The importance of low inharmonicity in the bass.

1. **Introduction.**

In a parlour grand piano the string scale is optimised. The length of the longest bass string of this parlour grand piano is 1249 mm. (Key1). In de bass the goal was to make the inharmonicity constant equal to the inharmonicity constant of a large concert grand.
In this article will be shown that lowering the inharmonicity constant in the bass of a small grand piano clearly improves the tone quality in the bass.
Three sound examples are given, namely:
a. the note 2A (A0) of a Steinway-D, length string 2012 mm.
b. the note 2A (A0) of a parlour grand piano with original string, length string 1249 mm.
c. the note 2A (A0) of the same parlour grand piano with optimised string.
Of these three cases are given the curves of the inharmonicity constant, the load, the tension of the chords and the basic sound volume. Also the measured spectra are given.

2. **Definition basic sound volume**

The basic sound volume is given in dB x 10, that is to say, that on the vertical axis for example 230 means 23 dB and in the vertical direction each division is one dB.
The sound volume, which a tone can produce, is proportional to the total tension of the chord concerned. The basic sound volume (BSV) is equal to 10*LOG[tension of a chord], with the understanding that the jumps in tension of the chords in the bass section are corrected. This difference in tension is especially made to prevent an audible difference in sound volume by these transitions. It is commonly known, that a mono-chord with the same tension as a bi-chord sounds more loudly.
The reason to introduce the unit dB is, that this unit is usual in acoustics. The advantage of using dB instead of using factors is among others, that dB's can be added and factors have to be multiplied. The absolute value of the basic sound volume is of no importance, because the produced sound volume depends among others of the force with which the hammer hits the string and the properties of the hammer and soundboard. But the shape of the curve of the basic sound volume as a function of the key number is important. Research has proved, when the sound level of two tones varies less than 1 dB, this difference in loudness is not audible. A rather fluctuating curve of the tension of the chords is, if one looks to the curve of the basic sound volume, often acceptable.

