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A COMPREHENSIVE APPRAISAL ON A MIXED CONVECTION BOUNDARY LAYER FLOW OVER A PLATE

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ABSTRACT

This study was a Systematic Literature Review (SLR) using the PRISMA model by identifying various appropriate and relevant kinds of literature to identify a mixed convection boundary layer flow induced in a nanofluid due to a stretching sheet. The analysis is conducted up to the 5th order of approximation, exploring the effects of various physical parameters like Prandtl number, Grashof number, suction/injection parameter, thermal radiation parameter, heat generation/absorption coefficient, and Hartman number on dimensionless velocity, temperature, and heat transfer rate. The results are quantitatively examined and presented through graphical representations. Data was obtained using specifications determined by analyses from several sites, including Google Scholar, ScienceDirect, IEEE Xplore, Scopus, Jstor, ResearchGate, and other platforms since SLR was used to analyse papers that came from these databases. In total of 46 articles were retrieved; only 15 articles were relevant to this study. The results showed that three main research themes have been found, namely the purpose of study, design of the plate and methods of the research used.

Keywords*: mixed convection, stretching sheet, boundary layer, and similarity solution.*

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1. Introduction

The main objectives of this paper are to perform a comprehensive review, analysis, and categorization of the body of latest research that deals with the research of mixed convection boundary layer flows over a plate. This comprehensive review of the literature analyses patterns of research to identify commonalities among the objectives of the research, the particular target audience, the theoretical and conceptual frameworks, and the research methods used. The themes of this study are shown in Table 1.

Table 1: Themes of this study.

No.	Themes of This Study
1	Purpose of the study
2	Design of the plate
3	Methods of the research

Mixed convection boundary layer flows have a significant impact on heat and mass transfer phenomena in both environmental and industrial environments. It is crucial to comprehend and characterize these complex flows in order to optimize diverse industrial processes and designs, and to ensure the sustainable environmental practices. Convective heat transfer in porous media that are saturated with fluid is extremely interesting for a variety of engineering applications, including mechanical, chemical, and civil engineering. The study interest in thermally induced flows in porous media has been inspired by the wide variety of applications, including electrochemistry, geophysical systems, food processing and storage, nuclear reactors, and many more.

2. Literature Review

A specific strategy employed in literature reviews is the systematic literature review (SLR). It entails a thorough analysis of prior research employing precise criteria to respond to research questions. According to another definition, SLR is a type of research that assesses literature using an analytical framework and, as a result, defines the body of literature in the field of study. The SLR approach is centred on locating relevant data to acknowledge, evaluate, and interpret research findings connected to particular research challenges.

An illustration of such a framework is the Preferred Reporting Item for Systematic Reviews and Meta-analysis (PRISMA). PRISMA defines a systematic, precise, and reliable literature review as one that responds to questions that have been explicitly and systematically defined by utilising systematic and explicit techniques to identify, select, and critically evaluate relevant results from research (Safitri & Suryani, 2022).

3. Research Methodology

With the view to systematically gather, identify, analyse, and synthesise a wide range of research on mixed convection boundary layer flows over a plate, this study used the Systematic Literature Review (SLR) method. SLR is a strict way to conducting literature reviews that adheres to established scientific procedures to guarantee objectivity and reduce the possibility of systematic or biased errors. Additionally, with the aim to conduct a systematic review and meta-analysis for this study, the researchers followed various PRISMA phases, including identification, screening, eligibility, and inclusion. The methodical technique used to answer the research topic is shown in Figure1. Thus, 15 articles were chosen for additional study after the data search was completed, as shown in the Table 2.

