Journal of Biomedical and Pharmaceutical Research
Available Online at www.jbpr.in
CODEN: - JBPRAU (Source: - American Chemical Society)
NLM (National Library of Medicine): ID: (101671502)
Index Copernicus Value 2021: 83.38
Volume 12, Issue 4, July-August: 2023, 36-41

ISSN (Online): 2279-0594
ISSN (Print): 2589-8752

Research Article

Radiation Absorption on Non- Newtonian Fluid over A Vertical Plate with Radiation Heat Flux

Pallapatisaidulu[2], Dr. Rajeev Kumar[2]

[1]Research Scholar, Sunrise University, Alwar

[2]Associate Professor, Sunrise University, Alwar

Article Info: Received: 27-06-2023 / Revised: 08-07-2023 / Accepted: 02-08-2023
DOI: https://doi.org/10.32553/jbpr.v12i4.1017
Address for Correspondence: Pallapatisaidulu
Conflict of interest statement: No conflict of interest

Abstract:
The study of radiation absorption in non-Newtonian fluids flowing over a vertical plate subjected to radiation heat flux is a complex yet critical area of research that finds wide applications in engineering, physics, and environmental sciences. In this investigation, we explore the intricate interplay between radiation heat transfer, the unique rheological properties of non-Newtonian fluids, and the resulting fluid dynamics and heat transfer phenomena. Non-Newtonian fluids, characterized by their nonlinear relationship between shear stress and shear rate, exhibit behavior that deviates from traditional Newtonian fluids. This departure introduces complexity into the heat transfer process when subjected to radiation heat flux. The vertical plate, a common boundary encountered in practical engineering scenarios, serves as a platform for examining these interactions. Research in this field employs a multidisciplinary approach, encompassing experimental investigations, mathematical modeling, and computational simulations. These methodologies are instrumental in unraveling the complexities of radiation absorption in non-Newtonian fluids over vertical plates and provide a foundation for advancements in various engineering and scientific domains.

Keywords: Radiation, Absorption, Transfer, Modeling, non-Newtonian

Introduction

Radiation absorption in non-Newtonian fluids over a vertical plate with radiation heat flux is a complex and intriguing phenomenon that finds applications in various engineering and scientific disciplines. This research topic involves the study of how non-Newtonian fluids, which do not follow the classical Newtonian viscosity behavior, interact with thermal radiation when flowing over a vertical surface subjected to radiation heat flux.

The interaction between radiation and fluid flow is of paramount importance in various engineering applications, such as in the design of solar collectors, cooling systems, chemical processes, and geophysical fluid dynamics. Understanding the behavior of non-Newtonian fluids in the presence of radiation is crucial for optimizing the efficiency and performance of these systems.

In the context of this research, the term "non-Newtonian fluids" refers to a class of fluids that exhibit viscosity behavior different from that of Newtonian fluids. These fluids may have shear-thinning (decreasing viscosity with increasing shear rate) or shear-thickening (increasing viscosity with increasing shear rate) properties, among others. Examples of non-Newtonian fluids include polymer solutions, slurries, and certain biological fluids.

The vertical plate, on which the fluid flows, can represent various physical scenarios, such as a cooling fin, a solar collector surface, or a heat exchanger plate. The presence of radiation heat flux on this plate introduces an additional heat transfer mechanism, which can significantly affect the fluid flow and temperature distribution near the surface.

Newton’s Law Of Viscosity

Viscosity, often known as internal friction, is a crucial feature of fluids that offers some resistance between adjacent layers of the fluid. According to Newton's rule of viscosity, the tangential stress acting on one of the object's surfaces is proportional to the relative velocity of the two surfaces and inversely proportional to the distance h separating them.

$$\tau \alpha \frac{U}{h} \Rightarrow \tau = \frac{U}{h}$$

where, μ is the surface relative velocity U, and the proportionality constant is the coefficient of viscosity. Normal fluids are displaced so that their layers move evenly over one another, and the surface never experiences a slip state. A layer of fluid y units away from the plate has a velocity u equal to

$$u = \frac{Uy}{h}.$$

If we substitute the velocity gradient du/dy for U/h in the previous equation, we get

$$\tau = \mu \frac{du}{dy}.$$

Newton's law of viscosity describes this phenomenon. A fluid's viscosity is defined as the tangential forces per unit area necessary to keep two layers at constant relative velocity when the distance between them is one unit.