3. **Analysis and optimisation data.**

a. **Analysis Steinway-D**

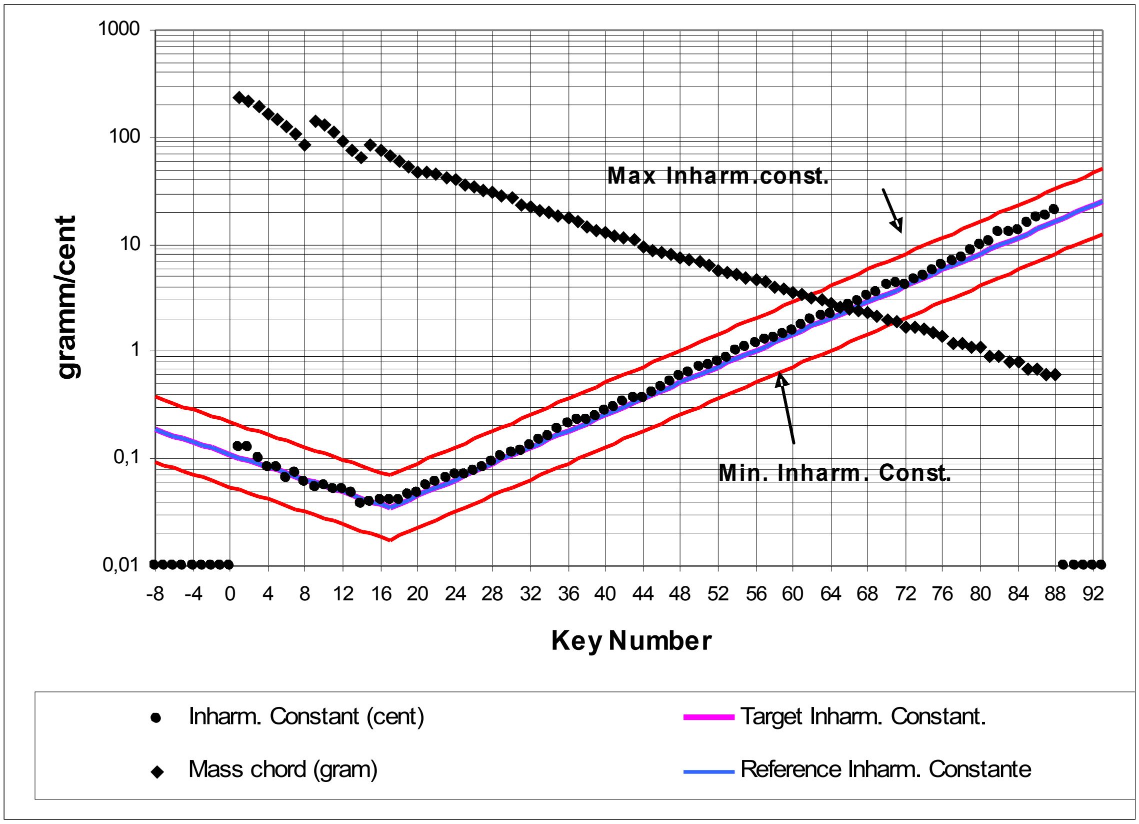

Fig.1

