Modelling of a Wool Hydrolyses Reactor

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Introduction

Wool from EU sheep farming and butchery industry is essentially a worth noting by-product perceived as a waste which is mostly disposed of. The Life+ GreenWoolF project is aimed at demonstrating that green hydrolysis with superheated water is an effective and profitable way to convert wool wastes into organic nitrogen fertilisers with good soil amendment properties. This is carried out designing, building and testing a pilot plant equipment able to convert significant amounts (1 kg) of wool into an organic fertilizer. The core of the process is represented by the reaction tank (Figure 1), in which the hydrolysis reactions of wool proteins take place.

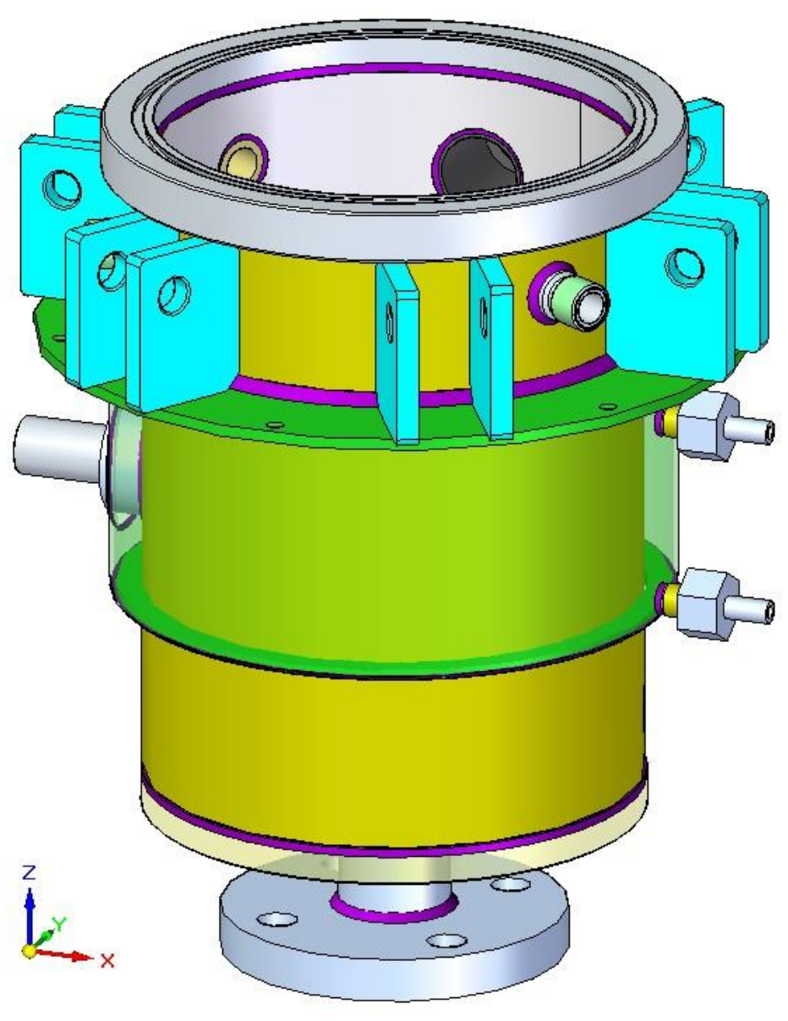

Figure 1. 3D view of the reaction tank of the pilot plant equipment.

One of the most influencing parameter is represented by the temperature of the material during the reaction, which has to be as much homogeneous as possible, and is directly connected with the bulk density of the material, the reaction time and the amount of water needed for the reaction.

Computational Methods

2D simulations of the reaction tank have been performed to study the heat transfer propagation and temperature distribution within the cylindrical 10 L volume tank, considering a 2 kW electrical band resistance, placed at the bottom of the reactor. Wool fibres agglomerates were considered as a porous matrix, completely filled with water and contained in a perforated drum. The drum has been designed with or without an inner spindle in which the liquid can come in contact with the innermost part of the fibres agglomerates (Figure 2).

