Multiple timescale modelling of particles de-agglomeration in metal melts subjected to external forces

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ABSTRACT

Aluminium and magnesium based metal matrix composites (MMC) with ceramic reinforcements promise low weight with high durability and superior strength, desirable properties in aerospace, automobile and other applications. Ceramic micro- and nano-particles are added into the metal melt, and electro-magnetic (EM) stirring is used to enhance the dispersion of the particles. Experiments however demonstrate the large particle agglomerates which lead to adverse effects on final properties of the MMCs: large-size clusters no longer act as dislocation anchors, but instead become defects. The formation of clusters is explained by the van der Waals and adhesion forces, which are of particular importance in the case of nano-particles. To prevent agglomeration and to break up the clusters, ultrasonic (US) processing is used via an immersed sonotrode, or alternatively electromagnetic (EM) vibration.

A model has been developed to account for the complex interaction of the particles with each other as well as with the flow of the metal melt. Particles are modelled as elastic spheres with adhesion. Adhesion is incorporated in the model using the Johnson, Kendal, Robert (JKR) and Derjaguin, Muller, Toporov (DMT) theories. The case of the oblique impact of the particles is modelled according to the Thornton and Yin method based on the partial-slip theory developed by Mindlin&Deresievics. The developed particle model is then coupled with the magneto-hydrodynamics (MHD) code in order to demonstrate the effect of the EM stirring and vibration.

Multiple time-scales are used which permits modelling the realistic time range of metal-processing and at the same time capture the individual collisions between particles with sufficient precision. Several methods of predicting the particle collisions are employed and their efficiency is compared for the cases of dilute and dense particle arrangements.