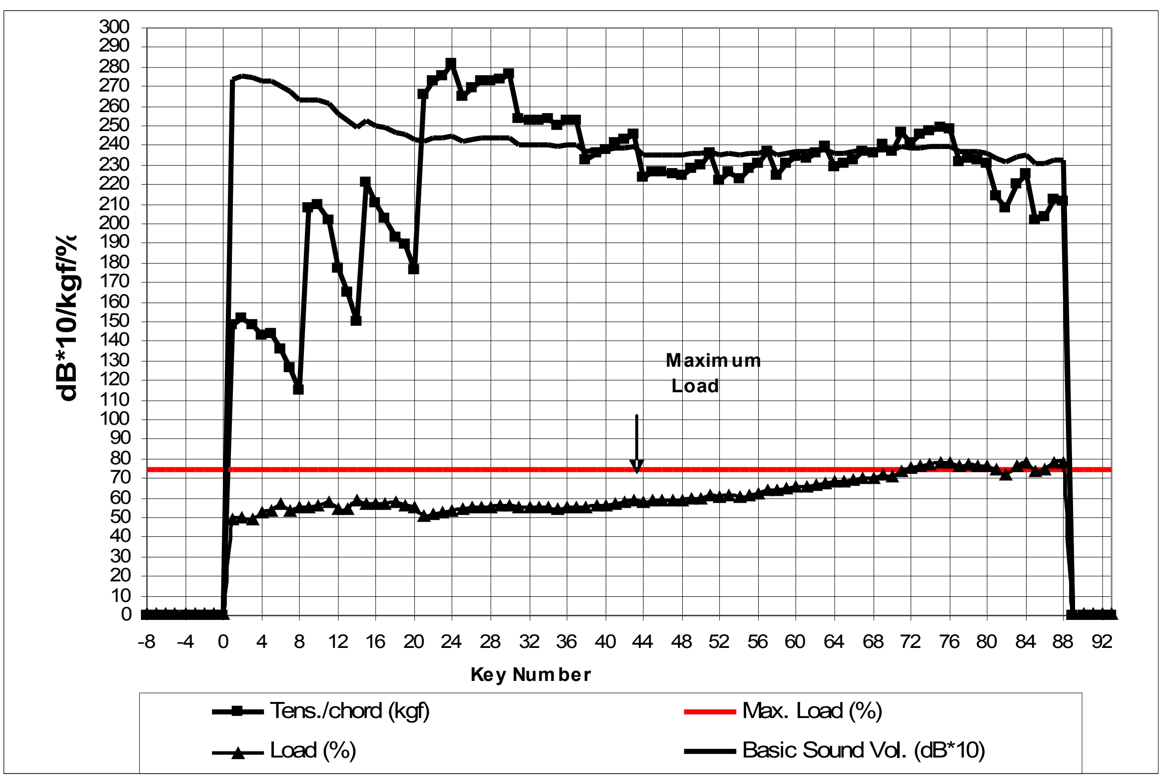

Fig.2

For the basic sound volume applies: one division in vertical direction is 1 dB.