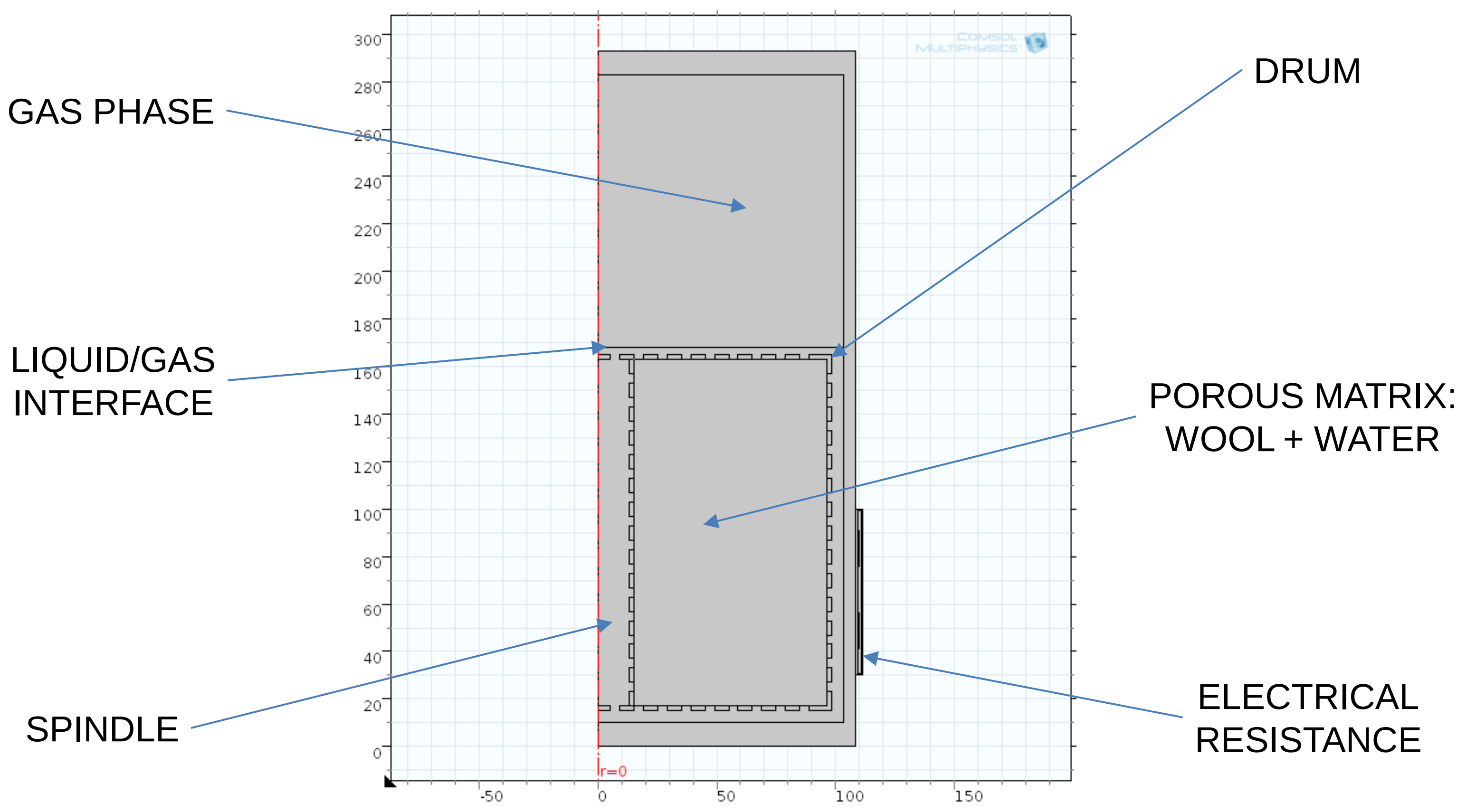

Figure 2. 2D axisymmetric front view of the reaction tank with drum and spindle.

For the study of this system, Heat Transfer in Porous Media, Non-Isothermal Flow and Laminar Two-Phase Flow physics have been used. Complementary equations and physical correlations were also introduced to describe the complex behaviour of the wool material.

In the reactor no artificially circulation of the liquid is induced, thus only the natural convection phenomenon is present and has been simulated by means of volume forces within the fluid phases. It is interesting to evaluate the initial transition phase necessary to bring the pre-heated (60 °C) material to the set point temperature (170 °C), at which the reaction starts.

