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Geometrical, Flexural and Vibroacoustical Characterization of Saxophone Reeds

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Introduction

The sound production by the saxophone, a single-reed wind instrument, relies mainly on the control of the vibration of a plate by the player's lower lip and the air blown into the instrument. This vibrating plate is securely attached to the mouthpiece and is known as a reed. In this study, we have investigated eight different reeds, including both (natural) cane reeds and reeds made of synthetic materials, compared their design, material and vibroacoustic properties. The long-term aim of this study is to facilitate the fabrication of reeds aiming to aide musicians in customizing their reeds aligning with their specific needs.

Synthetic and natural reeds

Fig 1 describes the anatomy of the simple reed (A) with saxophone (C) and mouthpiece in (B). Traditionally reeds are manufactured from the natural material *Arundo donax* L (ADL). Though, it also has specific drawbacks [2]. Like, material fatigue, durability, etc, To address these inconsistencies, synthetic reeds have emerged as an alternative.

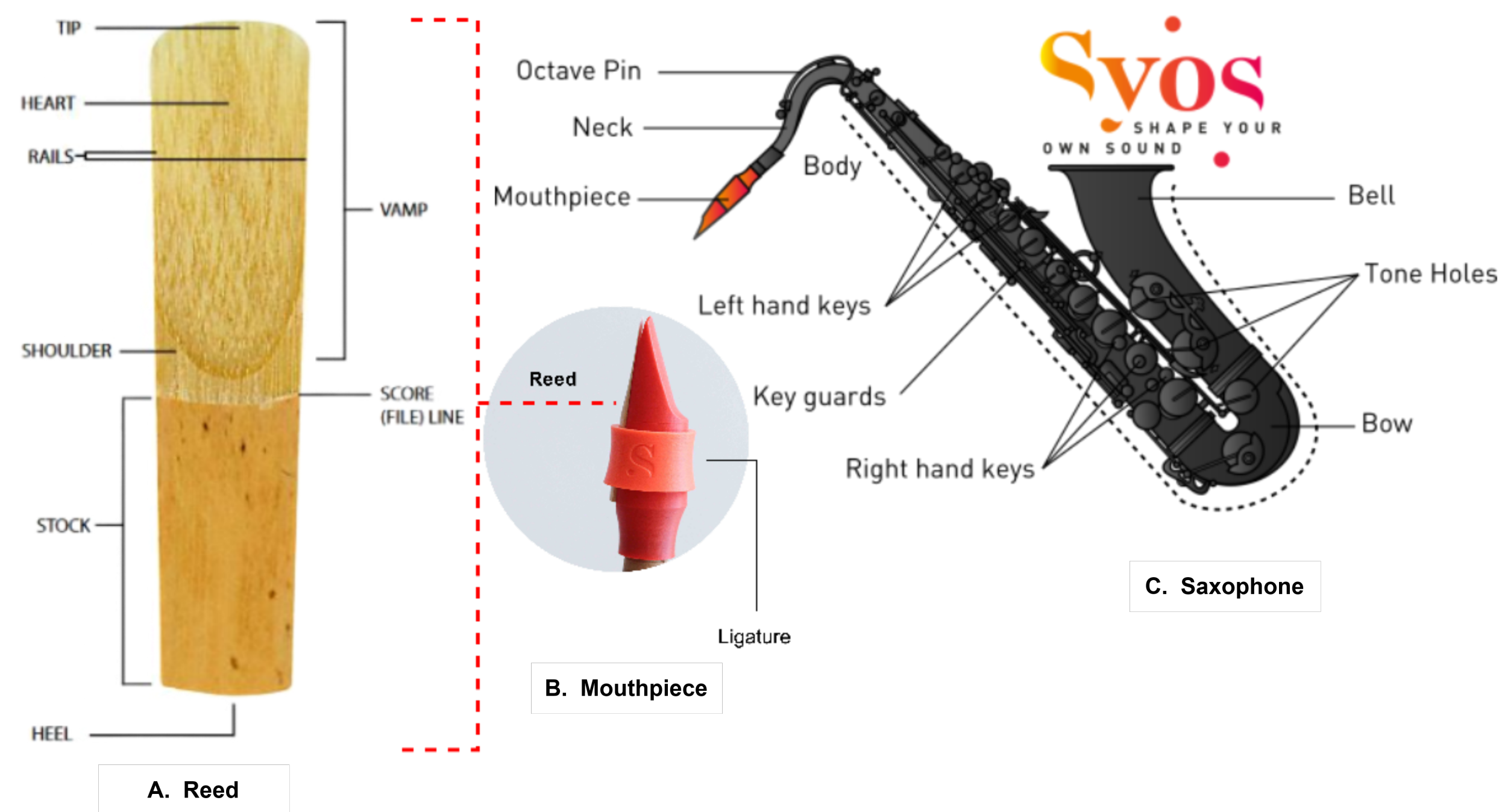


Figure 1. A) Reed anatomy B) Mouthpiece with reed C) Saxophone