b. **Analysis parlour grand piano with original strings.**

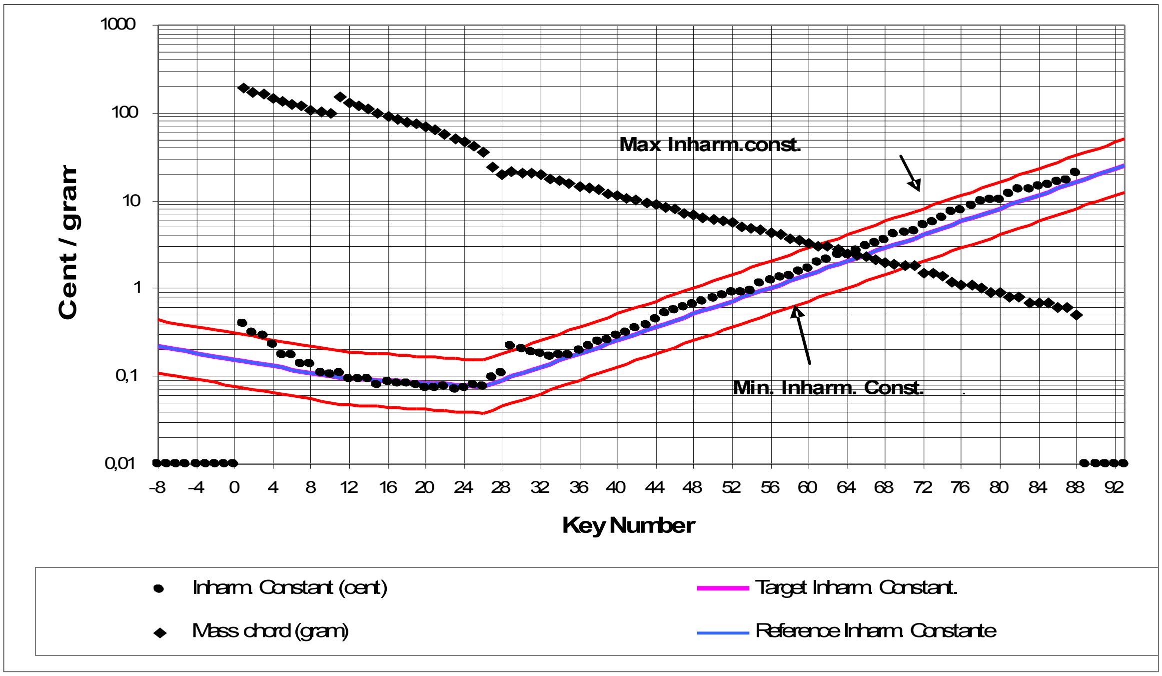

Fig.3

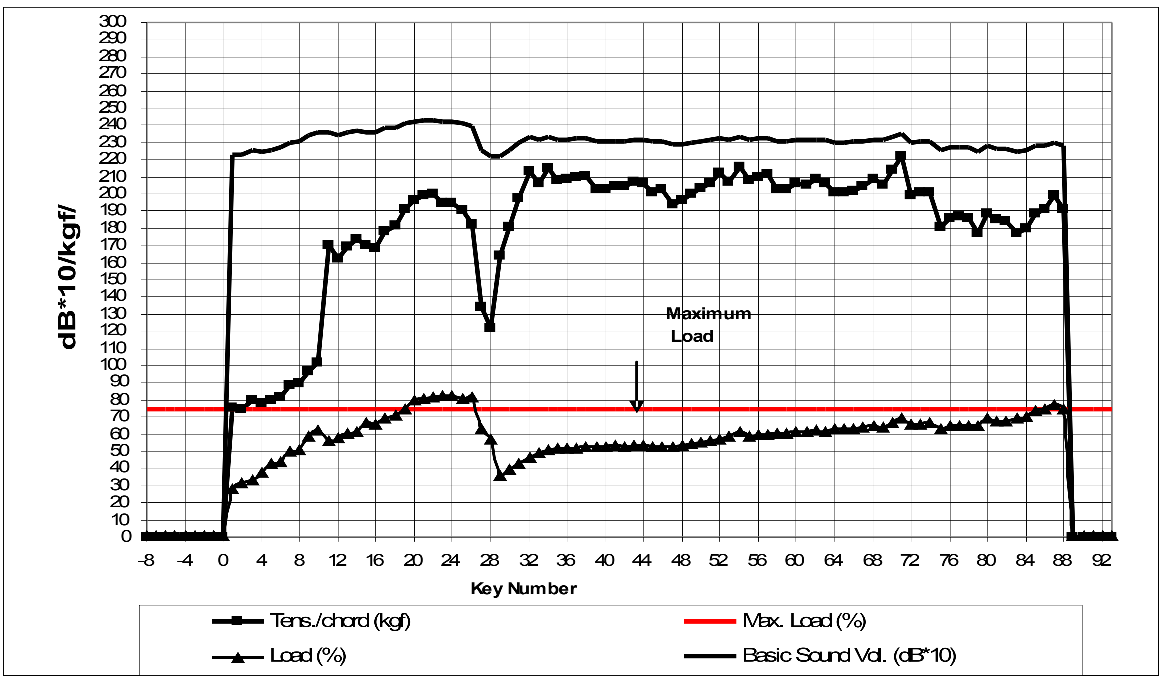

Fig. 4.

For the basic sound volume applies: one division in vertical direction is 1 dB.

Do we compare figure 3 with figure 1, we see that in the bass the inharmonicity constant of the parlour grand piano is considerable higher than the inharmonicity constant of the Steinway-D. Do we compare figure 4 with figure 2, it turns out that the basic sound volume at key 1 of the Steinway-D is circa. 5,5 dB more than the basic sound volume of the parlour grand piano. The lesser basic sound volume of the parlour grand piano is not a problem, because this type of instrument is used in smaller rooms. From key 19 through key 27 the load of 75 % of the break tension is exceeded.

