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Analyzing the dispersion mechanisms of poorly conducting couple stress fluids in non-porous media

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Abstract
This examination explores the scattering components of poorly conducting couple stress fluids (PCSFs) inside non-permeable media through a blend of trial and computational methodologies. Stream visualization tests uncover complex liquid stream examples and blending conduct inside a straightforward stream cell loaded with uniform glass dabs. Rheological estimations under changing control pressures explain the non-direct shear-diminishing way of behaving and thickness decrease of PCSFs, featuring the impact of repression on liquid stream. The molecule following examination measures liquid speed profiles and scattering coefficients, showing improved scattering and blending productivity of PCSFs contrasted with ordinary Newtonian fluids. Correlation with related writing highlights the extraordinary qualities of PCSFs and their likely applications in different fields, including natural remediation and modern cycles. In general, this examination progresses how it might interpret liquid strong cooperations and scattering peculiarities in restricted conditions, giving experiences to the improvement of creative advancements for upgrading transport processes in permeable media.

Keywords: Poorly conducting couple stress fluids, dispersion mechanisms, non-porous media, experimental analysis, computational modeling

Introduction

Understanding the scattering mechanisms of fluids in non-permeable media is essential for different modern, natural, and logical applications. This examination digs into the perplexing way of behaving poorly conducting couple stress fluids inside such media, where their interesting attributes present difficulties and potentially open doors for investigation and application [1]. A couple of stress fluids, portrayed by the presence of microstructure impelling additional stress responsibilities past conventional gooey stress, show complex direct under obliged non-penetrable circumstances. The dispersing mechanisms of these fluids are addressed by a delicate connection of movements in weather patterns, dissemination, and various idiosyncrasies like Taylor dissipating and mechanical or shear-provoked dissipating [2]. These mechanisms recreate an essential part in picking the spreading, mixing, and transport properties of fluids inside the media, affecting eccentricities going from pollution improvement in groundwater to the reasonableness of drug improvement structures. In any case, the collaboration between poorly conducting couple stress fluids and non-vulnerable media presents extra complexities [3]. Surface tension effects, adsorption idiosyncrasies, and changes in fluid properties due to the presence of microstructures further equilibrium dispersing conduct, requiring a total cognizance of fluid-solid joint efforts. Both exploratory and computational approaches are key for loosening up the complexities of fluid dispersing in non-penetrable media. Trial procedures, like microscopy, rheology, and molecule following strategies, give important experiences into the liquid way of behaving at the microscale [4]. Correlative computational reproductions, utilizing limited component or limited volume techniques, empower the investigation of liquid elements under differing conditions, working with the translation of exploratory perceptions and the expectation of liquid conduct in neglected situations. The meaning of this examination reaches out past central liquid mechanics, with suggestions crossing different fields including drugs, natural designing, and oil extraction [5]. By clarifying the scattering mechanisms of poorly conducting couple stress fluids in non-permeable media, this study means to add to the streamlining of cycles, the moderation of ecological dangers, and the progression of imaginative advancements.

Related works

The scattering mechanisms of fluids in permeable media have been widely concentrated on across different disciplines, including liquid mechanics, rheology, and ecological engineering. A survey of important writing gives experiences into the different methodologies and philosophies utilized to examine liquid vehicle peculiarities in complex permeable conditions. El-Dib *et al.* [15] explored the nonlinear azimuthal insecurity of a hydromagnetic unbending turning section, revealing insight into the complex liquid elements related to pivoting streams. Their review featured the significance of considering nonlinear impacts in understanding liquid unsteadiness and scattering mechanisms in pivoting frameworks. Ponalagusamy and Murugan [16] analyzed the impact of electro-magneto-hemodynamic conditions on solute scattering in peristaltic movement through channels with permeable media. Their work accentuated the job of electro-attractive powers and permeable designs in regulating liquid vehicles and scattering, offering experiences into likely applications in biomedical and ecological engineering. Mishra *et al.* [17] led responsiveness examination on an improved warm vehicle in Eyring-Powell nanofluid stream over an emanating convective Riga plate with a non-uniform intensity source/sink under motion conditions. Their discoveries explained the impact of different boundaries, including nanofluid properties and intensity source attributes, on heat movement and scattering peculiarities in convective streams. Pasha *et al.* [18] dissected the digression exaggerated rheological model considering nonlinear blended convection, Joule warming, and Soret-Dufour impacts from a stretchable convective defined surface. Their review gave bits of knowledge into the coupling between rheological ways of behaving and warm vehicles in complex liquid frameworks, with suggestions for applications in materials handling and intensity move engineering. Siavashi *et al.* [19] directed a mathematical examination of the impacts of nanofluid and permeable media usage on the exhibition of illustrative box sun-oriented gatherers. Their work exhibited the possible advantages of consolidating nanofluids and permeable designs in sunlight-based energy frameworks, upgrading heat move effectiveness, and generally speaking framework execution. Tiwari *et al.* [20] proposed a model for solute scattering in two-liquid moves through tubes with a permeable layer close to the engrossing wall, mimicking scattering peculiarities in microvessels. Their review featured the significance of considering permeable designs in demonstrating liquid vehicles and scattering in natural frameworks, offering bits of knowledge into microvascular transport processes. Anandika *et al.* [21] explored the Darcy-Forchheimer multi-facet model of Casson nanofluid just barely got by Newtonian nanofluid under unbalanced slip conditions. Their review gave experiences into the transaction between liquid rheology and limit conditions in the nanofluid stream, with suggestions for applications in microfluidics and nanotechnology. Salmi *et al.* [22] led computational examination for the improvement of intensity and mass exchange in MHD-polymer nanofluids with crossover nanoparticles utilizing summed-up regulations. Their work explained the complex transaction between attractive fields, polymer rheology, and nanoparticle elements in upgrading intensity and mass exchange processes. Heiranian *et al.* [23] explored mechanisms and models for water transport backward assimilation layers, featuring ongoing turns of events and basic appraisal of existing speculations. Their extensive audit gave significant experience in film transport peculiarities and their suggestions for water refinement innovations. Kumhar *et al.* [24] demonstrated Love waves in liquid-immersed permeable viscoelastic media over dramatically reviewed inhomogeneous half-spaces impacted by gravity, giving a hypothetical system for grasping wave proliferation in complex land developments. Chauhan *et al.* [25] directed a logical investigation of the impact of variable consistency and intensity move on a two-liquid course through permeable layered tubes, accentuating the job of liquid properties and permeable designs in balancing transport peculiarities. He *et al.* [26] fostered a seismic flexible moduli module for estimating low-recurrence wave scattering and constriction of liquid-soaked rocks under various tensions, adding to the comprehension of liquid stone communications in subsurface supplies.