Hence, for the purpose of our study, **eight different reeds** were taken into consideration as illustrated in Fig 2. Their respective **brands, commercial strengths** and **measured masses** are provided in Table 1. Among these only Rigotti reed are naturally made from ADL.



Figure 2. Basic comparison of selected reeds

Name	Bari	Yamaha	Hinoki	Rigotti	Legere	Fibreed Carbon	VENN	Fibracell
Strength	M	3	H	3	3	MH	2.5	3.5
Mass (g)	3	2.65	2.84	1.37	2.29	2.77	3.16	2.23

Table 1. Strength of reeds

Reed-making company employs its own unique system for differentiating reeds, often using alphabets such as M, H, MH (M: Medium, MH: Medium Hard, H: Hard), or numerical designations like 1, 2, 2.5, 3, and so on. These codes in Table 1 essentially indicate the Stiffness of the reeds during playability.

Geometrical Characterization

Microtomography, specifically micro-CT scanning, was employed to perform design analysis on all reeds (see Fig 3.A), i.e., to extract x, y and z coordinate points from the scanned images using a custom image processing Python routine. A smooth surface is achieved by fitting the measured data points with splines. Each reed was divided into 11 segments (splines) along the Z-Y plane.

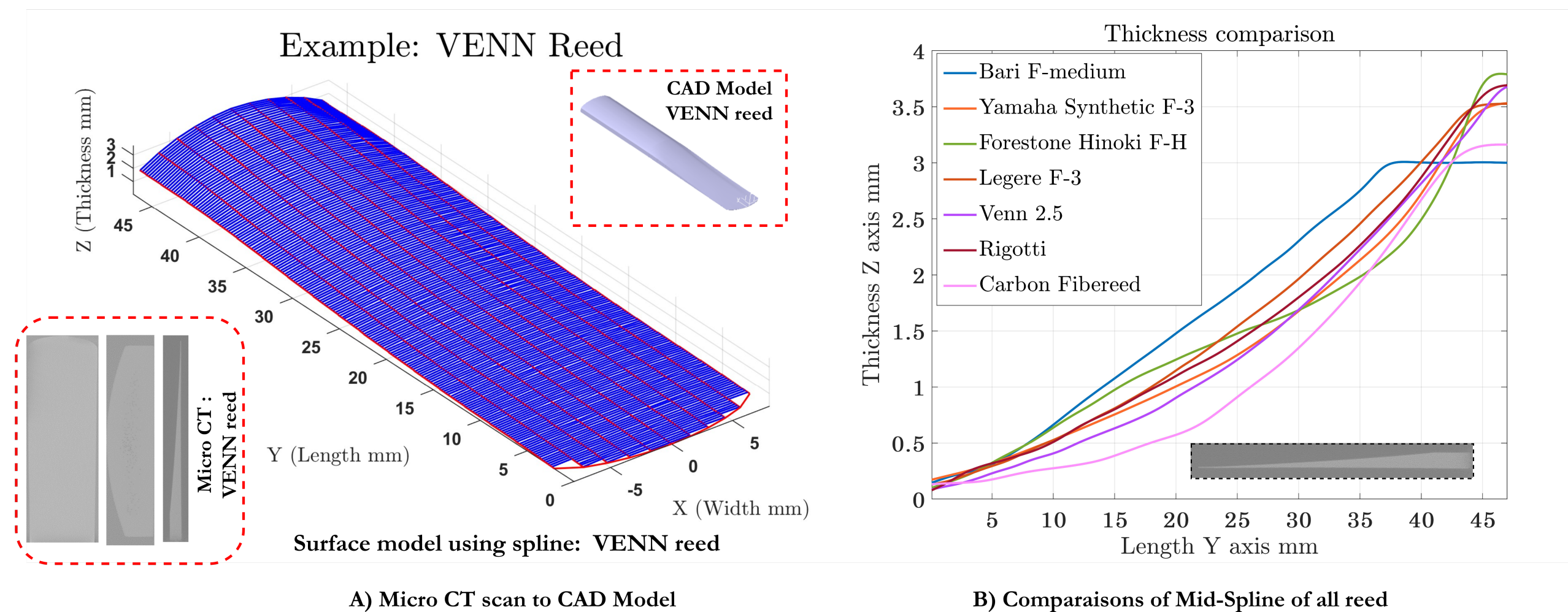


Figure 3. A) Micro CT scan to CAD Model and B) Comparisons of Mid-Spline among reeds