Results

When wool fibres agglomerates are placed inside the perforated drum, they can be compressed in order to reach a high or a low bulk density, respectively 500 or 160 kg/m^3. The simulations have been carried out in order to evaluate the temperature profiles of the porous matrix with the change in density.

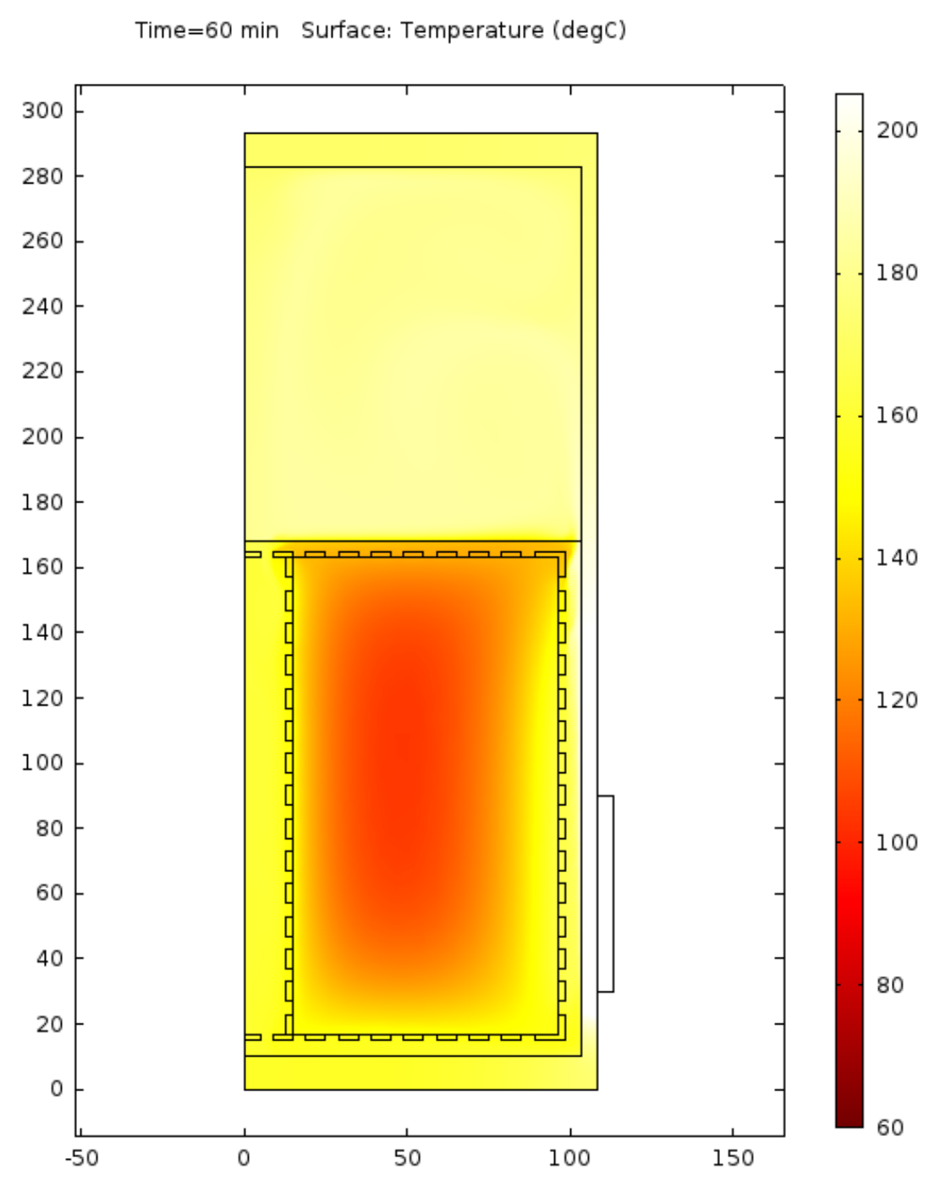

Figure 3. Temperature distribution in the reactor at 170°C (water temperature) for a high bulk density porous matrix (500 kg/m^3).