c. **Parlour grand piano with optimised string scale.**

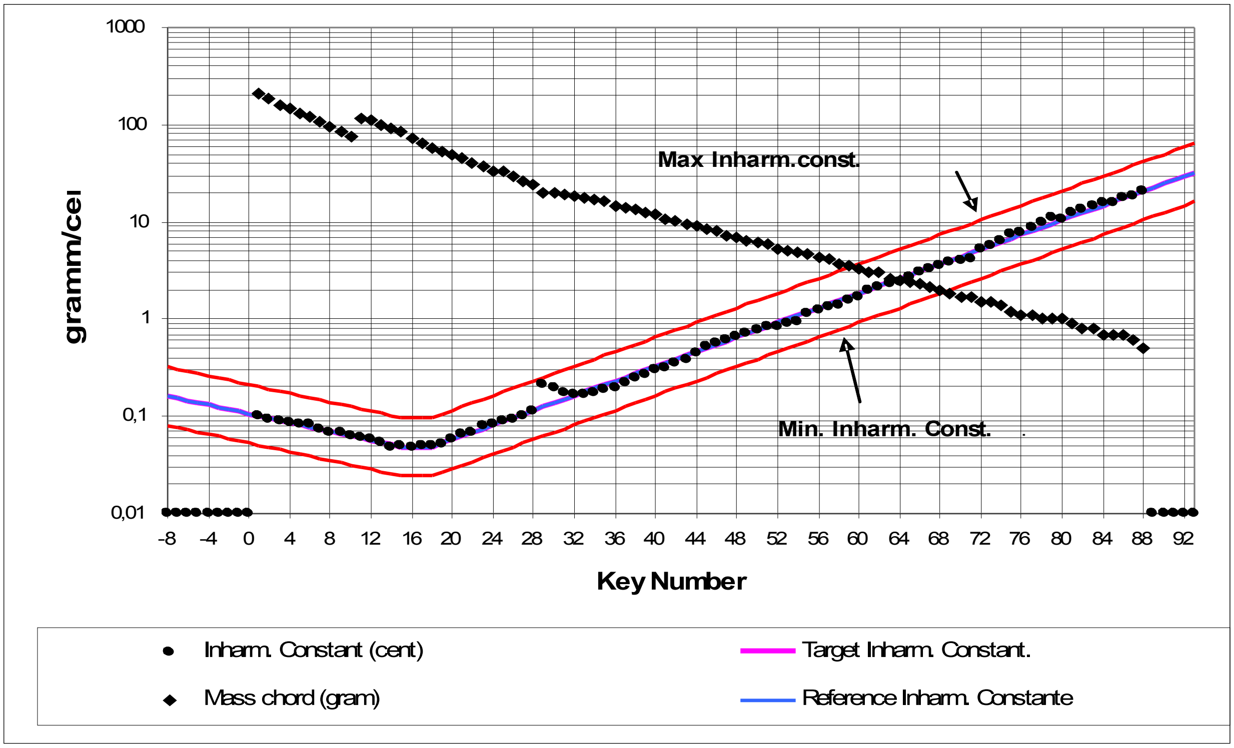

Fig.5.