$$\mu = \tau \frac{dy}{du}.$$

Where M is the μ mass, L is the length, and t is the time, the units of is ML-1 t -1. The ratio of the viscosity coefficient to the density ρ. establishes the extent to which viscosity μ affects the momentum of a fluid. Kinematic viscosity of the fluid, symbolized by v, is defined as

$$v = \frac{\mu}{\rho}.$$

whose dimensions are L-2 t -1. For a fluid with a general shear stress equation, we have

$$\tau = \mu[\frac{\partial u}{\partial y}]^n.$$

History of Non-Newtonian Fluids

The physical states of matter that are capable of flow are referred to as fluids. Sir Isaac Newton (1642-1727) dedicated Book II of his "Principia of Mathematics" to the study of fluid dynamics and fluid statics, which offered a quantitative physical and mathematical knowledge of fluid movement. In his article "General Principles ofthe Motion of Fluids" from 1755, Swiss mathematician Leonardo Euler developed the equation of fluid flow for ideal (non-viscous) fluids. Since then, this area of study has advanced quickly. The stress tensor is assumed to be a linear function of the strain rate tensor and the stress for ideal or non-viscous fluids.

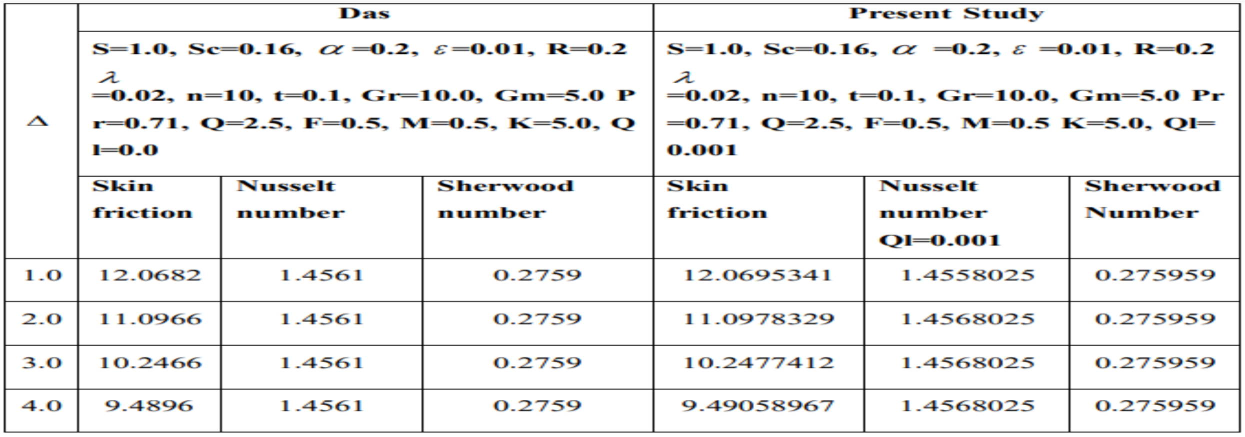
When a planar surface is in contact with a fluid, the I vector is perpendicular to the surface. Although Euler's partial differential equations were non-linear, solutions were found for flows around spherical and ellipsoid obstacles. For specific types of issues, like wave generation and tidal movements, the ideal fluid theory provided optimal solutions. When a solid travels through a fluid at rest at infinity, according to the ideal fluid hypothesis, the solid encounters no resistance. D'Alermbert's paradox said that this idea ran counter to observational evidence. To account for the resistance, the idea of a viscous, Newtonian fluid was created. However, the stress vector on a surface is not perpendicular to that surface, even if the stress tensor for viscous Newtonian fluids is a linear function of the rate of strain tensor.

The equations of motion for these fluids were separately discovered by Navier (in 821) and Stokes (1845). Exact solutions for flows between plates and in pipes and annuli between translating and rotating coaxial cylinders were found using the NavierStokes equations and the no-slip requirements at the surfaces through which viscous fluids flow. Flows past abruptly accelerated plane barriers, flows near oscillating flat plates, flows near rotating disks, and stagnation flows have all been solved exactly. Even for extremely slow movements and lubricant flows, good approximation solutions were found. While the results were intriguing, there was a lack of precision when it came to engineering-critical challenges.

In 1904, Prandtl made a groundbreaking suggestion with his daring premise throughout the endless process ofsearch for perfection. According to his hypothesis, the boundary layer is where the viscous effect is most pronounced when a fluid flows past a surface. Once you get through that layer, you may treat the flow as if it were an ideal fluid. It is now feasible to calculate the resistance to ship motion and the lift and drag on airplane wings using this theory. The boundary layer theory has made significant contributions to our understanding of fluid dynamics and has elevated the field to one of critical relevance in engineering.