These splines were then used to construct a surface model using Catia V6. This process facilitated the creation of a comprehensive and accurate volumetric representation of the reed. The same methodology was applied to the remaining reeds, and their mid-line spline were plotted in Fig 3.B providing a clear visualization of their distinct forms.

References

- Matthew S. Allen and Jerry H. Ginsberg, "A global, single-input-multi-output (SIMO) implementation of the algorithm of mode isolation and application to analytical and experimental data". In: *Mechanical Systems and Signal Processing* 20.5 (July 2006), pp. 1090-1111. ISSN: 08883270. DOI: 10.1016/j.ymssp.2005.09.007.
- Voichita Bucur, "Traditional and new materials for the reeds of woodwind musical instruments". In: *Wood Science and Technology* 53.5 (Sept. 2019), pp. 1157-1187. ISSN: 0043-7719. 1432-5225. DOI: 10.1007/s00226-019-01117-9.

Flexural Characterization

The so-called strength of the reed is the primary criterion used by the musicians to choose reeds. In mechanical terms, it essentially relates to the bending stiffness determined by both the materials and the design. An experimental setup is proposed to evaluate the bending stiffness. Stocks of the reeds were attached to the bending test machine and point load applied at 10mm from the tip of the reed. Loading force and relative displacement of the loading point were measured using a load cell and image processing (tracking of an Aruco mark), respectively (see Fig. 4.A).

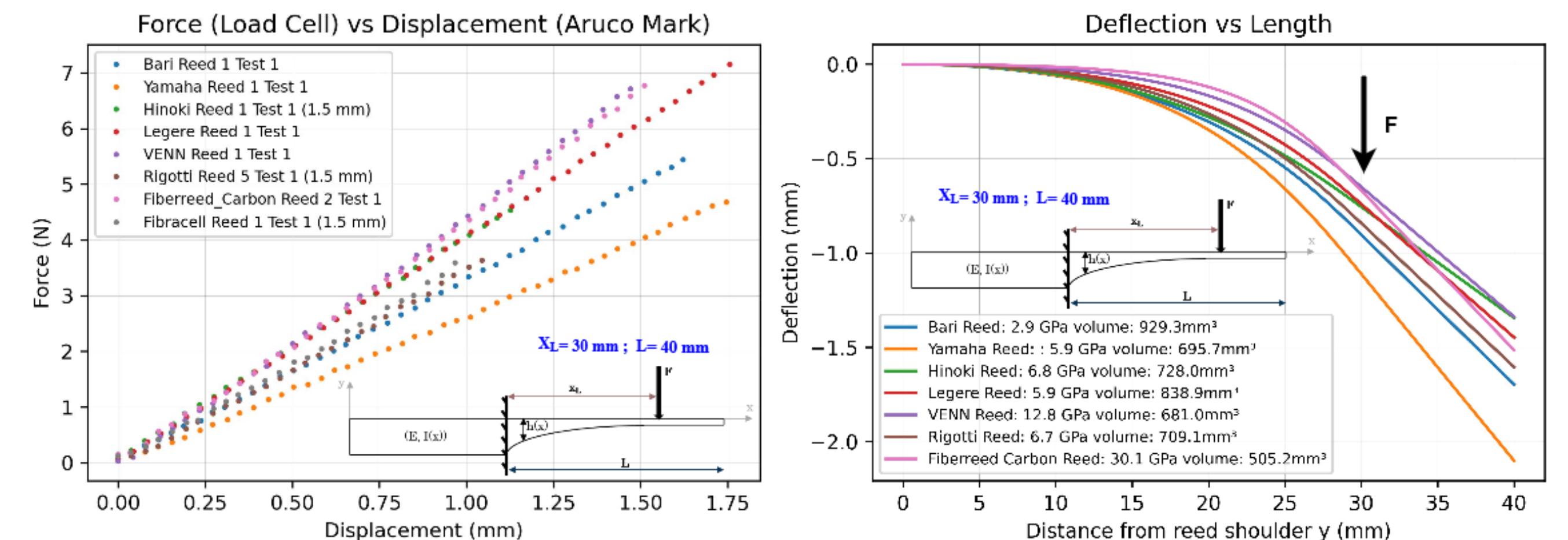


Figure 4. A) Experiment: Force vs Displacement. B) Numerical modeling: Deflection of reed

