Commun. Comput. Phys.
doi: 10.4208/cicp.191114.270315a

Vol. **18**, No. 3, pp. 707-722
September 2015

# Direct Numerical Simulation of an Open-Cell Metallic Foam through Lattice Boltzmann Method

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Received 19 November 2014; Accepted (in revised version) 27 March 2015

**Abstract.** In this paper Lattice Boltzmann Method (LBM) has been used in order to perform Direct Numerical Simulation (DNS) for porous media analysis. Among the different configurations of porous media, open cell metallic foams are gaining a key role for a large number of applications, like heat exchangers for high performance cars or aeronautic components as well. Their structure allows improving heat transfer process with fruitful advantages for packaging issues and size reduction. In order to better understand metallic foam capabilities, a random sphere generation code has been implemented and fluid-dynamic simulations have been carried out by means of a kinetic approach. After having defined a computational domain the Reynolds number influence has been studied with the aim of characterizing both pressure drop and friction factor throughout a finite foam volume. In order to validate the proposed model, a comparison analysis with experimental data has been carried out too.

**PACS**: 47.11.-j, 47.11.Qr, 47.15.Rq, 47.56.+r

**Key words**: LBM, DNS, porous media simulation, metallic foam characterization.

## 1 Introduction

Metallic foam components are gaining an always rising up relevance and their applications in a large number of engineering processes are occurring. For example, porous media, like metallic foams, are nowadays applied to heat exchangers both for industrial or electronic devices [1–3]. Then a precise and accurate knowledge about fluid-dynamic

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phenomena which take place into a porous medium is becoming really helpful for future developments. Being the metallic foam randomly organized, the mathematical solution of involved continuum equations is a challenging issue to be solved, [2]. Many authors [1, 4–8] used a simplified cell derived from the Lord Kelvin one, commonly named tetrakaidecahedron. The main disadvantage of this approach is the lack of randomness due to the intrinsic cell structure. On the other hand, starting from the images obtained by means of micro-tomography, an alternative approach, based on random packing distribution, has been proposed [9, 10], with apparent benefits in terms of mesh generation. Then, the aim of this paper is to couple the latter approach with a three dimensional Lattice Boltzmann scheme.

During last decades, in fact, Lattice Boltzmann Method (LBM) has gained an always rising importance over numerical simulation methods due to its simplicity on implementation and accuracy in solving fluid-dynamics problems in the range of small Knudsen numbers [11–13]. In order to speed up simulation, an optimized parallel version of the source code has been developed with significant benefits in computational time. Lattice Boltzmann Equation (LBE) may be used in order to solve a wide range of cases where the fluid compressibility may be neglected. As already pointed out by [14, 15] Lattice Boltzmann Method may be applied for a large number of applications which involve multiphase flows too. More precisely, in this paper, the attention is addressed to the definition of an alternative approach for metallic foam simulation. The main advantage in using a LBM is to perform a direct numerical simulation and to locally solve involved equations in a large number of grid points but with relatively low computational requirements also for complex geometries like porous media. More specifically, starting from a random sphere packing approach, the laminar flow behaviour of a metallic foam is deeply analysed, by varying Reynolds number, porosity level and grid definition as well. The goal is to find a correlation between numerical model and experimental results, presented by [10] and in the same time to define Ergun equations coefficients, [16], for the specific test case. After model validation, a sensitivity analysis to geometric parameters and material properties is carried out with the aim of predicting the fluid-dynamic behaviour of a generic metallic foam. This approach allows determining a foam characteristics at the beginning of the design phase with obvious advantages during project development.

## 2 The Lattice Boltzmann Method

The LBM represents a useful alternative to standard Navier-Stokes models. Starting from a microscopic kinetic approach for fluid flow solution, it mathematically describes movements and interactions of the small particles that constitute the flow. The LBM is based [11–13] on a discrete decomposition of Boltzmann equation into velocity space, which allows writing the discrete form of the Boltzmann equation for a set of speeds as