Chloride addition for improving operational range of Molten salts for high temperature CSP applications

Siddhesh Pawar, Varun Shrotri, Dr. Luckman Muhmood
Department of Mechanical Engineering, K.J. Somaiya College of Engineering, Mumbai, India.

Abstract
Molten Nitrate salts are promising Heat transfer fluids (HTF) and Thermal energy storage (TES) materials in Concentrated Solar Power plant (CSP) than the traditionally used Heat transfer oils. Solar salt® (40%KNO3-60%NaNO3) is commonly used as a HTF in CSP's. It has a freezing point of 221°C [1] and decomposition point (where 3% mass loss occurs) is around 630°C [2]. A similar ternary nitrate salt, Hitec has comparatively lower melting point of 142°C [1] compared to Solar salt but the decomposition temperature is 604°C [2]. There has been work directed towards improving high temperature stability of these salts by adding a chloride component [3]. In the current work a new ternary mixture comprising of $Ca(NO_3)_2$–KNO_3–$NaNO_3$ termed as "Base salt" was prepared. It has freezing point of around 145°C and decomposition temperature is 663°C. Addition of various chloride components like NaCl, KCl, LiCl and CaCl2 in various proportions was done to the Base salt and the thermogravimetric analysis was carried out in a custom made TGA set up to study its effect on decomposition temperature. Cooling curve analysis was also carried out to determine the freezing point of the salt mixtures. From the above studies it can be concluded that the addition of 5%NaCl and 5%KCl to Base salt can improve its high temperature stability while reducing the freezing temperature, hence increasing the overall operating range of the nitrate salt.

Introduction

- A new ternary salt mixture comprising of 44%KNO_3- 32% $Ca(NO3)_2$-24%$NaNO_3$ (Base Salt) was prepared.
- The melting point of this mixture is 145°C and decomposition point (3% mass loss of the total mass) is around 663°C.
- The challenge is to increase the operating range of the salt mixture by addition of chloride component such as Sodium chloride (NaCl), Potassium chloride (KCl), Lithium chloride (LiCl) and Calcium chloride ($CaCl_2$) as these compounds are found to be stable above 700 °C.

Methodology

To prepare a new salt composition of $Ca(NO_3)_2$ -KNO_3-$NaNO_3$ (ratio 32:44:24 by weight) also termed as BASE salt

↓

Thermogravimetric analysis (TGA) of the base salt

↓

Addition of NaCl, KCL,$CaCl_2$ and LiCl in 5% and 10% proportion by weight to Base salt. Performing TGA of all composition

↓

Selection of best composition that has higher stability at elevated temperature

↓

Performing cooling curve analysis to determine freezing temperature of the selected salt mixture

↓

Report/ Publishing

Figure 1. Flowchart of methodology

Experimental setup

- The custom-made Thermogravimetric analysis (TGA) setup includes the following instruments:

i. Muffle furnace
ii. Vertical tube furnace
iii. Precision mass recorder
iv. Thermocouple with data recorder
v. Water circulator cum chiller
vi. Crucibles made from stainless steel 316L grade (16mm diameter, 30mm length).

- 1 gram of salt samples were taken in the crucibles for the TGA.
- All the experiments were conducted in argon atmosphere.

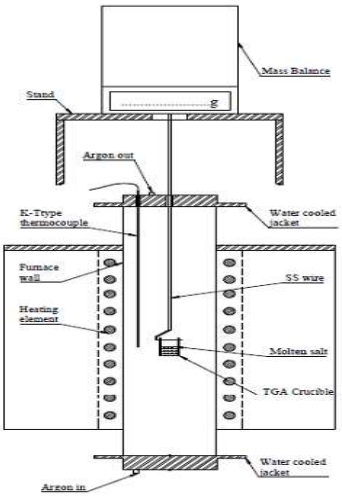

Figure 2. Setup for TGA

Results

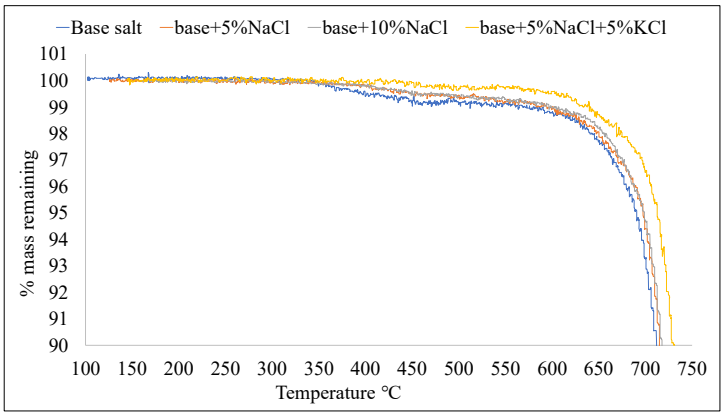

Figure 3. TGA graph of salt mixtures

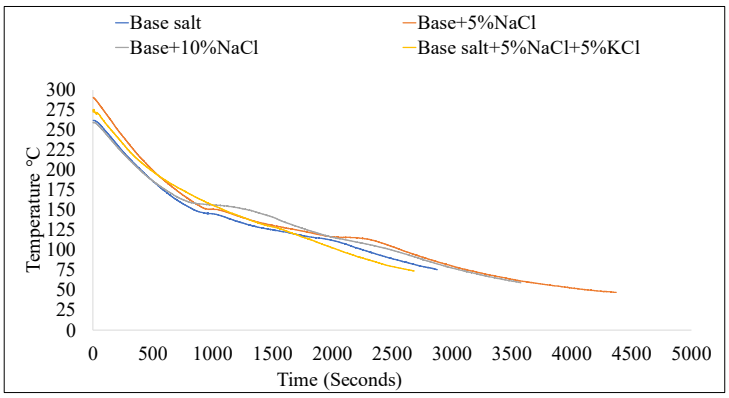

Figure 4. Cooling curve analysis of salt mixtures

Conclusion

	Base salt	Base salt + 5%NaCl+ 5%KCl	Solar salt	Hitec® salt
Decomposition Temperature(A) (3% mass loss)	663°C	695°C	630°C	604°C
Freezing point(B)	145°C	125°C	221°C	142°C
Operating range(A-B)	518°C	570°C	409°C	462°C

Table 1. Comparison of freezing, decomposition point and operating range of various salt mixtures

- The addition of 5%KCl+5%NaCl to Base salt had following effects
  - ➢ High temperature stability improved from 663°C to 695°C
  - ➢ The freezing temperature reduced from 145°C to 125°C
  - ➢ The overall operating range improved from 518 °C to 570 °C

Acknowledgement

The authors would like to acknowledge the Department of Science and Technology (SERB/EMR/2016/002784) for funding the project.

References

[1] Kearney, D., et al. Overview on Use of a Molten Salt HTF in a Trough Solar Field (Presentation). No. NREL/PR-550-40028. National Renewable Energy Lab.(NREL), Golden, CO (United States), 2003.
[2] Gimenez, P., and S. Fereres. "Effect of heating rates and composition on the thermal decomposition of nitrate based molten salts." Energy Procedia 69 (2015): 654-662.
[3] Fernández, A. G., et al. "Thermal characterization of HITEC molten salt for energy storage in solar linear concentrated technology." Journal of Thermal Analysis and Calorimetry 122.1 (2015): 3-9.