Dynamic Properties of Bovine Cancellous Bone: Influence of the Microstructure.

[1] Sebastien Laporte, [1] Franck David, [2] Valerie Bousson and [3] Stephane Pattofatto

[1] Arts et Métiers ParisTech, CNRS, LBM, 151 Boulevard de l'Hôpital 75013 Paris, France
[2] Service de Radiologie Ostéo-Articulaire, Hôpital Lariboisière, Paris, France
[3] ENS Cachan, CNRS, Université Paris 6, LMT, 61 Avenue du Président Wilson, Cachan, France

INTRODUCTION

Dynamic properties of cancellous bone are needed for the development of finite elements model of the human body for car safety simulation. Very few studies focussed on this mechanical caracterisation [1, 2]. Furthermore, the link between the dynamic mechanical and the microstructural properties is not described in the literature.

The aim of the presented study is then to identify the dynamic behaviour of bovine cancellous bone and to identify correlations between the mechanical properties and microstructural properties.

METHODS

Fifteen specimens were harvested from the distal part of bovine femoral bones (diameter 41 mm, thickness 14 mm). Specimens were then frozen at – 20 °C in vacuum-sealed plastic bag until the tests. Specimens were slowly thawed 12 hours at +5°C before the tests.

The microstructural characterization of the cancellous bone is identified from the peripherical quantitative tomodensitometry technique (XtremeCT Scancomedical). The calculated parameters chosen for this study are: BV/TV (Bone Volume / Total Volume) and Tb.Th (Mean Thickness of Trabeculae).

Quasi-static experimentations are performed by compression tests at a nominal strain rate of 0.001 s^{-1}.

The dynamic characterization is performed by dynamic compression tests on Split Hopkinson Pressure Bars at a nominal strain rate of 1000 s^{-1}. The apparatus is made of 41 mm diameter nylon bars. A fast camera is used to follow qualitatively the deformation of the specimen during compression [3].

For quasi-tatic and dynamic experimentations, the mechanical parameters identified are the classical ones of a foam-type behavior: E (Apparent Young Modulus), SIGy (Yield Stress), SIGp (Plateau Stress).

Non parametric tests were used to analyze the effect of the velocity and the correlation between the microstructure and the mechanical parameters.

RESULTS AND DISCUSSION

Table one gives the mean results for each the mechanical parameter calculated. Values are coherent with the literature [2]. Yield and Plateau stresses increase with the velocity ($p > 0.001$). The apparent Young modulus seems to decrease with the velocity, even if the difference is not significant. This result needs to develop specific modeling in order to understand the mechanism of decrease of the apparent Young modulus; structural effects could explain this specific property.

Table 1: Mean and standard deviation of the identified mechanical properties for quasi-static and dynamic tests.

Tests	E (MPa)	SIGy (MPa)	SIGp (MPa)
Quasi-static	**269** *(52)*	**5.9** *(1.4)*	**5.5** *(1.1)*
Dynamic	**170** *(77)*	**10.6** *(3.1)*	**8.5** (3.8)

Only the yield and plateau stresses are correlated with BV/TV (Figure 1 & 2) ($p < 0.05$). These results underline the role of the trabecular bone in the resilience of the spongy bone.
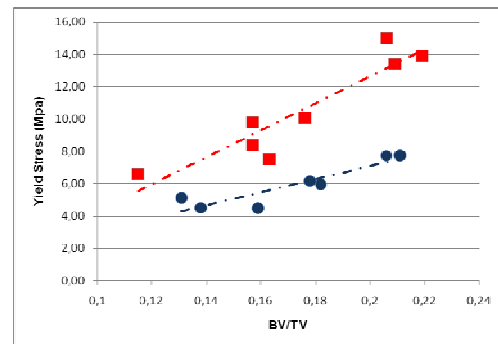
Figure 1: Graph of the Yield Stress versus BV/TV. Circles: quasi-static values – Squares: dynamic values
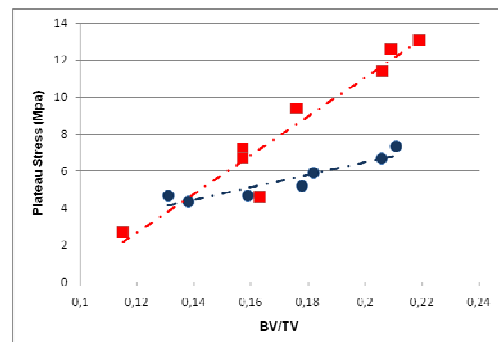
Figure 2: Graph of the Plateau Stress versus BV/TV. Circles: quasi-static values – Squares: dynamic values

REFERENCES

1. Shim VPW., et al, *Int J Impact Eng*. **32**: 525 – 540, 2005.
2. Chaari F., et al., *Int. J. Crashworthiness.* **12**: 247 – 253, 2007.
3. Pattofatto S., et al., J Mech Phys Solid, **55**: 2672-2686, 2007