the response of the instrument, micro 2 is located -for reference- above the loudspeaker inside the measuring head. Both channel data are sampled down, smoothed and processed by a 16k FFT. The quotient of the magnitude of both spectra is displayed as "impedance curve" on screen (Fig.1). Calculation of pulse response is done automatically, evaluation of intonation, responsiveness, timbre, etc. can be done by a mouse click. The software requires WINDOWS and is written in C and Visual Basic. The frequency resolution is 0.5 Hz, respectively 2 cm for the pulse response. The system is calibrated in acoustic Ohms.

REFERENCES

[1] A. BENADE (1976) "The Brass Wind Instruments" in "Fundamentals of Musical Acoustics", NY, Oxford University Press, 391-430.

[2] G. WIDHOLM, W. WINKLER (1994) "Evaluation of musical instrument quality by computer systems. Examples of realisation." in "Proceedings of SMAC 93", Stockholm, Royal Swedish Academy of Music No 79, 560-565.