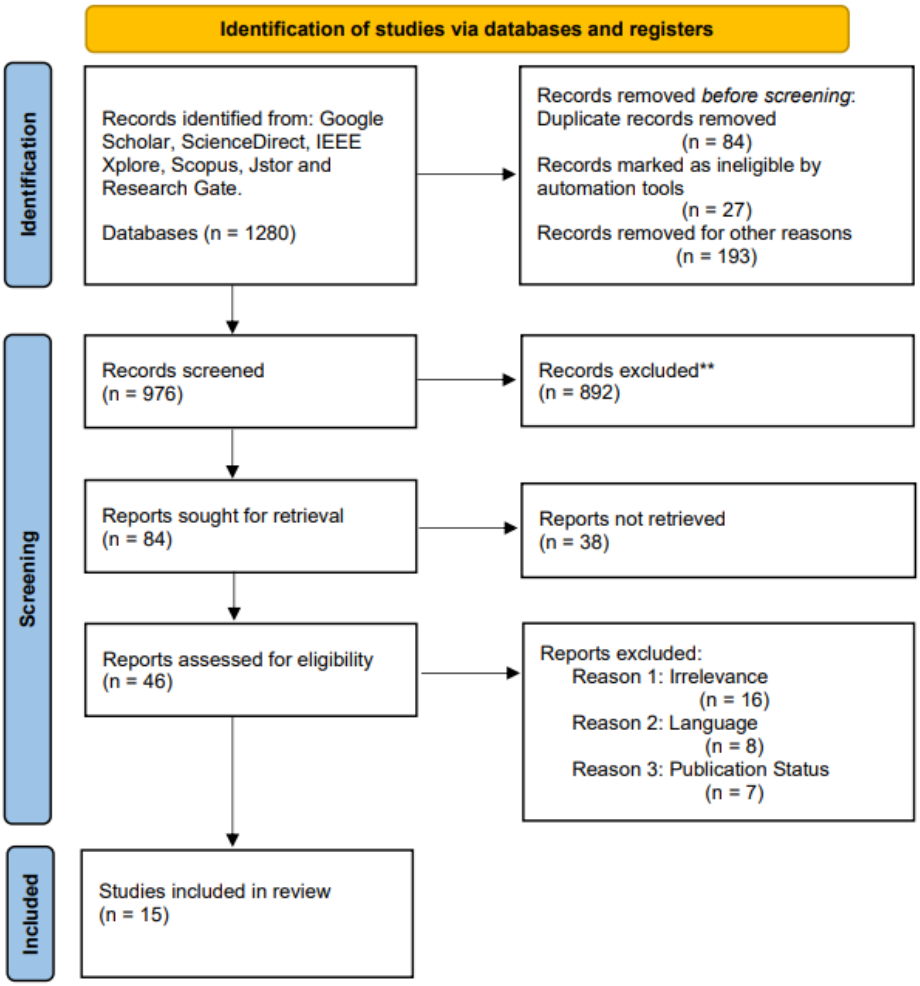

Figure 1. Research Data Search and Selection Flow

Table 2: Identify of the articles to be analysed further.

No.	Article Title	Year	Author's Name	Journal Name
1	Effect of radiation on MHD convection flow and heat transfer of a viscoelastic fluid over a stretching surface	2015	S. Eswaramoorthi, M. Bhuvaneswari, S. Sivasankaran, S. Rajan	Procedia Engineering
2	Thermal boundary layer flow on a stretching plate with radiation effect	2011	Siti Khuzaimah Soid, Anuar Ishak.	International Conference on Business, Engineering and Industrial Applications

