Functionally Graded Materials in Biological Systems with Impact Loading

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Abstract

Propelled by the technological demand for versatile high-performance materials and the study of biological contact solutions Functionally Graded Materials (FGM) have encountered a lot of scientific interest and research in the past years. The use of FGM is proven to be possibly beneficial in both physical [1] and biological [2] applications.

Impact loading is considered a serious source of damage and possibly failure in any tribological system. With respect to Functionally Graded Biological Systems, like bones or joints, impact loading does not only refer to the impact of macroscopic particles but also to traumata or even simple body movement [3]. The talk will deal with the influence (and the possible advantages) of the use of FGM in tribological systems with impact loading. As an example, which permits analytical treatment, the focus is on the impact of a rigid sphere onto an elastic medium, in which the modulus of elasticity increases or decreases with depth in form of a power-law. Such forms of FGM have long been used in soil mechanics and are reanalyzed nowadays for example in protheo-synthesis. Both stiff and soft surfaces (compared to core stiffness) can be studied, depending on the exponent of the power-law.

During the examination of the impact problem, quasi-stationarity and the validity of the half-space hypothesis are assumed, and analytical and numerical methods are used. Amontons-Coulomb friction without adhesion and frictionless adhesion in the Johnson-Kendall-Roberts approximation are considered. As the focus lies on avoiding damage only elastic deformations are allowed.

The rigorous solution of the Hertzian impact problem with and without adhesion for the considered class of inhomogeneous materials is presented and it is demonstrated how by the use of FGM the maximum normal stresses during the impact (and thus the impact resistance) can be reduced.

As most biomaterials also exhibit viscoelastic behavior, the influence of graded viscosity is also studied for the normal impact problem based on the elastic-viscoelastic correspondence principle [4]. The viscous losses can, as expected, to some extent also be influenced by material grading.

The general, oblique collision problem is solved numerically using the Method of Dimensionality Reduction [5]. It turns out that, when FGM are used, parameter combinations are possible in which the oblique impact with friction can be completely energy-retaining if the coefficient of friction is large enough. For homogeneous materials, this is impossible even with an infinitely large coefficient of friction due to inevitable relaxation damping [6].

The talk is mostly based on the publications [7] and [8], which can be consulted for a more detailed analysis.

References

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