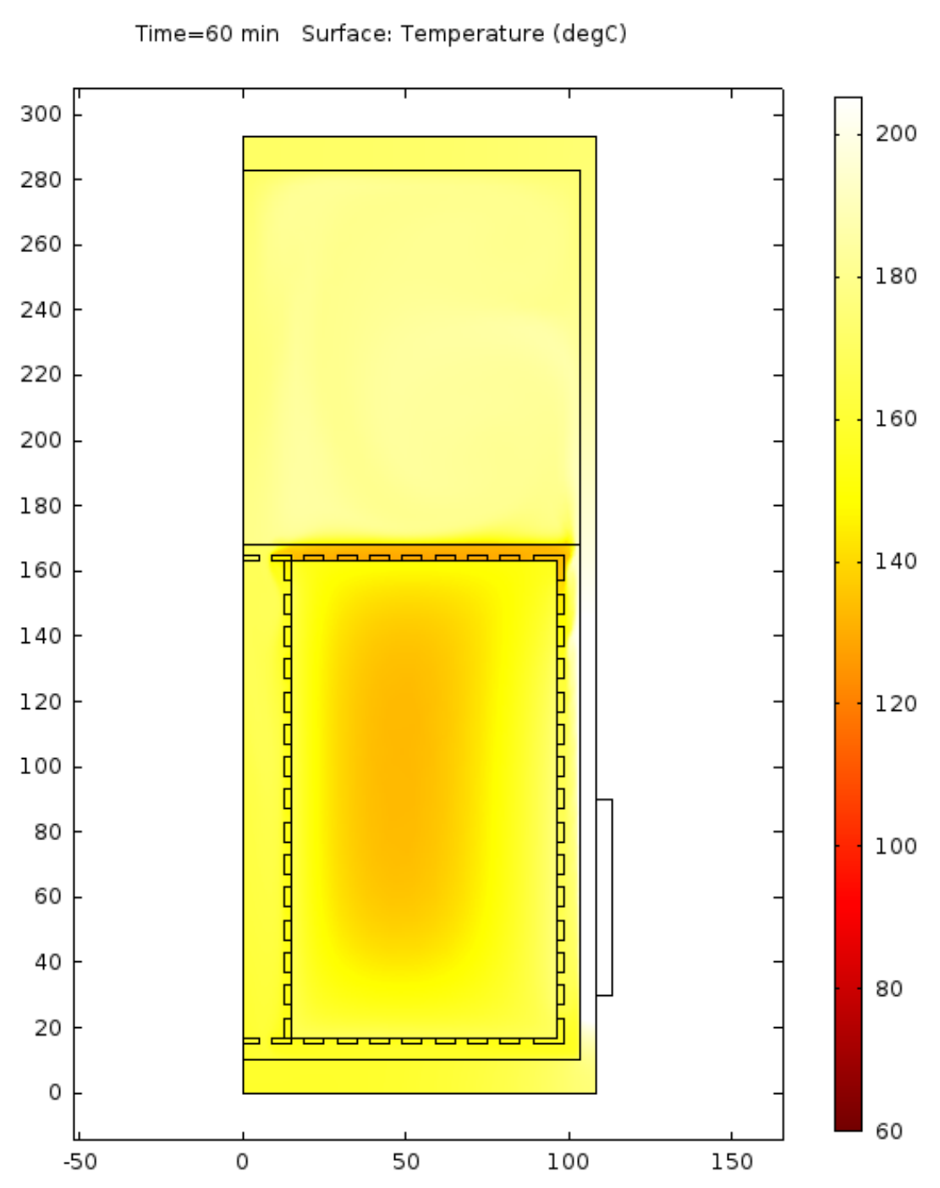

Figure 4. Temperature distribution in the reactor at 170°C (water temperature) for a low bulk density porous matrix (160 kg/m3).

Figure 3 and 4 represents the temperature distributions after 60 min, when the water temperature reached the set point temperature (170 °C). As can be seen, the heat transfer is highly dependent from the porous matrix bulk densities. In both cases the inner spindle is very important to allow a minimum liquid circulation, which is only due to the natural convection. This can be seen in Figure 5, where the velocity field in the reactor is reported.