3	Thermal Radiation on Mixed Convective Flow in a Porous Cavity: Numerical Simulation	2018	B.M.D. Hidayathulla Khan, V. Ramachandra Prasad, and R. Bhuvana Vijaya	Nonlinear Engineering
4	Solar radiation effects on MHD stagnation point flow and heat transfer of a nanofluid over a stretching sheet	2021	S.E. Ghasemi, M. Hatami	Case Studies in Thermal Engineering
5	Mixed convection boundary layer flow over a vertical flat plate with radiative heat transfer	2012	Sadia Siddiqa, M.A. Hossain	Applied Mathematics
6	Thermal radiation and double diffusive effects on bioconvection flow of a nanofluid past an inclined wavy surface	2021	D. Srinivasacharya, K. Sita Ramana	Thermal Science and Engineering Progress
7	Boundary-layer flow of a nanofluid past a stretching sheet	2010	W.A. Khan, I. Pop	International Journal of Heat and Mass Transfer
8	Boundary layer flow of a nanofluid past a stretching sheet with a convective boundary condition	2011	O.D. Makinde, A. Aziz	International Journal of Thermal Sciences
9	Boundary Layer Flow of a Nanofluid Past a Stretching Sheet with a Convective Boundary Condition in the Presence of Magnetic Field and Thermal Radiation	2011	Gbadeyan, J.A. Olanrewaju, M.A. and Olenrewaju, P.O.	Australian Journal of Basic and Applied Sciences
10	Radiation effect on MHD mixed convection flow about a permeable vertical plate	2008	Orhan Aydin, Ahmet Kaya	Heat Mass Transfer
11	Effects of buoyancy and thermal radiation on MHD flow over a stretching porous sheet using homotopy analysis method	2015	Yahaya Shagaiya Daniel, Simon K. Daniel	Alexandria Engineering Journal
12	MHD flow and heat transfer of a hybrid nanofluid past a permeable stretching/shrinking wedge	2019	I. Waini, A. Ishak, I. Pop	Applied Mathematics and Mechanics (English Edition)

13	Entropy analysis for MHD flow over a non-linear stretching inclined transparent plate embedded in a porous medium due to solar radiation.	2012	M. Dehsara, M. Habibi Matin, N. Dalir	MECHANIKA
14	Numerical computation of buoyancy and radiation effects on MHD micropolar nanofluid flow over a stretching/shrinking sheet with heat source	2021	Saif Ur Rehman, Amna Mariam, Asmat Ullah, Muhammad Imran Asjad, Mohd Yazid Bajuri, Bruno A. Pansera, Ali Ahmadian	Case Studies in Thermal Engineering
15	Nanoparticles effects on MHD fluid flow over a stretching sheet with solar radiation: A numerical study	2016	Seiyed E. Ghasemi, M. Hatami, D. Jing, D.D. Ganji	Journal of Molecular Liquids

4. Data Collection and Analysis

A variety of electronic databases, which include but not limited to Google Scholar, ScienceDirect, IEEE Xplore, Scopus, Jstor, ResearchGate, and other platforms, were searched for data for this study. The terms mixed convection, heat transfer, radiation, stretching sheet, inclined surface, boundary layer, nanofluid, and similarity solution are some of the keywords utilised in data searches. Furthermore, the researchers applied specific criteria during the data analysis process. These analysis criteria were formulated by the researcher after referring to the predefined requirements. The criteria were chosen using the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-analysis) model equation for SLR. The data acquired from the selected publications, which were published in respectable scientific journals, are shown in Table 3 for the study.

Table 3: Data collected from the articles.

No	Article Title	Purpose of the Studies	Design	Methods
1	Effect of radiation on MHD convection flow and heat transfer of a viscoelastic fluid over a stretching surface	To study the unsteady MHD three-dimensional flow and heat transfer of a viscoelastic fluid over a stretching surface in the presence of radiation.	Stretching surface.	Homotopy analysis method (HAM)

