4.5 Rihs N., Gibiat V. and Castellengo M. : Period Doubling Production on a Bassoon.

Doublement de période au basson. L'obtention de scénarios de doublements de période a été prédite et démontrée sur des montages expérimentaux simulant des instruments à vent. Des doublements ont été observés dans des contextes particuliers mais ils n'ont en revanche pas encore été présentés comme un mode de jeu "normal" d'un instrument de musique. Nous présentons ici des résultats obtenus par l'un de nous (bassoniste) qui a fabriqué une anche permettant d'obtenir ces doublements de période. nous présentons ensuite le rôle des différents paramètres intervenant dans la description de l'instrument et montrons comment un doublement de période est possible avec une anche normale. Nous présentons ici une sélection des résultats expérimentaux qui seront discutés en particulier par rapport aux sons multiphoniques "harmoniques". Enfin nous montrons que ces résultats peuvent s'étendre aux autres instruments à vent.

PERIOD DOUBLING PRODUCTION ON A BASSOON

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ABSTRACT

Period doubling production on woodwinds has been pointed out in various papers since 1983. If laboratory experiments have been successfully driven to check this assumption, it has not yet been presented, with the exception of ref. [6], any musical realisation of such a scenario.
We present here some results from the realisation of one of us (bassoonist) who designed a special reed in order to obtained period doublings on the first register of a bassoon.
Then we discuss the role of the two main parameters : the resonator (the instrument) and the exitator, (musician and reed). Finally we show that a period doubling is perfectly possible with a "normal" reed on the highest part of the first register.
These results are to be related to the perception of "harmonic multiphonics". Experimental results are then discussed and we show how this particular kind of production could be extended to others division of the octave and to others instruments.

1. INTRODUCTION

Period doubling production on woodwinds has been pointed out in various papers since 1983 [1,2,3,4] where was first linked the behaviour of woodwinds and those of self sustained instruments with the theory of Non Linear Dynamical Systems. If laboratory experiments have been then successfully driven to check the period doubling scenario [2] it has not yet been presented musical realisation of such a behaviour. More, as far as we know, the ability for a musician to play one (or more than one) octave lower than the normal range of the instrument, for a wide part of the ambitus instrument has never been nor presented neither explained in terms of a period doubling scenario.

The results we present here are part of a collaboration of a musician (bassoonist) and two acousticians. A particular reed which allows us to explore one or more period doubling, leading to sounds one or even two octaves lower than the normal sound related to the fingerings. The embouchure (reed and musician in our case) is the main parameter of what is often referred as the non linear part of the woodwind. Crudely said, a hard reed correspond to a tight embouchure and a soft one to a loose embouchure. There is an obvious correlation between this and the shape of the non linear function which is used to described the embouchure [6].

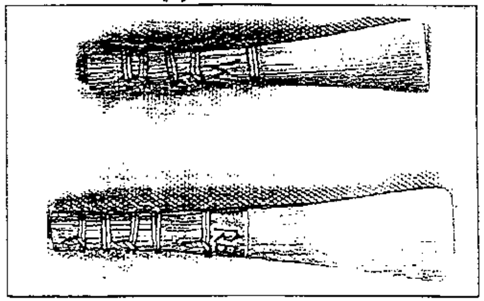

Figure 1
comparison of the two reeds used in the following (designed and realised by N. Rihs).

The second parameter of strong importance in the behaviour of the instrument, the resonator, will be studied through its impedance. the role of these two parts and their relationship with the kind of bifurcations it involves has been recently studied [3]. After the presentation of experimental results obtained with the particular reed designed and built by N. Rihs (see fig. 1) which clearly show that a period doubling cascade is possible with the reed alone and the instrument, we will show that this is perfectly possible with a "normal" reed on the highest part of the first register. Finally we will show how these results can be extended to other woodwinds with simple transformations.

2. EXPERIMENTAL PROCEDURE

The experimental work was done for the main part after that one of us (N. Rihs) has designed a special reed in order to sound his bassoon one octave lower than the normal ambitus of the instrument. the instrument was then blow and the sound recorded. It is obvious that these records includes informations not only about the behaviour of the oscillation of the instrument but also about the recording room. We are here only interested to the periodicity of the emitted signal and to the physical explanation that should be give to such a phenomenon. the special reed is a more larger one than a normal bassoon reed. It looks like a contrabassoon reed and its main characteristic is to be more soft than a normal reed. It follows the classical assumption of musicians for whom a hard reed is better for high notes and a soft for low.

. The musician played various fingering, with the special reed and then with a normal reed, with and without the instrument. The results presented for the reed alone refers obviously to the reed and the small tube that allows it to be connected with the bassoon.

3. RESULTS

When blown with the special reed, the bassoon sounds very particular. One can obtain the normal sound with the correct embouchure and then by changing the embouchure one can produce a sound one octave lower. This result is presented in terms of a time frequency representation (sonogram) on figure 2, and the spectra confirms the bifurcation between the two modes (normal and period doubled).

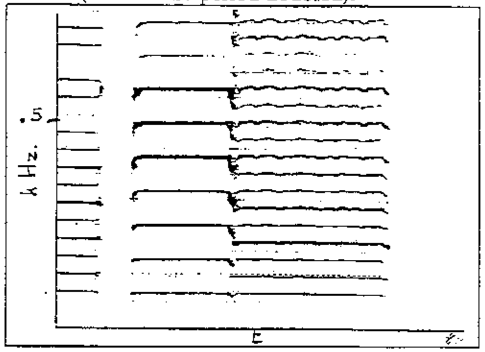

Figure 2
Sonogram of a period doubling obtained on the first regime of the bassoon with a specially designed reed for the lowest F.

