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Three-Dimensionally gradient harmonic structure design for high performance structural materials

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The Harmonic Structure (HS) is an innovative nano-micro scale materials design, which gives outstanding mechanical properties to structural metallic materials. In general, homogeneous and ultra-fine grain (UFG) structure enables the materials high strength. However, such a "Homo" and "UFG" does not, usually, satisfy the need to be both strong and ductile, due to the plastic instability in the early stage of the deformation. As opposed to such a "Homo and UFG", "HS" has a heterogeneous microstructure consisting of bimodal grain size together with a controlled and specific topological distribution of fine and coarse grains. In other words, the HS is heterogeneous on nano- and micro- but homogeneous on macro-scales. In the present work, the HS design has been applied to pure metals and alloys via a powder metallurgy route consisting of controlled surface severe plastic deformation of the corresponding powders, and subsequent consolidation. At a macro-scale, the HS materials exhibited superior combination of strength and ductility as compared to their homogeneous microstructure counterparts. Fig.1 demonstrates the comparison of mechanical properties of various metals and alloys with HS and their coarse-grained (CG) counterparts. It can be clearly noted that the normalized yield strength of the HS metals and alloys was considerably higher as compared to their CG counterparts. Since the area under the stress-strain curve is considered as a representation of the toughness of a material, the HS materials also exhibited improved toughness. These results clearly demonstrate that the HS design leads to improved mechanical properties in most of the metals and alloys which indicate that the HS metallic material would also result in improved performance in service. This behavior was essentially related to the ability of the HS to promote the uniform distribution of strain during plastic deformation, leading to improved mechanical properties by avoiding or delaying localized plastic instability.

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