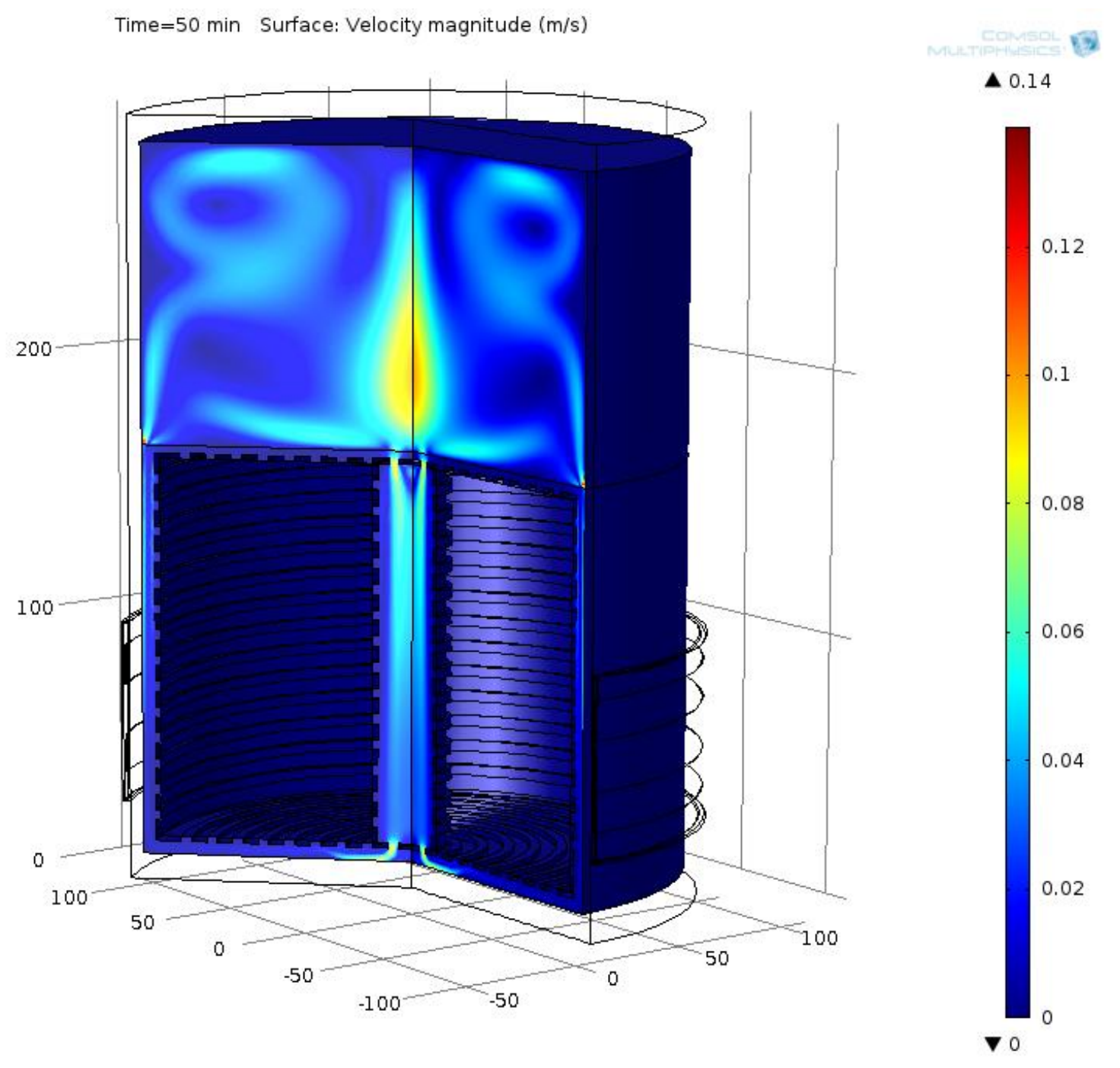

Figure 5. 2D revolution view of the velocity field in the reactor at a fixed time.

Conclusions

The present study demonstrated that the bulk density of the material strongly influences the temperature distribution. From an energy saving point of view, it is advantageous to reach a high bulk density with the lowest water content, but this is in contrast with the propagation of the heat transfer front through the fibrous material.

This issue has to be carefully taken into account for the scale-up and the design of the final equipment, which will able to convert a minimum of 500 kg/day of wool wastes into organic nitrogen fertilisers.

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