This result can also been obtained with the reed alone not only with the special reed but also with the normal one. Figure 3 shows an example of the signal and the evidence of a more complete scenario of period doublings. The scenario is easily obtained on most of the fingerings of the first regime of the bassoon.

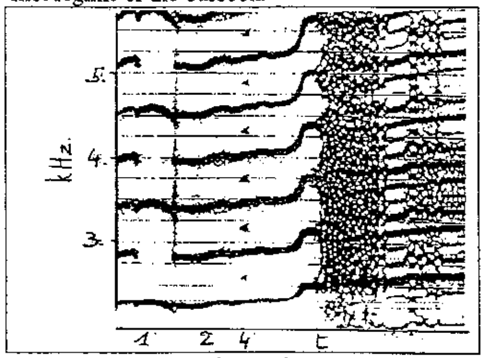

Figure 3
Period doubling cascade obtained with the normal reed alone. The sonogram scale does not begin at zero frequency. note the various divisions obtained: 2, 4 and after what looks like a chaos even divisions.

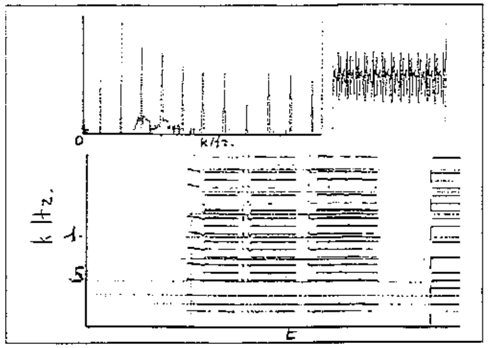

Figure 4
Period doubling obtained with a normal reed for a medium F fingering . The dotted line on the spectrum indicates the normal pitch of the note.

More interesting (and related with the results presented in [4]), one can obtain the same feature on some fingerings of the higher part of the first regime for a normal reed (fig. 4).

4. DISCUSSION

The basic description of a woodwind involves two equations

$$p(t) = \int u(t-\tau)d\tau \qquad (1)$$
$$u(t) = F_{nonLin}(p(t))$$

The first one describe the linear part of the instrument and is related with any description of it.: impedance/impulse response or other. The second relates with the excitatory system (the non linear part). It concerns obviously the reed. when simplifying the description of the instrument, this set of equations reduces to an iteration of the non linear function [2,4]. This description is crude but it gives the morphological description of the behaviour of the system when increasing the control parameter contained in the non linear function. This control parameter is to be understand as a gain factor which controls the shape of the function (see figure 6). For a given blowing pressure a hard reed corresponds to a tight embouchure and a low value of the gain factor since a soft reed corresponds to a loose embouchure and a higher value of the gain parameter. to follow the scenario obtained in [2] one then have to soften the reed or to loose the embouchure. what has been done with the special reed is only that. It allows to explore in "real playing situation" another bifurcation than that we usually used on woodwinds and then to produce a period doubling scenario. A quite complete period doubling cascade is presented on figure 4. It has been obtained with the normal bassoon reed. it confirms that in that non musical situation the reed and the small tube attached have the same behaviour than the bassoon with the special reed.

Since this is possible on a bassoon and that it has also been encountered on a trombone and a crumhorn [5], it should be possible to obtain such period doublings on single reed instruments. In order to verify this assumption we soften a clarinet reed as much as it was possible. Then the normal sounds remains possible since very nasal. The second register is no more playable but with a soft blowing pressure tones of the lower octave are easily produced. So the schema which consists in soften the reed or loosing the embouchure applies as well for single reed cylindrical instruments as for double reed conical ones.

Such sounds one octave lower (or presenting other divisions in the octave) seem to have been encountered in musical practice. Two of us have pointed some of them [5]. They are often mixed as the same kind of sounds as "harmonic multiphonics". These harmonic multiphonics are mainly quasi periodic sounds [4]. These sounds are related to another scenario of transition through chaos. The most of these multiphonics are easily described as the linear combination of two main basis frequencies :$mf_1 \pm nf_2$ [4]. In the present case the only frequency involved in the process is the normal played frequency. We expect in this case a complete bifurcation cascade as it seems to occurs on figure 3. When heard, the two classes of sounds should present common characteristics, nevertheless they drastically differs in the sense that the main parameter that allows such a production is, for the quasi periodicity the resonator, and for the period doubling the embouchure. for musical practice it should be noticed that in the two cases the most of the difficulty for the musician lie on the embouchure control since if resonances can make easier the production of quasi periodic multiphonics, one can also obtain them for "classical" fingerings [7]. It is not at all surprising since their is only a little instruments and fingerings that present perfect harmonic resonances

5. CONCLUSION

We show in this paper that the production of a period doubling scenario on a wide part of the ambitus of an instrument is possible. Others division of the basic period are also possible. For some fingerings one obtain easily a division by 3 and sometimes by 5 or 7 (with normal reed). As it is noticed in [5], we think that very often this particular feature has been ignored not only in musical practice but also in acoustical studies of the instruments, may be because of the lack of experience from acousticians in Non Linear Dynamical systems. During this collaboration, we found a lot of "curious musical signals" whose study should be of great interest as much for musical instruments understanding, musical practice and physics.

References

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