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Finite element modelling of bone adaptation of the 3^{rd} metacarpal in racehorses

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Fractures of the third metacarpal bone in thoroughbred racehorses are one of the main reasons of euthanasia in the UK. Most fractures occur due to the accumulation of tissue fatigue as a result of repetitive loading [1]. Bone adaptation in response to different loads is known to increase the resistance to fracture. It is believed that finite element analysis might provide better understanding of such complicated mechanisms. In this study, a well-established open system thermodynamics approach [2] was adopted to simulate density growth in equine third metacarpal. Implementing the model into a hierarchical approximation framework allowed for the efficient solution of large of problems in 3D, including entire bones with their complicated external structure. Coupled nonlinear governing equations of mass and linear momentum conservation were implemented in the finite element code MOFEM [3]. Its performance was demonstrated with benchmark problems. For example, bone density growth in healthy and prosthetic human femur with a total hip replacement was considered. Solving these problems on a parallel supercomputer system demonstrated a significant speed-up in computation time due to the application of field splitting. The geometries of the numerical models were accurately represented by processing CT scan images. Furthermore, loading conditions applied to selected bone regions were estimated based on contact forces at mid-stance of a gallop. The obtained density pattern was validated by comparison with the CT data from a racehorse metacarpal bone. It was shown that this method has the potential to accurately model the effect of loading on the bone and could be applied to future studies in order to reduce the risk of injuries. In addition, the prosthetic femur examples presented could be developed into a useful tool to detect possible zones of fracture or resorption, which may lead to loosening of the implants.

REFERENCES

[1] T D H Parkin, P D Clegg, N P French, C J Proudman, C M Riggs, E R Singer, P M Webbon, and K L Morgan. Risk factors for fatal lateral condylar fracture of the third metacarpus/metatarsus in UK racing. *Equine veterinary journal*, 37(3):192–199, 2005.

[2] E. Kuhl and P. Steinmann. Theory and numerics of geometrically non-linear open system mechanics. *International Journal for Numerical Methods in Engineering*,

58(11):1593–1615, 2003.

[3] Lukasz Kaczmarczyk, Zahur Ullah, Karol Lewandowski, Xuan Meng, Xiao-Yi Zhou, Chris Pearce, and Athanasiadis Ignatios. Mofem-v0.6.6. Nov 2017. http://mofem.eng.gla.ac.uk.