2	Thermal boundary layer flow on a stretching plate with radiation effect	To investigate the effect of radiation on the steady two-dimensional laminar forced convection boundary layer flow over a linearly stretching plate immersed in an incompressible viscous fluid.	Linearly stretching plate.	Runge-Kutta-Fehlberg method.
3	Thermal Radiation on Mixed Convective Flow in a Porous Cavity: Numerical Simulation	To examine the influence of mixed convection in a porous square enclosure under the effect of radiation.	Square cavity filled with porous medium.	MAC (Marker and Cell) method
4	Solar radiation effects on MHD stagnation point flow and heat transfer of a nanofluid over a stretching sheet	The aim of this study is investigation of solar radiation influences on two-dimensional stagnation point flow of nanofluid over a stretching sheet.	Stretching sheet.	Differential quadrature method (DQM)
5	Mixed convection boundary layer flow over a vertical flat plate with radiative heat transfer	To study the mixed convection boundary layer flow of viscous fluid along a heated vertical plate, and the analysis radiative component of heat flux emulates the surface temperature.	Vertical plate.	Integrated by applying straightforward finite difference method together with Gaussian elimination technique.
6	Thermal radiation and double diffusive effects on bioconvection flow of a nanofluid past an inclined wavy surface	To analyse the influence of thermal radiation on double-diffusive natural convection of a nanofluid past an inclined wavy surface in the presence of gyrotactic microorganisms.	An inclined wavy surface.	Bivariate Chebyshev pseudo-spectral collocation method
7	Boundary-layer flow of a nanofluid past a stretching sheet	To analyse the development of the steady boundary layer flow, heat transfer and nanoparticle fraction over a stretching surface in a nanofluid.	Vertically stretching surface.	Similarity solution and presented in tabular and graphical forms

8	Boundary layer flow of a nanofluid past a stretching sheet with a convective boundary condition	To investigate the effect of a convective boundary condition on boundary layer flow, heat transfer and nanoparticle fraction over a stretching surface in a nanofluid	Horizontal stretching sheet.	A fourth-fifth order Runge-Kutta-Fehlberg method
9	Boundary Layer Flow of a Nanofluid Past a Stretching Sheet with a Convective Boundary Condition in the Presence of Magnetic Field and Thermal Radiation	To study the boundary layer flow induced in a nanofluid due to a linearly stretching sheet in the presence of thermal radiation and induced magnetic field.	Stretching sheet.	A sixth order Runge-Kutta-Fehlberg method
10	Radiation effect on MHD mixed convection flow about a permeable vertical plate	To investigates mixed convection heat transfer about a permeable vertical plate in the presence of magneto and thermal radiation effects.	Permeable vertical plate.	A transformed set of non-similar equations have been solved using the Keller box scheme, an efficient and accurate finite-difference scheme.
11	Effects of buoyancy and thermal radiation on MHD flow over a stretching porous sheet using homotopy analysis method	To present a unified approach to solving the magnetohydrodynamics (MHD) flow due to influence of buoyancy and thermal radiation over a stretching porous sheet.	Horizontal stretching porous sheet	Homotopy analysis method (HAM).
12	MHD flow and heat transfer of a hybrid nanofluid past a permeable stretching/shrinking wedge	To investigate the flow and heat transfer of a hybrid nanofluid past a permeable stretching/shrinking wedge with magnetic field and radiation effect. Also analyses the hybrid nanofluids behaviour considering the nanoparticle solid volume fractions.	Stretching/shrinking wedge	The bvp4c function in the symbolic software, MATLAB.
13	Entropy analysis for MHD flow over a non-linear stretching	To study the MHD mixed convection flow and entropy generation over a	Stretching inclined plate.	Keller-Box method

	inclined transparent plate embedded in a porous medium due to solar radiation	nonlinearly stretching inclined transparent plate embedded in a porous medium with uniform porosity due to solar radiation flux.		
14	Numerical computation of buoyancy and radiation effects on MHD micropolar nanofluid flow over a stretching/shrinking sheet with heat source	To address magnetohydrodynamic (MHD) micro-polar nanofluid flow with multiple buoyancies over an extending sheet to enhance the heat transfer when nanostructures are diffused in the micropolar based fluid, and the radiative heat flux also improves the thermal distribution.	Stretching/ shrinking sheet.	Numerically solved by Runge - Kutta method with shooting scheme
15	Nanoparticles effects on MHD fluid flow over a stretching sheet with solar radiation: A numerical study	To obtain the solution of governing equation of solar radiation effect on the magnetohydrodynamic (MHD) nanofluid flow treatment over a flat plate.	Vertical plate.	The Keller-Box numerical method

5. Results and Discussion

5.1 Purpose of the studies

The data analysis employed in this study, with respect to this SLR, is content analysis. This method is employed to identify patterns in studies on a specific topic at the descriptive level. This approach includes three data analysis steps: (a) analysis of the purpose, (b) analysis of the plate design, and (c) analysis of the research technique. It can be concluded from the data in table 3 that the selected publications all have the same purpose which is to investigate how boundary layer flows, radiation, and nanoparticle fraction affect stretching or shrinking of the plates or surfaces.