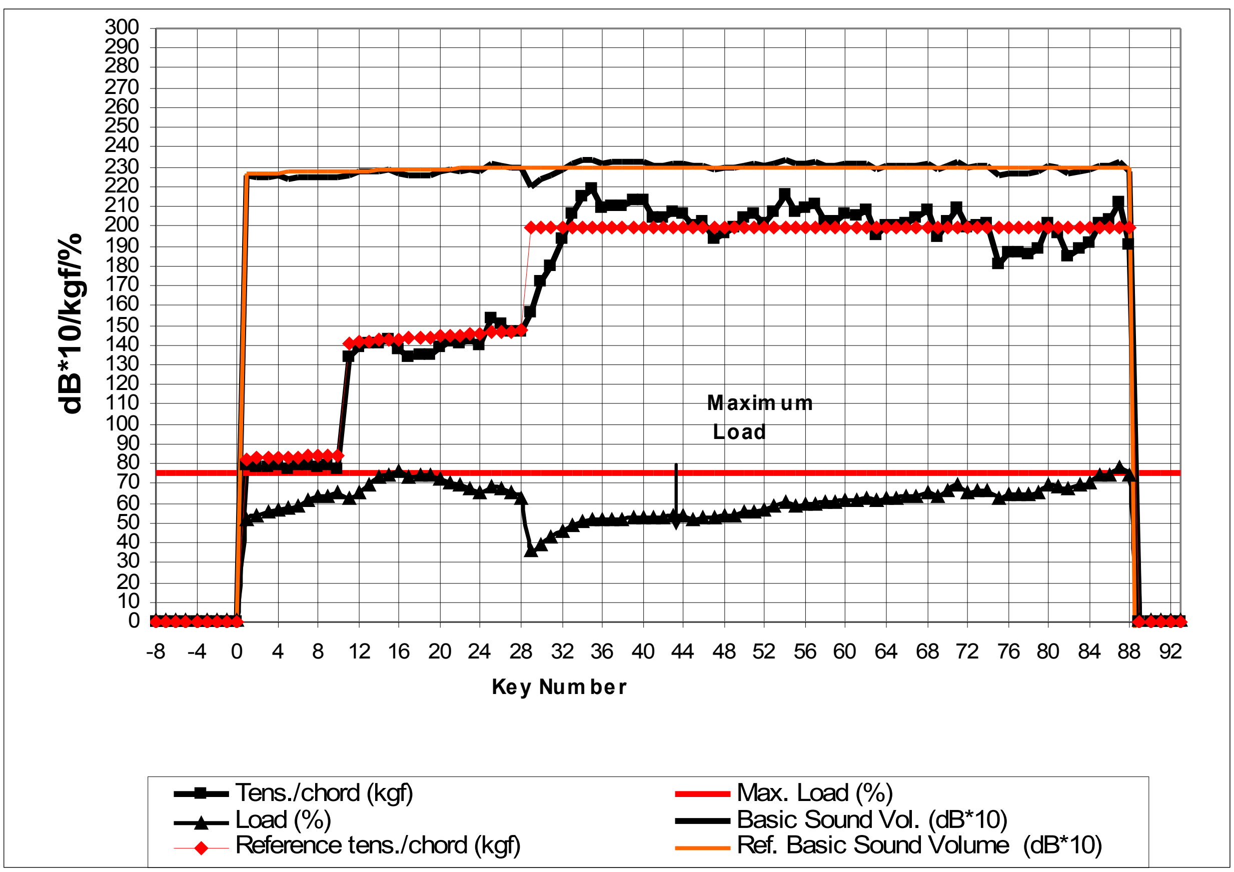

Fig. 6.
For the basic sound volume applies: one division in vertical direction is 1 dB.

The optimisation is carried out with the program “**Easy String Calc**.” This program offers the possibility in short time to optimise all strings to target values in two steps, namely first simultaneously all plain strings and after that simultaneously all wrapped strings. The target values are generated by the program or provided by the user.
By means of a special procedure the inharmonicity in the bass can be made close to the inharmonicity of the bass of a large concert grand. See for example the blue/violet target curve of the inharmonicity constant in figure 5 and the red target values in figure 6.

Do we compare figure 5 with figure 3 and figure 1, we see that in the bass of the parlour grand piano with the optimised strings, the inharmonicity constant is considerable less than in the parlour grand piano with the original strings and is almost equal to the inharmonicity constant of the Steinway-D.
This provides not only a better tone quality, but facilitates also the tuning of the bass.

Do we compare figure 6 with figure 2, it turns out that the basic sound volume at key 1 of the Steinway-D circa. 5,5 dB more is than the basic sound volume of the parlour grand piano. The lesser basic sound volume of the parlour grand piano is not a problem, because this type of instrument is used in smaller rooms. In the parlour grand piano with the optimised strings the 75 % limit of the load is not exceeded.

4. **Sound examples.**

The first sound example is key 1 of a Steinway-D grand.
The second sound example is key 1 of the parlour grand piano with original strings.
The third sound example is key 1 of the parlour grand piano with optimised strings.

Sound example 1. http://home.kpn.nl/velo68/STW-D T1.mp3
Sound example 2. http://home.kpn.nl/velo68/SV org T1.mp3
Sound example 3. http://home.kpn.nl/velo68/SV opt T1.mp3

It is clear that sound example 3 is more agreeable than example 2. Also the decay is extended.
In spite of the fact of that the inharmonicity constant in the bass of the optimised parlour grand piano is almost equal to the inharmonicity constant of the Steinway-D, a difference can be heard. The cause of this is among others the much smaller soundboard of the parlour grand piano.

