Simulation of Deposit Formation in Particle Laden Flows: Thermal Properties

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Fatty deposits formed on arterial walls leads to atherosclerosis but it is the interplay between these deposits and the vessel walls which govern the growth of plaque formation. Cells in the vessel walls trigger the body's defenses and through a series of mechanisms leads to the promotion of plaque growth. Crucially however the vast majority of acute coronary syndromes such as, myocardial infarction, and sudden ischaemic cardiac death are caused by atherosclerotic plaque rupture and not from a stenosis growing and blocking the blood flow. Although the stress caused by the blood flow does play a role in plaque rupture it has been found that the degree of stenosis is a relatively minor factor in predicting which plaques are most prone to rupture. In fact, atherosclerotic plaques expand into the vessel wall during much of their existence and this can make their detection problematic. However it would appear that the source of the problem, that is inflammation within the necrotic core of the plaque, can be used to detect which plaques may be vulnerable. Recent experiments have found that there is a measurable temperature difference between atherosclerotic plaques and normal vessels. An infrared angiothermography catheter and a thermistor probe catheter have been employed for generating thermal maps of arterial walls. The vulnerable plaques have a thin fibrous cap and a soft lipid core composed of macrophages, full of cholesterol, which release matrix-digesting enzymes during apoptosis leading to plaque rupture. The hotter arterial wall regions are caused by the release of heat from these activated inflammatory cells. Thus these thermal maps can identify the most likely sites for plaque rupture. If a direct link between the geometry of these deposits and their thermal properties could be found then non-invasive imaging techniques such as ultraound, MRI or CT scans could be used to spot vulnerable plaques.

One way to investigate such a link between deposit geometry and thermal properties is to simulate the process on computer. In this paper we describe our recent work on simulating the deposition arising from a particle laden flow by coupling together an Euler-Lagrangian bulk flow calculation with a Monte Carlo simulation near the wall boundaries. We have shown that the thermal conductivity of randomly accumulated deposits can be estimated from the geometry of the pore structure.

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