In fluid mechanics, the basic Newtonian fluid has come to be considered typical, whereas fluids exhibiting non-Newtonian flow behaviors have been deemed exceptional. However, non-Newtonian or "anomalous" fluids are abundant in nature, proving that the classical theory of fluids is inadequate.

Table 3.1: Comparison to Results for the Skin Friction Coefficient at the Plate for Various Values of Physical Parameters



Δ	Das			Present Study		
	S=1.0, Sc=0.16, α =0.2, ε=0.01, R=0.2 λ =0.02, n=10, t=0.1, Gr=10.0, Gm=5.0 Pr=0.71, Q=2.5, F=0.5, M=0.5, K=5.0, Ql=0.0			S=1.0, Sc=0.16, α =0.2, ε =0.01, R=0.2 λ =0.02, n=10, t=0.1, Gr=10.0, Gm=5.0 Pr =0.71, Q=2.5, F=0.5, M=0.5 K=5.0, Ql= 0.001		
	Skin friction	Nusselt number	Sherwood number	Skin friction	Nusselt number Ql=0.001	Sherwood Number
1.0	12.0682	1.4561	0.2759	12.0695341	1.4558025	0.275959
2.0	11.0966	1.4561	0.2759	11.0978329	1.4568025	0.275959
3.0	10.2466	1.4561	0.2759	10.2477412	1.4568025	0.275959
4.0	9.4896	1.4561	0.2759	9.49058967	1.4568025	0.275959

Tables show the numerical results for the coefficient of skin friction, the coefficient of couple stress, the Nusselt number, the Sherwood number, and the unsteady behavior of the coefficients of skin friction, the coefficient of couple stress, the rate of heat transfer, and the rate of mass transfer at different times.

Table 3.2: Effect of Q1, Df, H, Sc and Nr parameter on Cf and with $\varepsilon=0.01$, n = 0.1, n1=0.5, β=1, Gr=2, Gc =1, M=2, Pr=1, t=1, K'=5, Up=0.5

$Q1$	Df	Sc	Nr	H	C_f	C'_w
1.0	0.05	2.0	0.5	0.1	0.7239	0.0810
2.0	0.05	2.0	0.5	0.1	0.9753	0.1090
3.0	0.05	2.0	0.5	0.1	1.2266	0.1369
1.0	0.02	2.0	0.5	0.1	0.6937	0.0776
1.0	0.5	2.0	0.5	0.1	1.1769	0.1314
1.0	1.0	2.0	0.5	0.1	1.6801	0.1874
1.0	0.05	0.5	0.5	0.1	18.8513	2.0955
1.0	0.05	1.0	0.5	0.1	1.3284	0.1483
1.0	0.05	1.5	0.5	0.1	0.9849	0.1100
1.0	0.05	2.0	0.5	0.1	0.7239	0.0810
1.0	0.05	2.0	1.0	0.1	0.9558	0.1068
1.0	0.05	2.0	1.5	0.1	1.1229	0.1254
1.0	0.05	2.0	0.5	0.05	0.8065	0.0902
1.0	0.05	2.0	0.5	0.08	0.7554	0.0845
1.0	0.05	2.0	0.5	0.1	0.7239	0.0810

Table 3.3: Effect of Q1, Df, H, Pr and Nr parameter on with $\varepsilon=0.01$, n=0.1, n1=0.5, β=1, Gr=2, Gc =1, M=2, Sc=1, t=1, K'=5, Up=0.5

$Q1$	Df	Pr	Nr	H	$NuRe_x^{-1}$
1.0	0.05	1.0	0.5	0.1	0.3937
2.0	0.05	1.0	0.5	0.1	0.0865
3.0	0.05	1.0	0.5	0.1	-0.2207
1.0	0.02	1.0	0.5	0.1	0.4306
1.0	0.5	1.0	0.5	0.1	-0.1599
1.0	1.0	1.0	0.5	0.1	-0.7749
1.0	0.05	0.5	0.5	0.1	0.2270
1.0	0.05	0.8	0.5	0.1	0.3261
1.0	0.05	1.0	0.5	0.1	0.3937
1.0	0.05	1.0	0.5	0.1	0.3937
1.0	0.05	1.0	1.0	0.1	0.3094
1.0	0.05	1.0	1.5	0.1	0.2599
1.0	0.05	1.0	0.5	0.05	0.3359
1.0	0.05	1.0	0.5	0.08	0.3713
1.0	0.05	1.0	0.5	0.1	0.3937

