Using Geometric Model to predict the density of a quaternary nitrate salt system

Varun Shrotri [a], Dr. Luckman Muhmood [a]

[a] Department of Mechanical Engineering, K.J. Somaiya College of Engineering, Mumbai -77

Abstract

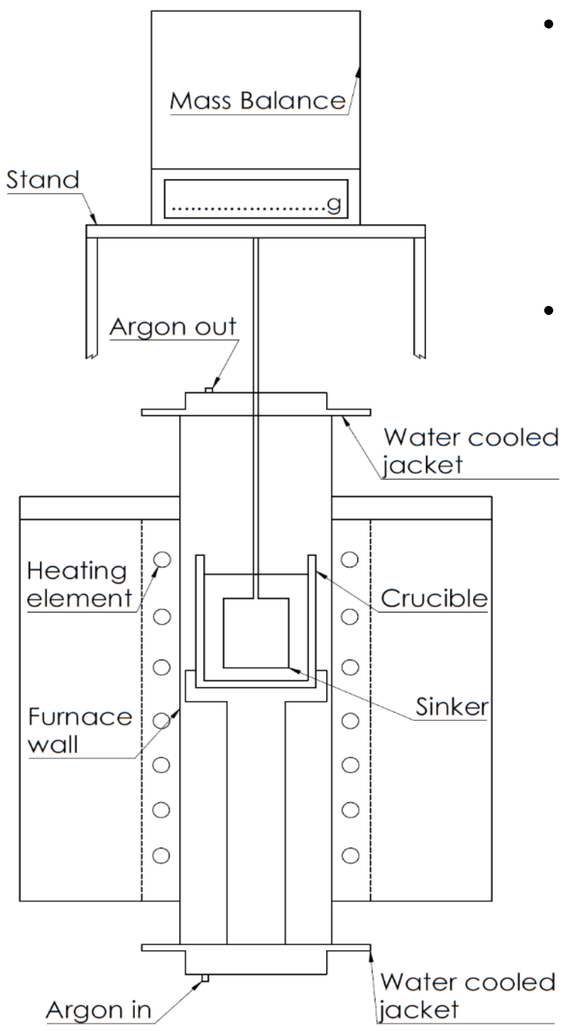
The current work deals with the measurement of thermophysical properties of $NaNO_3$-KNO_3-$LiNO_3$-$Ca(NO_3)_2$ based quaternary nitrate molten salts as heat transfer fluid for Concentrating solar power plants. These experiments provide the thermophysical data for the quaternary salt systems, data which is valuable in regards to the problem that it is difficult to obtain data as experimenting at high temperatures is challenging due to their complexity Hence, a geometric model proposed by K.C. Chou has been applied in this regard to calculating the density of the quaternary salt mixture. This model has been previously applied to other multicomponent systems successfully, and it has been demonstrated to work on ionic liquids with reasonable accuracy [1, 2].

Introduction

- Molten salts have been widely considered as a viable heat transfer fluid to be used in Concentrating solar power systems. They offer some very convenient advantages over conventional organic heat transfer fluids such as high volumetric heat capacity, compatibility with the environment, high operating and decomposition temperature [3].
- Binary and ternary alkali nitrate salt mixtures are currently in use as heat transfer fluids and thermal energy storage fluids. Higher order systems are under research to optimize their performance
- Experimentation at high temperatures is challenging and intricate
- K.C. Chou's geometric model [4] has been used to predict the density of a quaternary nitrate salt system containing sodium, potassium, lithium and calcium nitrates.

Methodology

- The density of salt mixture containing $NaNO_3$ (17.75 wt. %), KNO_3 (40.07 wt. %), $LiNO_3$ (17.75 wt. %) and $Ca(NO_3)_2$ (17.75 wt. %)
- A bottom loaded Mettler Toledo precision balance is used to measure the density of the molten salt.
- The sinker for density measurement is an SS 304 bob and the crucible used is also SS 304.



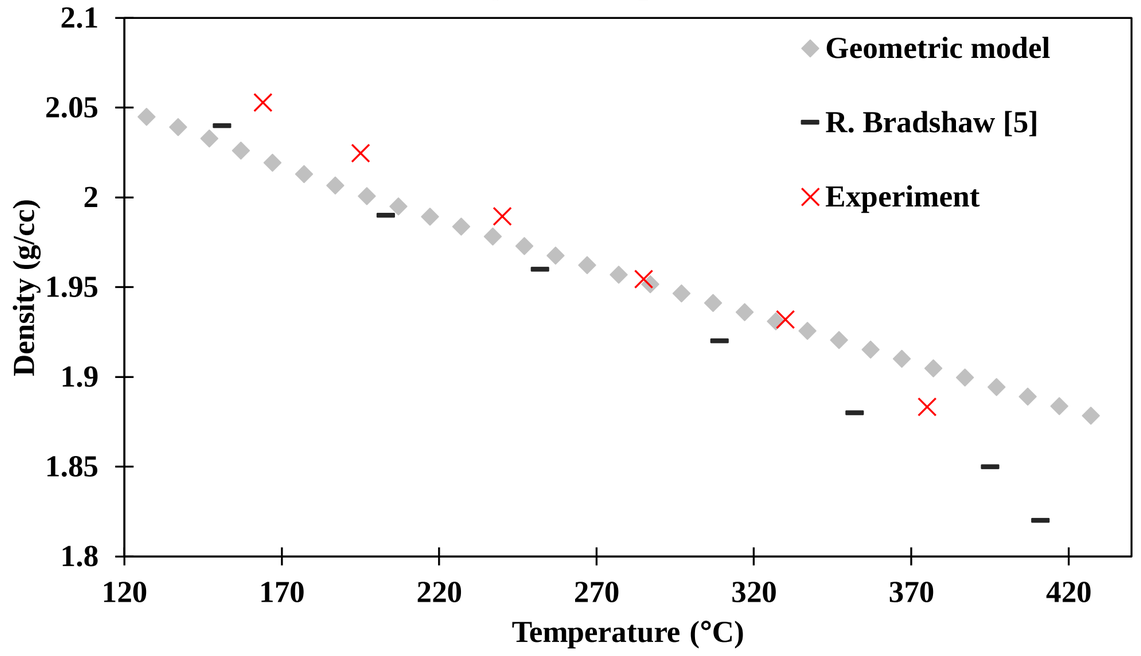
Setup for density measurement

- A General Solution Model proposed by Chou has been used to predict and compare the density of the quaternary alkali nitrate salt mixture.
- It predicts the properties of a multi-component system in terms of the properties of all the unary and binary systems present in the system.

Results

- Exponentially decreasing viscosity of the salt mixture was observed. The density of the quaternary mixture varied from 2.53 g/cc to 1.88 g/cc between 164 °C and 375 °C respectively
- A linearly decreasing trend in the density has been observed in the quaternary salt system and it has been correlated with R. Bradshaw [5] and the results obtained from the geometric model.
- The deviation in experimental density was observed to be about -1.97 % and the root mean square deviation was 0.02403 g/cc, in relation to literature data.
- The predicted density had an average error of -0.34 % and a root mean square deviation of 0.02386 g/cc compared to experimental results.

Density v/s Temperature



Conclusion

- A relatively high density of around 2 - 1.8 g/ cc for the quaternary mixture was observed.
- The experimental result compared to literature data had a reasonably low error of -1.97 %.
- The density prediction using Chou's geometric model resulted in good accuracy with the test results with a root mean square deviation of 0.02386 g/cc.

Acknowledgement

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