5.2 Design of the plate

Table 4. Plate Design in The Studies

Horizontally	Vertically	Square	Inclined	Wedge
n=7	n=4	n=1	n=2	n=1

Table 4 above displays various plate designs found in the analysed studies; each plate is designed to the specific objectives of the research. Among the 15 articles, one article each focused on square and wedge plates, while two articles examined inclined plates, and four articles investigated vertical plates. Majority of the articles, seven in total, employed horizontal plates. Based on this data, it can be inferred that a substantial number of studies concentrate on horizontal and vertical plates. Consequently, there is a potential need for more research articles to explore inclined, wedge, and square plates in the future, providing a more comprehensive understanding of these plate configurations.

5.3 Methods of the research

Table 5. Research Methods Used in The Studies

Homotopy Analysis Method (HAM)	Runge-Kutta-Felhberg Method	Marker and Cell Method (MAC)	Differential Quadrature Method (DQM)	Finite Difference Method with Gaussian Elimination Method	Similarity Solution	Bivariate Chebyshev Pseudo-Spectral Collocation Method	Bvp4c Function	Keller-Box Method
n=2	n=4	n=1	n=1	n=1	n=1	n=1	n=1	n=3

Table 5 above presents an overview of the research methods employed in the reviewed articles. Various research methods were utilized in these studies, including Homotopy Analysis Method (HAM), Runge-Kutta-Felhberg Method, Marker and Cell Method (MAC), Differential Quadrature Method (DQM), Finite Difference Method with Gaussian Elimination Method, Similarity Solution, Bivariate Chebyshev Pseudo-Spectral Collocation Method, Bvp4c Function, and Keller-Box Method. Specifically, four articles used the Runge-Kutta-Felhberg Method, three articles employed the Keller-Box Method, and two articles utilized the Homotopy Analysis Method. Each of the remaining methods, namely Marker and Cell Method, Differential Quadrature Method (DQM), Finite Difference Method with Gaussian Elimination Method, Similarity Solution, Bivariate Chebyshev Pseudo-Spectral Collocation Method, and Bvp4c Function, were used in one article each. There is potential for further research employing these methods to conduct comprehensive and valuable data analysis. Additionally, researchers can explore other methods using different software, such as Graphical User Interface (GUI) and Computational Fluid Dynamics (CFD), to investigate boundary layer flows in more depth and detail.

6. Conclusion

This study is a comprehensive appraisal on a mixed convection boundary layer flow over a plate, which analyses 15 articles that have been published from year 2008 until the year 2021 in reputable international journals and selected based on predetermined criteria. This article provides a clear picture to perform a comprehensive review, analysis, and categorization of the body of latest research that deals with the research of mixed convection boundary layer flows over a plate based on the research themes. There are three main themes found based on the data analysis; the purpose of the study, design of the plate and method use in the research. The findings of table 3 show that the chosen articles all had the same objective, which was to investigate boundary layer flows, radiation, and the effects of nanoparticle fraction on plate stretching or shrinking. Many studies have focused on horizontal and vertical plates, as shown in table 4, which raises the possibility that additional studies on inclined, wedge, and square plate configurations are necessary to gain a more complete understanding. Table 5 displays the variety of research approaches used, indicating the potential for additional studies using these techniques and even exploring new methods like GUI and CFD for in-depth boundary layer flow analysis. However, to gain deeper insights, researchers should be conscious of the limitations of content analysis and consider alternate strategies. This study has the main limitation of solely using content analysis to analyse data. Despite its ability to uncover patterns at a descriptive level, content analysis may not provide deeper insights or quantitative evaluations.

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9. Conflict of Interest

The authors have no conflicts of interest to declare.

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