Table 3.4: Effect of Sc parameter on with n=0.1, =0.01, n1=0.5, β=1, Gr=2, Gc=1, M=2, Up=0.5, t=1, Q1=1, Pr=1, H=0.1, Df=0.05 and K'=5

Sc	$ShRe_x^{-1}$
0.5	0.5065
1.0	1.0121
1.5	1.5176

Table 3.5: Unsteady behavior of the coefficient of skin-friction, couple stress coefficient, heat transfer and mass transfer with various value of t.

T	C_f	$C'w$	$NuRe_x^{-1}$	$ShRe_x^{-1}$
0	0.7203	0.0805	0.3934	2.0210
1	0.7239	0.0810	0.3937	2.0232
3	0.7324	0.0821	0.3943	2.0283
5	0.7427	0.0834	0.3952	2.0345
10	0.7798	0.0880	0.3981	2.0570
20	0.9415	0.1084	0.4112	2.1548
30	1.3812	0.1637	1.4465	2.4209

Radiation absorption in non-Newtonian fluids is a significant area of study within the broader field of fluid dynamics and heat transfer. In this context, we will delve deeper into the specific phenomenon of radiation absorption and its effects on non-Newtonian fluids.

Non-Newtonian Fluids: Non-Newtonian fluids are those that do not conform to the classical linear relationship between shear stress and shear rate observed in Newtonian fluids. Instead, their viscosity can vary with shear rate, temperature, or other factors. Examples of non-Newtonian fluids include polymer solutions, molten plastics, sludges, and biological fluids like blood and mucus.

Radiation Absorption: Radiation absorption refers to the process by which electromagnetic radiation, such as infrared or visible light, is absorbed by a material and converted into heat energy. When non-Newtonian fluids are subjected to radiation, several key phenomena come into play:

Temperature Distribution: Radiation absorption affects the temperature distribution within the fluid. As the fluid absorbs radiation energy, it heats up, leading to temperature gradients and variations.

Viscosity Variations: In non-Newtonian fluids, viscosity is not constant but can vary with temperature. Radiation-induced heating can alter the fluid's viscosity, affecting its flow behavior.

Heat Transfer: The absorbed radiation energy contributes to the overall heat transfer within the fluid. Understanding this heat transfer process is essential for various applications, including industrial processes, energy generation, and environmental studies.

Material Properties: Different non-Newtonian fluids may have distinct material properties and responses to radiation absorption. Research in this area aims to characterize these responses accurately.

Applications of studying radiation absorption in non-Newtonian fluids are diverse:

Biomedical Engineering: Understanding how biological fluids, such as blood or mucus, respond to radiation can be vital in medical applications, including hyperthermia treatment and diagnostic imaging.

Industrial Processes: In industries where non-Newtonian fluids are prevalent, such as food processing, cosmetics manufacturing, and polymer production, optimizing heat transfer through radiation absorption can enhance efficiency.

Environmental Sciences: Radiative heating of non-Newtonian fluids in natural environments, such as oceans or underground reservoirs, can impact geological and environmental processes.

Energy Generation: In solar thermal systems, understanding radiation absorption in non-Newtonian heat transfer fluids can improve the efficiency of solar collectors.

Research in this area involves experimental investigations, computational simulations, and mathematical modeling to better comprehend the intricate interplay between radiation absorption and the rheological behavior of non-Newtonian fluids. It contributes to advancements in various fields by enabling more accurate predictions and optimizations in systems where these fluids are encountered.

Conclusion

In conclusion, the study of radiation absorption on non-Newtonian fluids flowing over a vertical plate subjected to radiation heat flux represents a fascinating and multifaceted area of research with diverse applications across engineering, physics, and environmental sciences. This research topic sheds light on the complex interplay between heat transfer mechanisms, fluid behavior, and radiation energy absorption.The interaction between non-Newtonian fluids and radiation heat flux involves a combination of heat transfer mechanisms, including conduction, convection, and radiation. Understanding how these mechanisms operate simultaneously is essential for accurate modeling and prediction.The rheological properties of non-Newtonian fluids play a pivotal role in this scenario. Variations in viscosity with temperature and shear rate, characteristic of non-Newtonian fluids, significantly influence flow patterns, boundary layer development, and heat transfer rates.In essence, the study of radiation absorption on non-Newtonian fluids over vertical plates with radiation heat flux showcases the intricate relationship between fluid dynamics and heat transfer. It provides a foundation for optimizing the efficiency and performance of systems in which these phenomena are encountered, contributing to advancements in various industrial and scientific fields.

