

CFD analysis of the convective wine flow in cylindrical, truncated conical and egg-shape tanks: application to the mixing of light lees

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Abstract :

After alcoholic fermentation, the wine-producer can proceed to an early clarification of the wines followed by storage on light lees which are periodically stirred to resuspend the lees. This process of mechanical mixing is purely empirical and does not comply with any specifications. Initially sought by oenologists, it promotes the redistribution of the polysaccharides, amino acids, nucleic acids and esters contained in lees and well known for their strong flavors.

In the absence of any mechanical system, wine stored in tanks may be subject to slight variations in temperature, but nevertheless sufficient to set it in free convection motion. These temperature variations are only related to ambient temperature variations in the areas where the tanks are stored. This fluid motion is due to density differences in the fluid in the vicinity of the tank walls due to these temperature gradients. In such a case, the movement of the wine then makes it possible to redistribute within the liquid the quantity of light lees whose size varies from a micron to a couple of dozen microns and which could not be deposited due to their low sedimentation rate.

The motor of this movement is the thermal gradient between the outside and inside of the tank. The heat transfer mode is threefold and involves forced convection between the outside and the tank because wine tanks are generally stored in hangars where draughts are present, conduction in the thickness of the tank walls and free convection between the inside of the tank and the liquid medium.

The question that motivated this study is whether these natural movements are sufficient to obtain an effective stirring inside the tank to resuspend the light lees. Are the vortex distribution and the intensity of the inherent velocities of the fluid sufficient to compensate for the natural sedimentation rate of these suspended particles? To answer this question, two complementary approaches have been developed. The first, experimental, highlights by PTV and PIV (2D2C) the way in which light lees are resuspended under the action of positive and negative temperature gradients between the outside and inside of the tank. In the second approach a purely CFD numerical study focused on the liquid medium was established, based on thermal conditions recorded in November in the Champagne-Ardenne region of France where the stored wine tanks were subjected to outside temperatures ranging from 4°C in the morning to 20°C in the afternoon. Moreover, this study is completed by considering different common tank geometries, ranging from cylindrical to truncated conical shapes, the objective being to evidence the role of the tank geometry on the mixing process.