Analysis of Mash Tun Flow: Recommendations for Home Brewers

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Abstract

Introduction
The major steps in the beer making process are so simple that with some skill, rather good brew can be produced using a common picnic cooler. First, grain (usually barley) is wetted and allowed to partially germinate before dried in a kiln (malting) in order to convert starch reserves within the grain into more easily fermentable sugars. Next, the malted grains are soaked in hot water in to extract the fermentable sugars and then rinsed slowly to ensure as much sugar is removed as possible. This step is the called "mashing," and the device in which it is conducted is called a "mash tun." The mashing process is critical to the final taste, aroma, color, and body of the beer, and provides an excellent opportunity to use science and technology to improve the homebrewing experience. In order to analyze the extraction efficiency and wort quality of a mash tun, computational fluid dynamics simulations were performed using the COMSOL Multiphysics® software. The results of this experience are described in this paper.

Use of COMSOL Multiphysics
A model of the mash tun reactor was created using the Free and Porous Media Flow interface. Instead of a full three-dimensional model two types of 2-dimensional models were built by taking various x-y plane and y-z plane cuts (Figure 1). The results of the individual models were combined to develop ideas for improving the mash tun design.

Two separate regions were considered in the COMSOL models (the small fluid region sitting on top of the grain bed and the wort region underneath). Water properties were used for the top region and recommended values of viscosity, density, porosity and permeability were used in the wort region. An outflow condition was used to simulate draining through the pipes and enough input water as introduced at the top to maintain a constant level of fluid in the system.

Results
The two dimensional models allowed fast running of a rather large number of computer experiments. The goal was to obtain insight that could be used to optimize extraction in the mash tun reactor. As an example, figure 2 shows streamlines and pressure contours along the two perpendicular cuts for the base reactor consisting of four manifold legs. Figure 3 shows calculated extraction efficiencies and percentages of bed oversparged for various reactor designs.

Conclusion
COMSOL software proved useful as a stimulant of the idea generation process involved in the improvement of mash tun reactors. The results of the study indicate that, in terms of wort quality, the ideal mash tun design would include as many manifold legs as can possibly be fit into the mash tun.

Reference

1. Narziss, Ludwig. The Technology of Brewing Beer. Ferdinand Enke Verlag, Stuttgart, Germany, 1992.
2. Bear, Jacob. Dynamics of Fluids in Porous Media. Dover Publications, 1972.
3. C. J. Walsh, Design Recommendations for Homebrewers Based on CFD Analysis of Mash Tun Flow, Mechanical Engineering Master's Project Report, Rensselaer at Hartford, 2013.

Figures used in the abstract

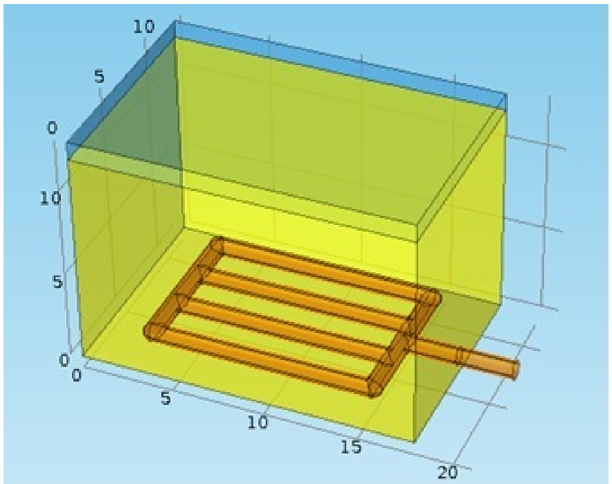

Figure 1: Schematic representation of the mash tun home brewing reactor.

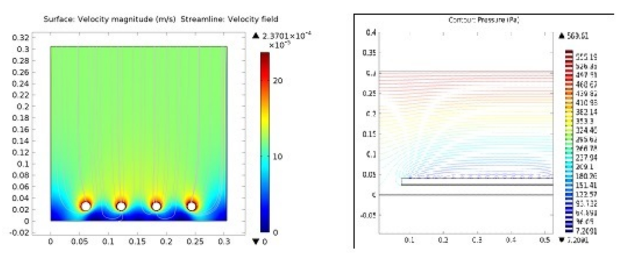

Figure 2: Computed streamlines and pressure contours on the two central planes of the tun.

Figure 3 COMSOL Results from Varying Number of Manifold Legs

Configuration	Percent Efficiency	Percent of Grain Bed Oversparged
1 leg	89.9%	45.8%
2 legs	91.4%	46.9%
3 legs	91.4%	45.1%
4 legs	91.2%	42.4%
5 legs	91.0%	39.5%
8 legs	88.4%	28.5%

Figure 3: COMSOL results from varying number of manifold legs.