Modification in Specific Heat of Heavy Earth Moving Machinery Coolants with CuO, Al$_2$O$_3$, TiO$_2$ and SiO$_2$ Nanoparticles

1Ankit Kotia, 2Srijan Vaibhav Pathak
1School of Mechanical Engineering, Lovely Professional University, Jalandhar, India
2Central Coalfields Ltd (a subsidiary of Coal India Ltd), Ranchi, Jharkhand.

Abstract
Nano particles in conventional coolant of HEMM (Heavy Earth Moving Machinery) are used for enhancement in thermophysical properties. In present study the change in specific heat HEMM coolants with the dispersion of nanoparticles is evaluated. Specific heat determines by using well-known correlations. The effect of CuO, Al$_2$O$_3$, TiO$_2$, and SiO$_2$nano-particles with water and ethylene glycol has been investigated.

Nomenclature
T Temperature, K
C Specific heat capacity ($C_p$)
$\phi$ Volume fraction of suspension particles
$\rho$ Density

Subscripts
bf and nf for base and nanofluids respectively
s and m for solid and medium respectively

Introduction
The limiting heat transfer properties of water, ethylene glycol (EG) and lubricating oil are key hurdle in durability of Heavy Earth Moving Machinery (HEMM). Dispersion of nanoparticles to improve thermal conductivity are widely employ, but it produces decrement in specific heat capacity. The use of solid nanoparticles as an additive are termed as nanofluids [1-2]. This suspension of solid particles also create problem of channel clogging and pressure drop [3-4].
In the present paper, the effect of CuO, Al$_2$O$_3$, TiO$_2$, and SiO$_2$ nano-sized particles on the HEMM coolants specific heat are investigated.

2. Mathematical models of Nanofluids used
Existing literature reveals the dominance of model 1 (Pak and Cho [5]) and model 2 (Xuan and Roetzel [6]) for determination of specific heat. Equation 1 and 2 shows the model 1 (Pak and Cho [5]) and model 2 (Xuan and Roetzel [6]) respectively.

\[ C_{ps} = \phi C_{pp} + (1 - \phi)C_{pm} \]  

(1)
\[ C_p^f = \frac{(1 - \phi)(\rho C_p)_n + \phi(\rho C_p)_p}{(1 - \phi)\rho_n + \phi\rho_p} \]  

(2)

3. Results and discussions

Using the above mentioned theoretical models, the results were plotted for nanofluids. The variation in behavior of different nanofluids was studied with variation in volume fraction of the added particles.

Figure 1 shows the variation \( C_p \) of TiO\(_2\)–water nanofluid with respect to the nano particle volume fraction. Graph is plotted using values obtained by equations and experimental values. It can be depicted from Figure 1 that specific heat values obtained by models and experimental values are almost linear with negative slope. Magnitude of slope of Model II and experimental value are almost equal and is greater than the magnitude of slope of model I. General trend is that \( C_p \) of nano-fluids decreases with the increase in the \( \text{vf} \) of the nano fluids using both the models.

![Figure 1: \( C_p \) variation for TiO\(_2\)-water nanofluid](image1)

Figure 2 shows the variation of \( C_p \) of TiO\(_2\)–EG nanofluid wrt the nano particle \( \text{vf} \). Graph is plotted using values obtained by models and experiment. Graph plotted by models and experimental values are almost linear with negative slope. Magnitude of slope of Model II and experimental value are almost equal and is greater than the magnitude of slope of graph I. General trend is that \( C_p \) of nf decreases with the increase in \( \text{vf} \) of nano fluids using both the models.

![Figure 2: \( C_p \) variation for TiO\(_2\)-EG nanofluid](image2)
Figure 3 shows the variation of $C_p$ of Al2O3–EG nanofluid with respect to the nano particle volume fraction. Graph is plotted using values obtained by models and experiments. Graph plotted by models and experimental values are almost linear with negative slope. Magnitude of slope of Model II and experimental value are almost equal and is greater than the magnitude of slope of graph I. General trend is that $C_p$ of nfs decreases with the increase in the vf of the nano fluids using both the models.

![Graph of $C_p$ variation for Al2O3-EG nanofluid](image)

**Figure 3**: Specific heat variation for Aluminum oxide -EG nanofluid

Figure 4 shows the variation of $C_p$ of Al2O3 – water nanofluid wrt the nano particle volume fraction. Graph obtained by models and experimental values are almost linear with negative slope. The curve of experimental values lies below the values obtained with Model II. Magnitude of slope of Model II is greater than the magnitude of slope of curve obtained by Model I. General trend is that $C_p$ of nano-fluids decreases with the increase in the vf of the nano fluids using both the models.

![Graph of $C_p$ variation for Al2O3-EG nanofluid](image)

**Figure 4**: Specific heat variation for Aluminum oxide-EG nanofluids

Figure 5 shows the variation of $C_p$ of silicon oxide- water nanofluid with respect to the nano particle volume fraction. Graph obtained by models and experimental values are almost linear with negative slope. Curve obtained by plotting experimental values lies between the curve obtained by Model I and Model II. Magnitude of slope curve obtained by Model II is greater than the magnitude of slope of curve obtained by Model I. General trend is that $C_p$ of nfs decreases with the increase in the vf of the nano fluids using both the models.

![Graph of $C_p$ variation for silicon oxide-water nanofluid](image)
Figure 5: Specific heat variation for Silicon oxide-EG nanofluids

Figure 6 shows the variation of $C_p$ of Copper oxide- water nanofluid with respect to the nano particle volume fraction. Graph obtained by model I, model II are linear with negative slope whereas the curve obtained by plotting experimental values is non-linear. Curve obtained by plotting experimental values lies below the curve obtained by Model I and Model II. Magnitude of slope curve obtained by Model II is greater than the magnitude of slope of curve obtained by Model I. General trend is that $C_p$ of nfs decreases with the increase in the vf of the nano fluids using both the models.

Figure 6: Specific heat variation for Copper Oxide -EG nanofluid

4. Conclusion

The present paper various mathematical models were used to study the variation of $C_p$ of nanofluids with CuO, Al$_2$O$_3$ TiO$_2$ and SiO$_2$ in base fluids water and ethylene glycol. The general trend of the $C_p$ was found to be decreasing with increase in volume fraction of nano particles.

References:


