Numerical Simulation on Influence of Nozzle to Plate Distance for Spout Impact Cooling with Water-Al_2O_3 Nanofluid

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Abstract: Present exploration connect with the influence of nozzle to plate distance aimed at spout impact cooling through water-Al_2O_3 nanofluid. CFD codes got established to compute the governing equalities of mass, force and drive for envisaging the thermal issues. CFD codes got executed through water-Al_2O_3 nanofluid spouts to envisage thermal issues on the chosen plate. It uses 60 m/s spout velocity, 3 mm nozzle dimension and varying nozzle to plate distances of 3, 4, 5 and 6 mm. As projected from every temperature arena, the temperature gently grows from spout impact spot on chosen plate along centrifugally peripheral course. This could stand because of thermal outflow using water-Al_2O_3 nanofluid. The developments of temperature disparities alongside the radial course aimed at the identified cases are really similar. Still, the extreme temperatures over the chosen plate for situations with nozzle to plate distances of 3, 4, 5 and 6 mm are detected to remain 318, 314, 310 and 316 K, respectively. Well along the nozzle to plate distance of 5 mm embraces rather lesser mean temperature and so, it stands as the perfect one.

Index Terms: CFD Codes, Nozzle to Plate Distance, Spout Impact, Water-Al_2O_3 Nanofluid.

I. INTRODUCTION

The impacting spouts caught numerous routines for illustration in paper parching, textile treating, automobile fabrication, metal normalizing, gadget thermal control, etc. The standard thermal control arrayed heretofore for illustration atmospheric convection inappropriate for extreme thermal flux treatments. Still, in the preceding years the strange way of thermal control has compelled the researchers' everywhere within the domain for the routine of fluid spout impact cooling.

Furthermore, the nanofluid thermal control is candidly spirited as ambient thermal control is poor to deliver the drive. Numerical and experimental reviews on heat spreading over rectangular domain are existent in texts [1-7]. Computational and experimental work with solidification are also presented [8-20].

Regardless of the information that the fluid spout impact cooling equivocates the issues about the extreme heat battle as to ambient thermal control, then again, the treatment of nanofluid for impacting spout remains the significant drive of the extant exploration. Here, the thermal controls of impacting spout through water-Al_2O_3 nanofluid stand explored computationally. Besides, the extant CFD exploration recounts to the influence of nozzle to plate distance on spout impact cooling through water-Al_2O_3 nanofluid.

II. EXPLICATION OF PHYSICAL TOPIC

Figure 1 unveils the physical topic course purview covering a chosen hot plate indicating the foot edge, a nozzle of inflow velocity at mid of the upper edge and two upright edges signposted through outflow boundary state with exodus pressure conforming to ambient pressure.

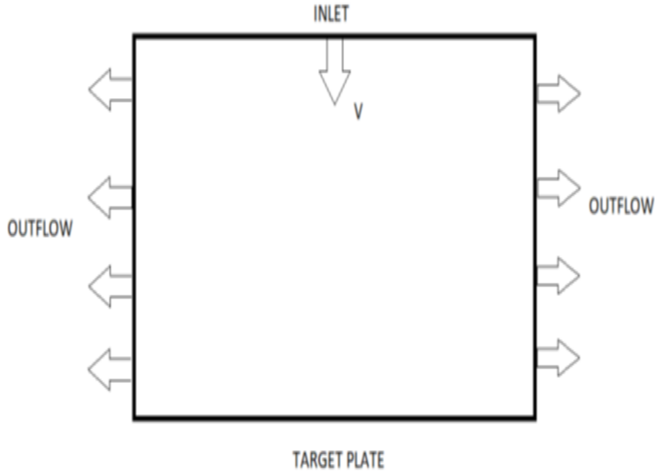

Figure 1. Physical topic course purview

III. COMPUTATIONAL METHODOLOGY

Figure 2 reveals the CFD Worktable aimed at computing the above declared physical topic course. To facilitate the CFD forecasts the binding stages such as constructing geometry and purview, meshing and initialization are followed to run the simulation. Here, the prevailing equalities (as termed below through equalities 1-4) of mass, force and drive beside the edge states are chosen. Linearized equalities are computed through the CFD codes. After the development of computations, CFD codes form the shapes and curls through that numerous graphs stand strained to amalgam the CFD forecasts through the prognoses.

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With the later dispensation the forecasts are scrupulously explored aimed at receiving abundant acumens.

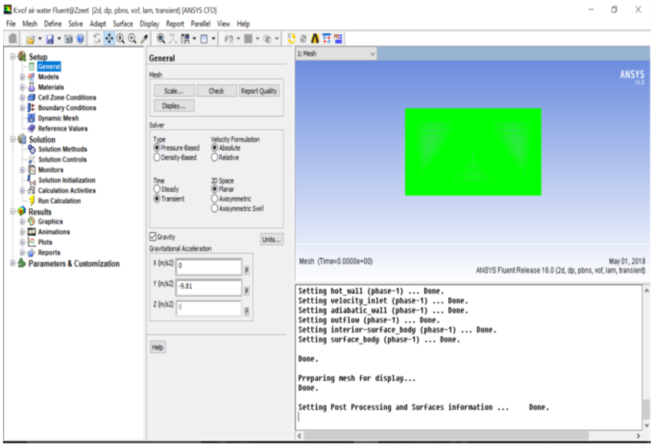

Figure 2. Course purview inside CFD interface

Continuity:
$$\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} = 0 \quad (1)$$

X-momentum:
$$\rho\left(\frac{\partial u}{\partial t} + u\frac{\partial u}{\partial x} + v\frac{\partial v}{\partial y}\right) = -\frac{\partial P}{\partial x} + \mu\left(\frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2}\right) \quad (2)$$

Y-momentum:
$$\rho\left(\frac{\partial v}{\partial t} + u\frac{\partial v}{\partial x} + v\frac{\partial v}{\partial y}\right) = -\frac{\partial P}{\partial y} + \mu\left(\frac{\partial^2 v}{\partial x^2} + \frac{\partial^2 v}{\partial y^2}\right) + \rho g \quad (3)$$

Energy:
$$\left(\frac{\partial T}{\partial t} + u\frac{\partial T}{\partial x} + v\frac{\partial T}{\partial y}\right) = \alpha\left(\frac{\partial^2 T}{\partial x^2} + \frac{\partial^2 T}{\partial y^2}\right) \quad (4)$$

In the existent analysis, CFD codes are executed with water-Al_2O_3 nanofluid spouts. It envisages the influence of nozzle to plate distance on thermal issues with 60 m/s spout velocity, 3 mm nozzle dimension and varying nozzle to plate distances of 3, 4, 5 and 6 mm. The convective governing equalities of mass, force and drive are computed for envisaging the thermal issues. The time pace selected throughout the intact computation is 0.0001 s.

Besides, the thermo-physical data of Al_2O_3 nanoparticles reflected in the existent analysis plus the ambient situation involved in the current course computations, are briefed too in understated Table 1.

Table 1. Thermophysical and ambient data.

Nanoparticle Data	Al_2O_3
Density, ρ (Kg/m^3)	3970
Specific heat, C_P (J/kg-K)	765
Thermal conductivity, k (W/m-K)	36
Ambient temperature	300 K

IV. RESULTS AND DISCUSSION

Influence of Nozzle to Plate Distance on Cooling Issue

CFD codes are executed with water-Al_2O_3 nanofluid. It envisages the influence of nozzle to plate distance on thermal issues with 60 m/s spout velocity, 3 mm nozzle dimension and varying nozzle to plate distances of 3, 4, 5 and 6 mm.

A. Instance Study with Nozzle to Plate Distance of 3 mm

Figure 3 reveals the tinted temperature arena integrated with the tinted flat scale for chosen plate. Obviously, it relates to nozzle to plate distance of 3 mm. As projected, the temperature gently grows from spout impact spot on chosen plate along centrifugally peripheral course. Additionally, the prophesied temperature ranges between 300 K (at spout impact spot) to 318 K (on outlying arena) over the chosen plate. This could stand because of thermal outflow using water-Al_2O_3 nanofluid.

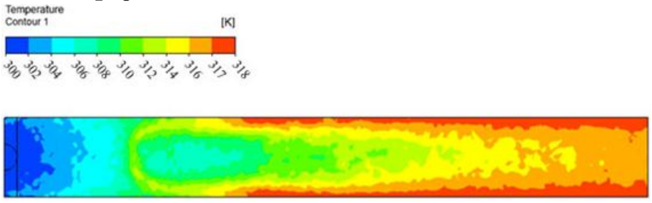

Figure 3. Temperature arena for nozzle to plate distance of 3 mm

B. Instance Study with Nozzle to Plate Distance of 4 mm

Figure 4 reveals the tinted temperature arena integrated with the tinted flat scale for chosen plate. Obviously, it relates to nozzle to plate distance of 4 mm. As projected, the temperature gently grows from spout impact spot on chosen plate along centrifugally peripheral course. Additionally, the prophesied temperature ranges between 300 K (at spout impact spot) to 314 K (on outlying arena) over the chosen plate. This could also stand because of thermal outflow using water-Al_2O_3 nanofluid.

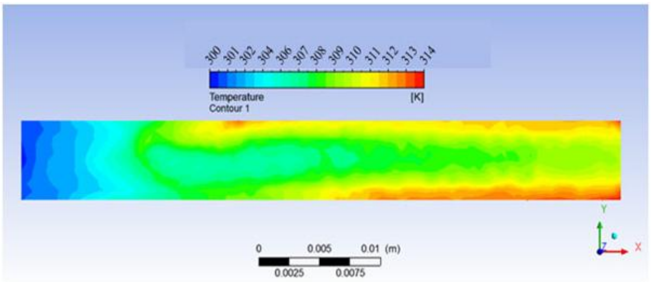

Figure 4. Temperature arena for nozzle to plate distance of 4 mm

C. Instance Study with Nozzle to Plate Distance of 5 mm

Figure 5 reveals the tinted temperature arena integrated with the tinted flat scale for chosen plate. Obviously, it relates to nozzle to plate distance of 5 mm. As projected, the temperature gently grows from spout impact spot on chosen plate along centrifugally peripheral course. Additionally, the prophesied temperature ranges between 300 K (at spout impact spot) to 310 K (on outlying arena) over the chosen plate. This could also stand because of thermal outflow using water-Al_2O_3 nanofluid. Furthermore, the advent of barrier form inside the temperature arena could stand owing to the incidence of trivial turbulence alongside the stream.

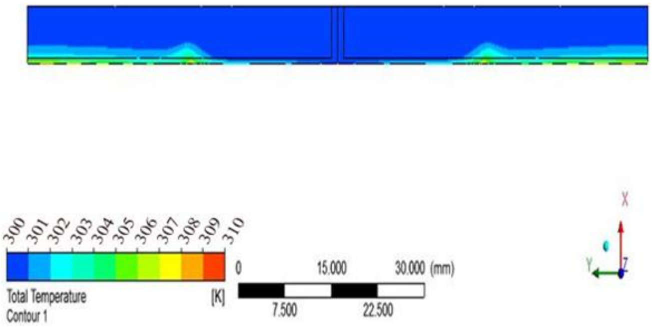

Figure 5. Temperature arena for nozzle to plate distance of 5 mm

D. Instance Study with Nozzle to Plate Distance of 6 mm

Figure 6 reveals the tinted temperature arena integrated with the tinted flat scale for chosen plate. Obviously, it relates to nozzle to plate distance of 6 mm. As projected, the temperature gently grows from spout impact spot on chosen plate along centrifugally peripheral course. Additionally, the prophesied temperature ranges between 300 K (at spout impact spot) to 316 K (on outlying arena) over the chosen plate. This could also stand because of thermal outflow using water-Al_2O_3 nanofluid.

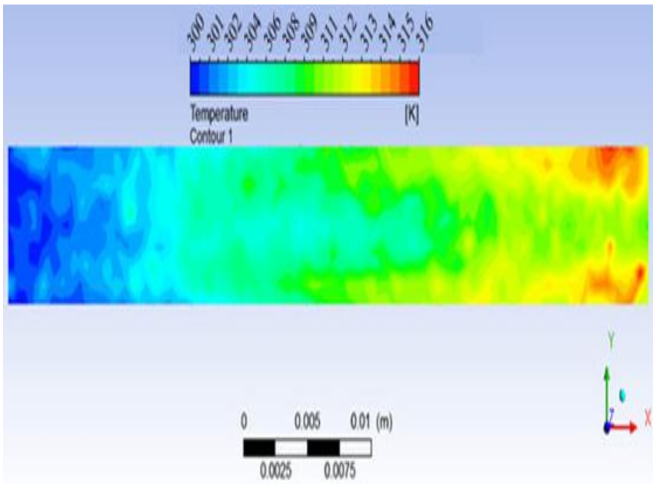

Figure 6. Temperature arena for nozzle to plate distance of 6 mm

Assessment of Instance Studies with Varying Nozzle to Plate Distances

Figure 7 establishes the reasonable graphs vis-à-vis temperature against radial distance for varying nozzle to plate distances of 3, 4, 5 and 6 mm. The developments of temperature disparities alongside the radial course aimed at the identified cases are really comparable. Still, the extreme temperatures over the chosen plate for situations with nozzle to plate distances of 3, 4, 5 and 6 mm are detected to remain 318, 314, 310 and 316 K, respectively. Well along the nozzle to plate distance of 5 mm embraces rather lesser mean temperature and so, it stands as the ideal one.

Besides, the identified situations are more emphasized in Table 2 alongside figure 8. Together express the difference in extreme temperature on the chosen plate for varying nozzle to plate distance. Further, this earmarks the untouched ideal instance of 5 mm nozzle to plate distance conforming the optimum temperature of 310 K on the chosen plate equally recognizable from the itemized table/graph.

Table 2. Nozzle to plate distance with extreme temperature over chosen plate.

Nozzle to plate distance (mm)	Extreme Temperature (K)
3	318
4	314
5	310
6	316

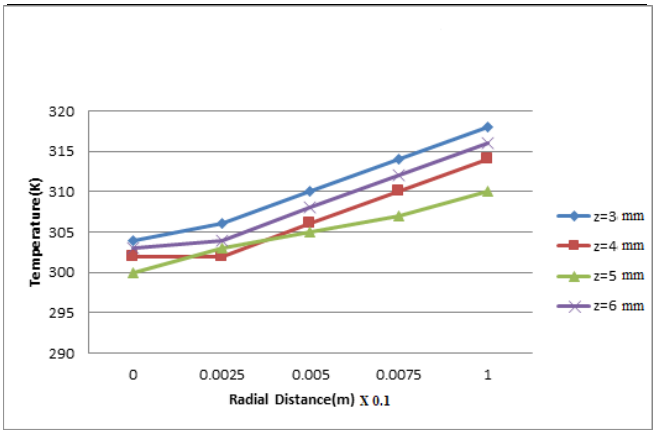

Figure 7. Temperature vs. radial distance

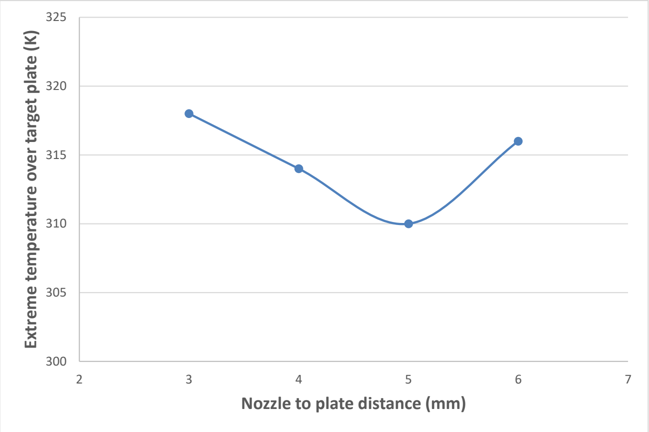

Figure 8. Nozzle to plate distance vs. extreme temperature over chosen plate

V. CONCLUSION

Current exploration connect with the influence of nozzle to plate distance aimed at spout impact cooling through water-Al_2O_3 nanofluid. CFD codes got established to compute the governing equalities of mass, force and drive for envisaging the thermal issues. CFD codes got executed through water-Al_2O_3 nanofluid spouts to envisage thermal issues on the chosen plate. It uses 60 m/s spout velocity, 3 mm nozzle dimension and varying nozzle to plate distances of 3, 4, 5 and 6 mm. As projected from every temperature arena, the temperature gently grows from spout impact spot on chosen plate along centrifugally peripheral course. This could stand because of thermal outflow using water-Al_2O_3 nanofluid. The developments of temperature disparities alongside the radial course aimed at the identified cases are really similar.

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REFERENCES

1. N. K. Kund, P. Dutta, 2010, Numerical simulation of solidification of liquid aluminium alloy flowing on cooling slope, Trans. Nonferrous Met. Soc. China, Vol. 20, pp. s898-s905.
2. N. K. Kund, P. Dutta, 2012, Scaling analysis of solidification of liquid aluminium alloy flowing on cooling slope, Trans. Indian Institute of Metals, Vol. 65, pp. 587-594.
3. N. K. Kund, 2014, Influence of melt pouring temperature and plate inclination on solidification and microstructure of A356 aluminum alloy produced using oblique plate, Trans. Nonferrous Met. Soc. China, Vol. 24, pp. 3465−3476.
4. N. K. Kund, 2015, Influence of plate length and plate cooling rate on solidification and microstructure of A356 alloy produced by oblique plate, Trans. Nonferrous Met. Soc. China, Vol. 25, pp. 61−71.
5. N. K. Kund, P. Dutta, 2015. Numerical study of solidification of A356 aluminum alloy flowing on an oblique plate with experimental validation, J Taiwan Inst. Chem. Ers., Vol. 51, pp. 159−170.
6. N. K. Kund, P. Dutta, 2016, Numerical study of influence of oblique plate length and cooling rate on solidification and macrosegregation of A356 aluminum alloy melt with experimental comparison, J. Alloys Compd., Vol. 678, pp. 343−354.
7. N. K. Kund, 2018, Effect of tilted plate vibration on solidification and microstructural and mechanical properties of semisolid cast and heat-treated A356 Al alloy, Int. J. Adv. Manufacturing Technol., Vol. 97, pp. 1617−1626.
8. N. K. Kund, 2019, EMS route designed for SSM processing, International Journal of Engineering and Advanced Technology, Vol. 8, pp. 382−384.
9. N. K. Kund, 2019, Cooling slope practice for SSF technology, International Journal of Engineering and Advanced Technology, Vol. 8, pp. 410−413.
10. N. K. Kund, 2019, Comparative ways and means for production of nondendritic microstructures, International Journal of Innovative Technology and Exploring Engineering, Vol. 8, pp. 534−537.
11. N. K. Kund, 2019, Simulation of electronics cooling deploying water-zinc oxide nanofluid, International Journal of Recent Technology and Engineering, Vol. 7, pp. 1076−1078.
12. N. K. Kund, 2019, Numerical studies on fuel cell cooling introducing water-copper nanofluid, International Journal of Recent Technology and Engineering, Vol. 7, pp. 1079−1081.
13. N. K. Kund, 2019, Computational modeling of fuel cell expending water-zinc oxide nanofluid, International Journal of Innovative Technology and Exploring Engineering, Vol. 8, pp. 424−426.
14. N. K. Kund, 2019, Investigations on modeling and simulation of electronics cooling exhausting water-aluminum nanofluid, International Journal of Innovative Technology and Exploring Engineering, Vol. 8, pp. 660−663.
15. N. K. Kund, 2019, Numerical study on effect of nozzle size for jet impingement cooling with water-Al_2O_3 nanofluid, International Journal of Engineering and Advanced Technology, Vol. 8, pp. 736−739.
16. N. K. Kund, 2019, Experimental investigations on impacts of nozzle diameter on heat transfer behaviors with water jet impingement, International Journal of Engineering and Advanced Technology, Vol. 8, pp. 745−748.
17. N. K. Kund, 2019, Comparative CFD studies on jet impingement cooling using water and water-Al_2O_3 nanofluid as coolants, International Journal of Innovative Technology and Exploring Engineering, Vol. 8, pp. 545−548.
18. N. K. Kund, 2019, Experimental studies on effects of jet Reynolds number on thermal performances with striking water jets, International Journal of Innovative Technology and Exploring Engineering, Vol. 8, pp. 2195−2198.
19. N. K. Kund, D. Singh, 2019, CFD studies on heat transfer and solidification progress of A356 al alloy matrix and Al2 O3 nanoparticles melt for engineering usages, International Journal of Innovative Technology and Exploring Engineering, Vol. 8, pp. 2043−2046.
20. N. K. Kund, S. Patra, 2019, Simulation of thermal and solidification evolution of molten aluminum alloy and SiC nanoparticles for engineering practices, International Journal of Innovative Technology and Exploring Engineering, Vol. 8, pp. 2047−2050.

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