4. Spectra

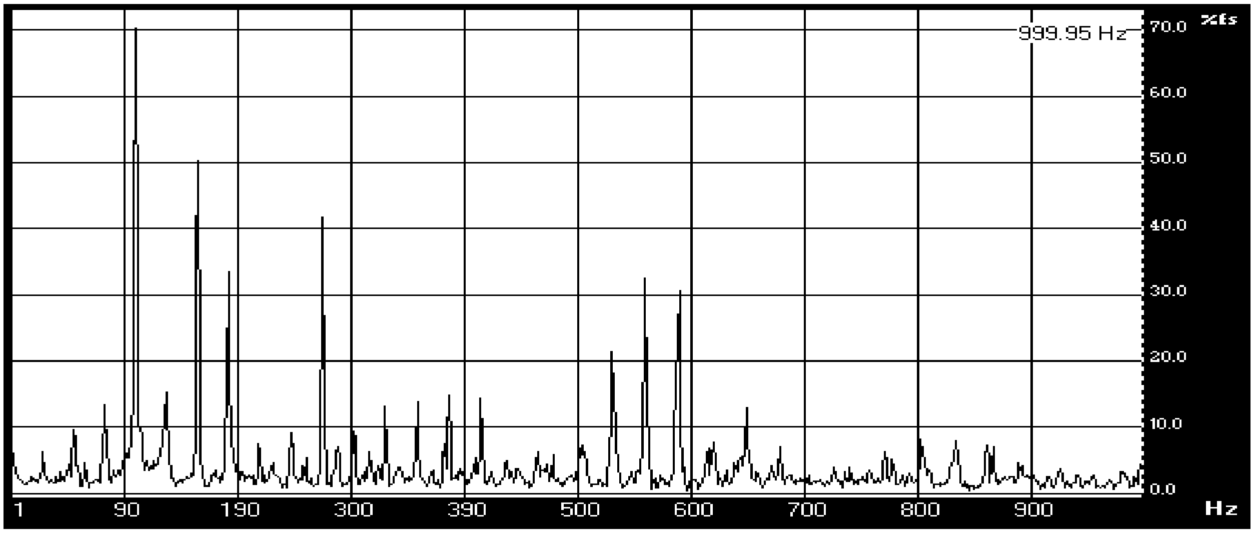

Fig. 7. Spectrum Steinway-D key 1

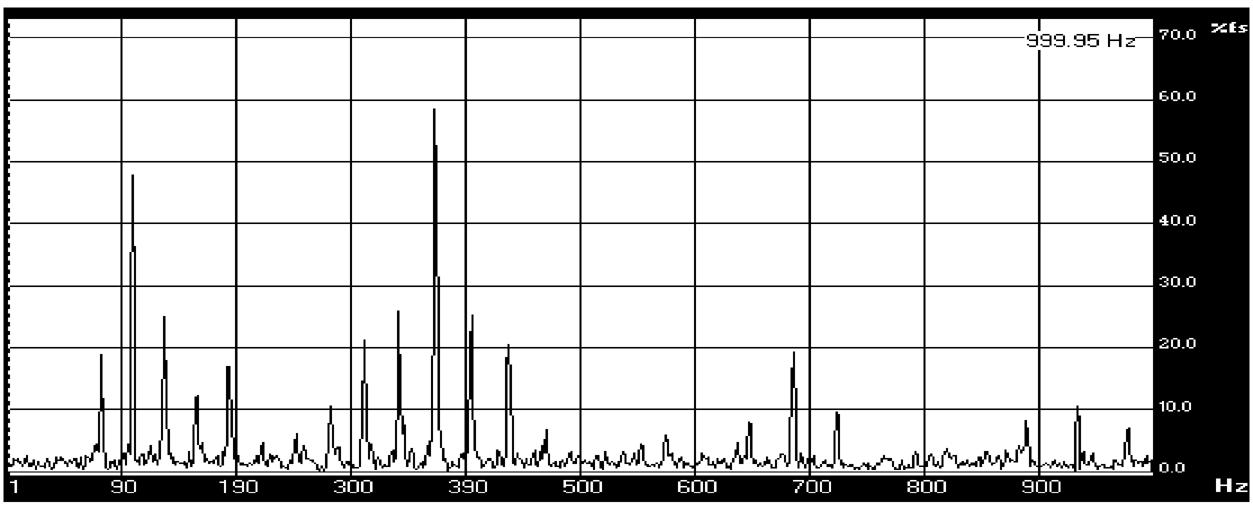

Fig. 8. Spectrum parlour grand piano key 1 with original string.

