

Materials with vortex-like structure produced by high pressure torsion extrusion

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In fluid dynamics, a vortex is a region in a fluid in which the flow is rotating around an axis line, which may be straight or curved. Vortices can be regular (water whirls, tornados, Saturn rings, galaxies, etc.) or stochastic (turbulent). In case of metals, the notion of a "vortex-like structure" refers to a composite consisting of two or more metals with a structure that looks like a vortex motion in a fluid or a gas. There is every reason to suppose that vortex-like structures open up new perspectives for the improvement of physical and mechanical properties of materials. For example, it was shown that thin pearlitic layers with a vortex appearance significantly improve the fracture toughness of swords made of Damascus steel.

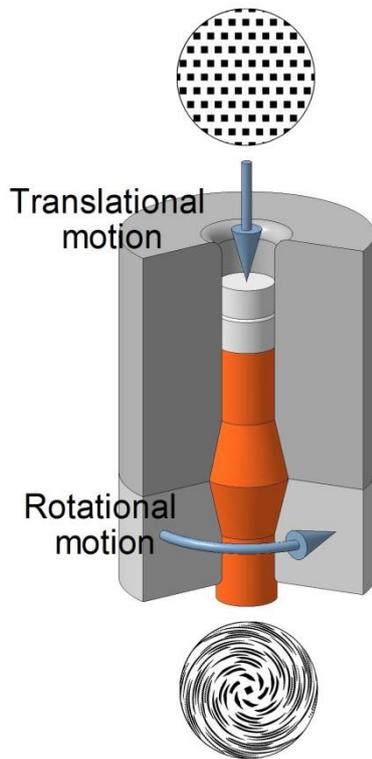


Fig.1 Schematic diagram of the HPTE process

In nature, similar structures were found in many living organisms and natural objects, giving rise to their outstanding mechanical properties [1]. Thus, in shells of an ancient tetrapod, a helical microstructure consisting of interlocking nanofibers provided enhanced fracture resistance [2]. Vortex structures can be straightforwardly formed by severe plastic deformation (SPD). It is well known that vortex-like structures occur in conditions of wear as a result of large shear strains in surface layers [3, 4]. It was also shown that they can form at large strains under high pressure torsion [5].

High pressure torsion extrusion (HPTE) is one of the SPD methods that allow producing specimens with vortex-like structure due to a pronounced velocity gradient. Fig.1 shows a schematic illustration of the HPTE process along with the results of finite element modeling of shearing of square elements after one HPTE pass. One can clearly see that the kinematics of the process promotes the vortex-like movement of the material in the shear plane. In the same way phases/precipitates or reinforcements will be distributed in the sample bulk after HPTE, which will influence the properties. This opens up new avenues for deliberately patterning the distribution of phases in a desired fashion. This report presents the outcomes of an investigation of the mechanics of vortex structure formation and the ensuing mechanical properties of the materials produced.

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