Name	Bari	Yamaha	Hinoki	Rigotti	Legere	Fibreed Carbon	VENN	Fibracell
Flexural Modulus (GPa)	2.9	5.9	6.8	5.9	12.8	30.1	6.7	5.23

Table 2. Flexural Young's modulus of reeds

The bending test also allows to estimate the flexural modulus E. This is obtained from the bending stiffness and the area moment of inertia I(y) (computed from CAD models) assuming the Euler-Bernoulli bending theory. Estimated flexural modulus are given in Table 2 and resulting deflections of the reeds are shown in Fig.4.B

Vibroacoustical Characterization

Vibroacoustic testing (Polytec PSV:400 Scanning Head Vibrometer) of the reeds is performed by acoustically driving the reed mounted on a Syos mouthpiece and measuring the resulting vibrations. No prestress is applied, i.e., there is no artificial lip on the reed. A band-limited noise signal is applied and transfer functions between the mouthpiece pressure (from GRAS 40SA probe microphone) and the reed velocity (see Fig. 5).

Single Input Multiple Output (SIMO) test
Pseudo Random Input signal (0-5 KHz)
215 Output points
Sampling interval: 1.5625 Hz
Number of samples: 3200
Sampling interval: 640 ms

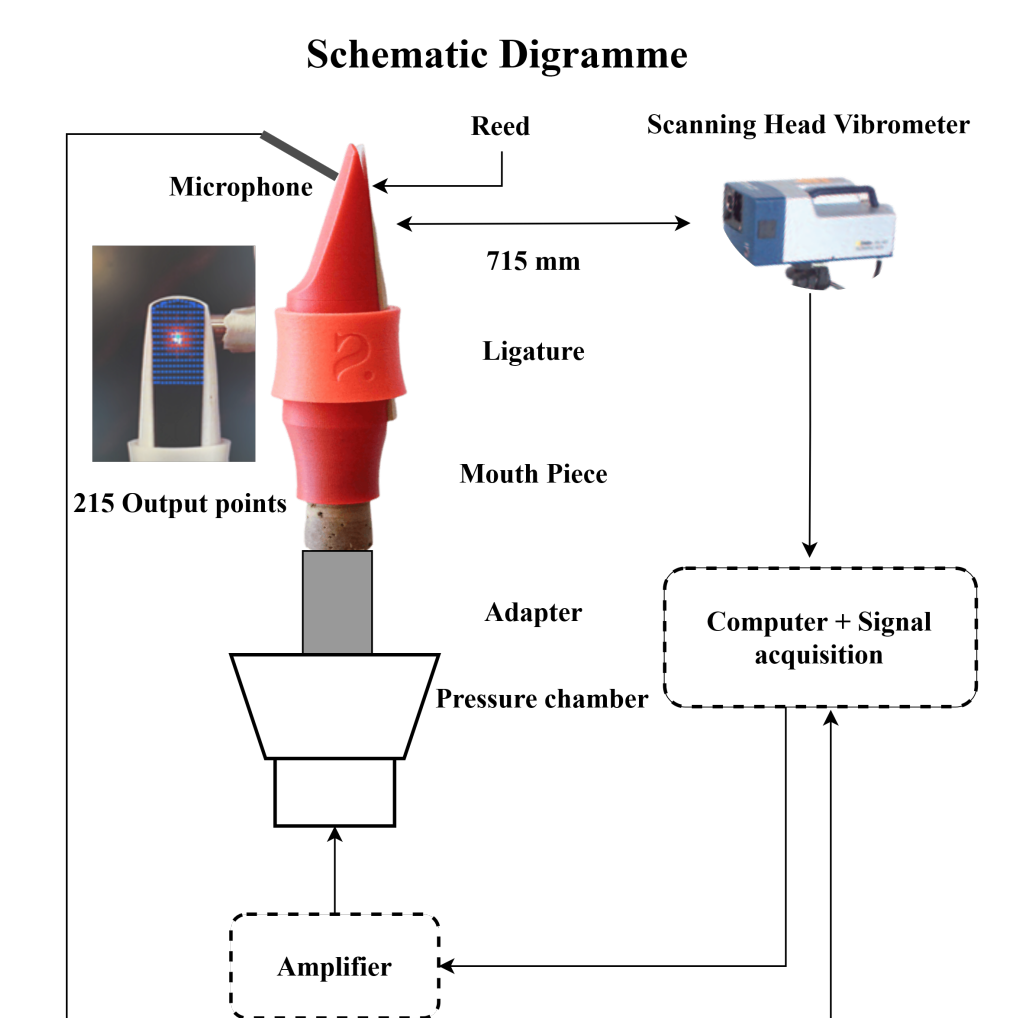


Figure 5. Vibroacoustic Test

Modal analysis on VENN reed (Algorithm of Mode Isolation, Matt Allen [1]) is then performed on the the Frequency Response Functions (FRF) to evaluate modal frequencies, damping factor and shapes (depicted in Fig. 6 and Table 3).

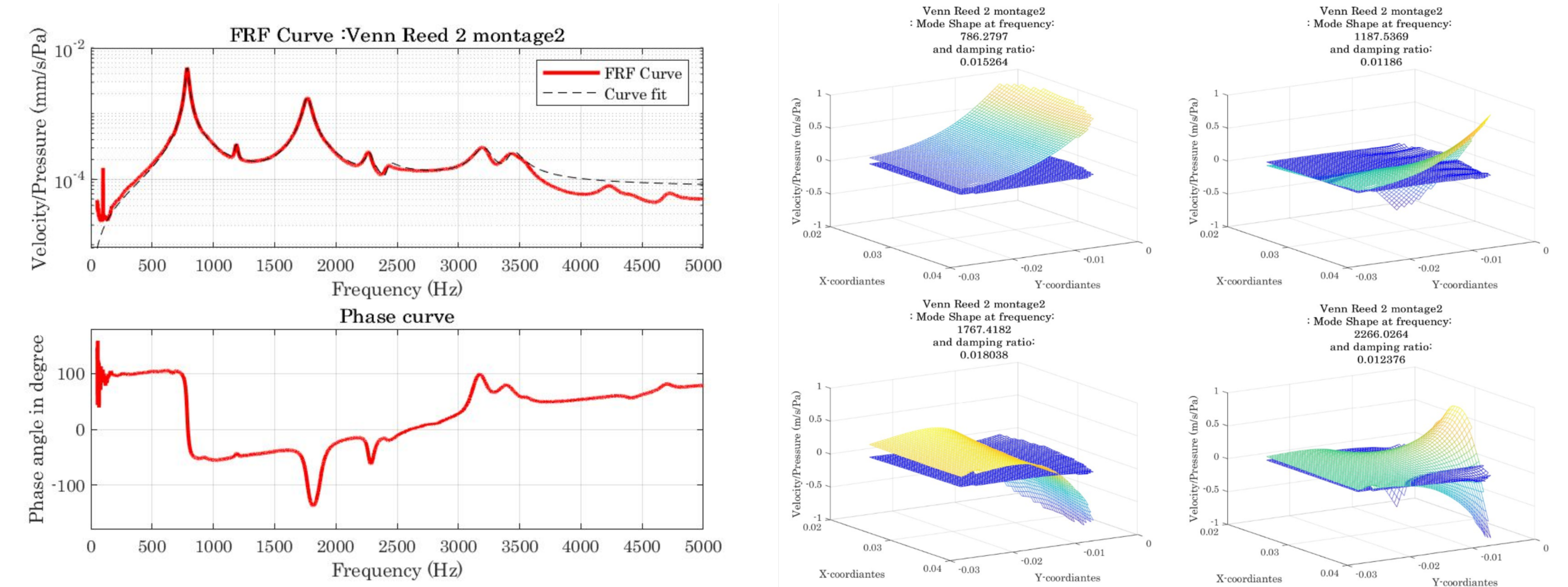


Figure 6. FRF and Mode Shapes for VENN Reed

Mode Shape	Natural Frequency (Hz)	Damping factor
1	786.27	0.015
2	1157.53	0.011
3	1767.41	0.018
4	2266.02	0.012

Table 3. Natural frequencies and their damping factor

Conclusions and Perspective

- Micro-CT was instrumental in extracting the shape of the reeds
- Thickness profiles of reeds were compared and CAD model developed
- Bending tests were conducted to compare stiffness and to extract material property of reeds
- Vibroacoustic test permits us to predict the vibroacoustical properties of reeds
- Perspective: Optimization of the shape of the reed based on material and modal properties