A Review of Bell Design and Tuning Techniques From Magic to Science

Miguel Carvalho,[1†] *Vincent Debut,*[1] *Jose Antunes*[2]

[1]INET-md, Universidade Nova de Lisboa
[2]C2TN, Instituto Superior Tecnico
[†]miguel.carvalho@ctn.tecnico.ulisboa.pt

ABSTRACT

The sound of a bell presents numerous partials resulting from its vibrational modes. Since the 17th century, it is commonly accepted among bellfounders, that to sound pure and clear, the first five partials (at least) of a bell must fall into specific musical frequency ratios, established at 0.5:1:1.2:1.5:2. Beyond this internal tuning, for carillons, bellfounders must also correctly tune their bells in relation to each other, in order to form a musical scale and provide a musical instrument able to play melodies and chords. Other peculiarity of bells sounds stems from the bell near-axial symmetry. Actually, during casting, the presence of slight defects in symmetry is unavoidable, which breaks the degeneracy of the normal modes and leads to audible beats in the radiated sound, a phenomenon which is usually referred to as warble by campanologists. On top of all this, the perceived pitch of a bell is a delicate phenomenon, related to psychoacoustic effects, which may correspond to a modal frequency or arise as a virtual pitch. Even today, the nature of the so-called bell strike-note is still a topic of debate.

One therefore easily understands the complexity of designing and tuning carillon bells. The evolution carillons face until they become musical instruments results from more than ten centuries of gradual transformation and development. It is based on the founders experience, acquired by trial and error, and has benefited from the increasing scientific interest for the phenomenon of bell partials. The secrecy under which such knowledge was kept is also another reason why there has been only a few bell founders capable of successfully casting and tuning carillons throughout the history. Nowadays, following the advances in structural dynamics modelling and computational techniques, bells can be designed on a scientific basis, the casting process can be fully monitored, and tuning can be accurately achieved by coupling physical modelling and optimization algorithms.

Based on an extensive bibliographical research, we provide in this paper an overview of bell design and tuning techniques, since its early stages of empiricism to the most recent scientific advances. Our work sums up and complements the scarce existing literature on bell tuning, and presents innovative strategies for assessing and improving the tuning of bells, using 3D-scan imaging technology, physical modelling and computational methods.