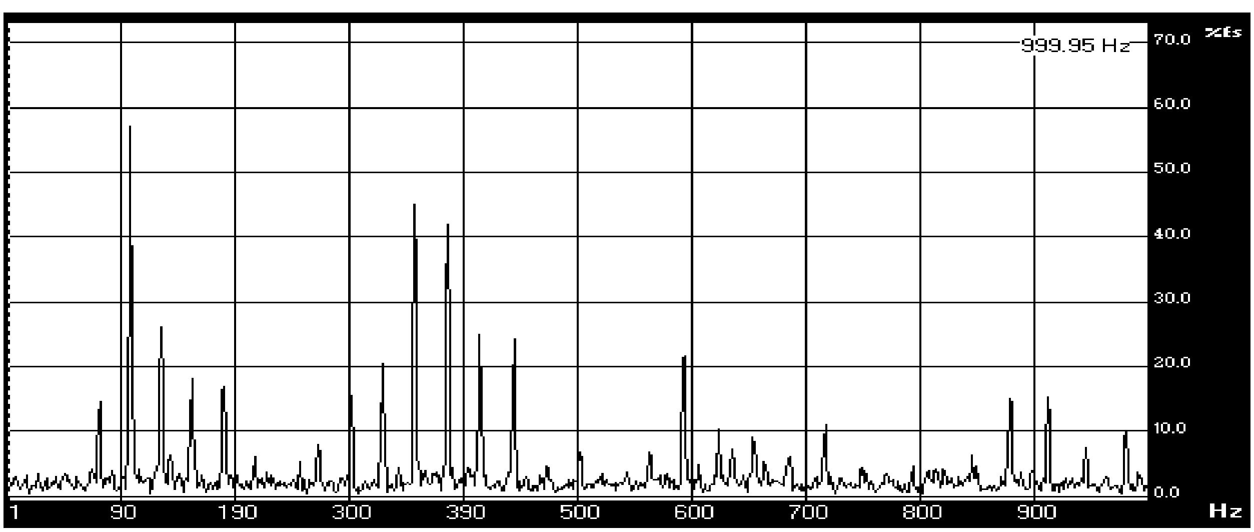

Fig. 9. Spectrum parlour grand piano key 1 with optimised string.

Do we compare figure 7 through 9 we see the following:
At key 1 of the parlour grand piano is for the original string as well for the optimised string the first partial (fundamental) and the second partial not present. Obviously the smaller soundboard is not able to radiate these frequencies (circa 27,5 and 55 Hz).
In case of the Steinway-D these frequencies are relatively weak present.
The perception of the fundamental has to be regenerated by the ear out of the difference of the partials. So it is important that these differences not much vary from the frequency of the fundamental. Is the inharmonicity low then this requirement is better fulfilled than in the case of a higher inharmonicity.
Do we compare figure 9 with figure 7, we see that the 11^{th} partial and the 15^{th} partial for both instruments are on nearly the same position, which proves that the inharmonicity of key 1 is nearly equal for these instruments.
For key 1 of the parlour grand with the original string the frequency of the 11^{th} and 15^{th} is higher, what indicates a higher inharmonicity.

5. Conclusion.

a. It turns out that decreasing the inharmonicity in the bass produces a more agreeable tone.
b. Decreasing the inharmonicity in the bass makes tuning easier.
c. Reducing the inharmonicity compared with the inharmonicity which is usually common in the bass of small instruments is possible.

HOME: http://home.kpn.nl/velo68