References

1. Reddappa, B. & Mallela, Sudheer &Sreedharamalle,

Sreenadh&Durgaprasad, P. (2023). The flow of non-Newtonian fluid in an inclined channel through variable permeability. Heat Transfer. 52. 10.1002/htj.22816.

2. Bognár, Gabriella & Gombkötő, Imre &Hriczó, Krisztián. (2012). Power-law non-Newtonian fluid flow on an inclined plane. International Journal of Mathematical Models and Methods in Applied Sciences. 6. 72-80.

3. Allouche, M. H. (2014). Theoretical and experimental study of the stability of non-Newtonian fluid films flowing down an inclined plane.

4. Allouche, M. H. & Millet, Severine & Botton, Valéry & Henry, Daniel & Ben Hadid, Hamda & Rousset, Francois. (2015). Stability of a flow down an incline with respect to two-dimensional and three-dimensional disturbances for Newtonian and non-Newtonian fluids. Physical Review E. 92. 1-9. 10.1103/PhysRevE.92.063010.

5. Dagois-Bohy, Simon & Allouche, M. H. & Millet, Severine & Botton, Valéry & Henry, Daniel & Ben Hadid, Hamda & Rousset, Francois. (2016). STABILITY OF A NON-NEWTONIAN FLOW DOWN AN INCLINE.

6. Tshehla, M. (2011). The flow of Carreau fluid down an incline with a free surface. Int. J. Phys. Sci. 6.

7. Rajagopal, K.R. &Saccomandi, Giuseppe &Vergori, Luigi. (2012). Flow of fluids with pressure and shear dependent viscosity down an inclined plane. Journal of Fluid Mechanics. 706. 10.1017/jfm.2012.244.

8. Samantaray, Saroj & Rout, Bijay & Mohapatra, Soumya & Munshi, Basudeb. (2017). Newtonian flow past a hollow frustum in vertical and inclined plane: An experimental observation for terminal velocity and drag coefficient. Powder Technology. 326. 10.1016/j.powtec.2017.12.049.

9. Maciel, Geraldo & Ferreira, Fabiana & Fiorot, Guilherme. (2013). Control of instabilities in non-Newtonian free surface fluid flows. Journal of the Brazilian Society of Mechanical Sciences and Engineering. 10.1007/s40430-013-0025-y.

10. Rafique, Khuram & Imran, M. &Misiran, Masnita. (2019). Numerical Study on Micropolar Nanofluid Flow over an Inclined Surface by Means of Keller-Box. Asian Journal of Probability and Statistics. 1-21. 10.9734/ajpas/2019/v4i430122.

11. Gaffar, S & Reddy, P & Prasad, V.Ramachandra& Subbarao, A. & Khan, B Md. (2020). Viscoelastic Micropolar Convection Flows from an Inclined Plane with Nonlinear Temperature: A Numerical Study. Journal of Applied and Computational Mechanics. 6. 183-199. 10.22055/JACM.2019.28695.1498.

12. Mukhopadhyay, Swati & Andersson, Helge. (2016). Shear flow of a Newtonian fluid over a quiescent generalized Newtonian fluid. Meccanica. 52. 10.1007/s11012-016-0434-y.

13. Allouche, M. H. & Botton, Valéry & Millet, Severine & Henry, Daniel &Dagois-Bohy, Simon & Guzel, Bulent & Ben Hadid, Hamda. (2017). Primary instability of a shear-thinning film flow down an incline: Experimental study. Journal of Fluid Mechanics. 821. 10.1017/jfm.2017.276.

14. Chinyoka, T. &Goqo, Sicelo& Olajuwon, B.I.. (2013). Computational analysis of gravity driven flow of a variable viscosity viscoelastic fluid down an inclined plane. Computers and Fluids. 84. 10.1016/j.compfluid.2013.06.022.

15. Supeni, E.E. & Mohd ariffin, Mohd khairolanuar& Abu Talib, Abd Rahim. (2019). Numerical investigation of flow through inclined fins under the absorber plate of solar air heater. Renewable Energy.141.10.1016/j.renene.2019.04.024 ..