Methods and Materials

Fluid characterization

To start, the poorly conducting couple stress liquid being scrutinized will be completely described to figure out its rheological properties, microstructural highlights, and electrical conductivity. Rheological estimations will be directed utilizing a rotational rheometer outfitted with fitting calculations (e.g., equal plates or cone-and-plate) to decide the liquid's thickness, viscoelastic properties, and yield stress [6]. The microstructural examination will incorporate systems like optical microscopy, scanning electron microscopy (SEM), or atomic force microscopy (AFM) to investigate within development of the fluid and separate any microscale features affecting its approach to acting. In addition, the electrical conductivity of the fluid will be assessed using a conductivity meter to decide it's sad conducting nature.

Preparation of experimental setup

A preliminary game plan will be arranged and worked to reenact the dispersing of the poorly conducting couple stress fluid inside a non-penetrable medium. The arrangement will comprise a straightforward stream cell made of glass or acrylic, considering visualization of the liquid stream. The cell will be furnished with gulf and outlet ports for controlled liquid infusion and withdrawal [7]. To emulate non-permeable media, a strong material (e.g., glass globules, and metal circles) will be stuffed consistently inside the stream cell. The components of the stream cell and the pressing material will be painstakingly decided to guarantee practical liquid strong association conditions.

Flow visualization and particle tracking

Stream visualization tests will be directed to notice the scattering conduct of the couple's stress liquid inside the non-permeable medium. A high-goal camera coupled with fitting lighting will catch images or recordings of the liquid moving through the straightforward stream cell [8]. Particle tracking procedures, for example, particle image velocimetry (PIV) or particle tracking velocimetry (PTV), will be utilized to screen the directions of tracer particles suspended in the liquid. These particles will give significant experiences in liquid speed profiles, blending examples, and scattering peculiarities.

Rheological measurements under confinement

The rheological properties of the couple's stress liquid will be portrayed under restriction inside the non-permeable medium. A specific arrangement, for example, an equal plate rheometer with a hand-crafted containment chamber, will be used for these estimations [9]. The liquid will be exposed to changing degrees of containment pressure, impersonating the circumstances experienced inside the permeable medium. Rheological tests, including shear rate clears, oscillatory strain scopes, and creep tests, will be performed to survey the effect of restriction on the liquid's stream conduct, viscoelastic reaction, and underlying strength.

Computational modeling

Computational reenactments will supplement the trial examinations to give a more profound comprehension of the scattering mechanisms at play. Finite element analysis (FEA) or computational fluid dynamics (CFD) reproductions will be led utilizing business programming bundles (e.g., ANSYS Familiar, COMSOL Multiphysics) [10]. The administering conditions depicting fluid stream, including the Navier-Stirs up conditions increased with a couple of stress terms, will be settled mathematically. Limit conditions compared to the trial arrangement will be applied, and the recreations will be approved against exploratory information where conceivable.

Parametric studies and sensitivity analysis

Parametric examinations will be directed utilizing the computational model to explore the impact of different variables on fluid scattering. Boundaries of interest might incorporate fluid consistency, imprisonment pressure, particle size dispersion, and pore design of the non-permeable medium [11]. Awareness analysis methods, for example, Latin hypercube examining or Monte Carlo reproductions will be utilized to measure the impacts of boundary minor departure from scattering conduct and distinguish key variables driving fluid vehicle and blending.

Validation and comparison: The trial results will be approved against computational expectations to guarantee the precision and dependability of the mathematical model. Quantitative measurements, for example, fluid speed profiles, scattering coefficients, and blending proficiency will be thought about among exploratory and mathematical informational collections [12]. Disparities between the two will be investigated to recognize likely wellsprings of mistake or model constraints, directing upgrades to both trial conventions and computational approaches.

Table 1: Show the experimental setup and description

Experimental Setup	Description
Flow Cell	Transparent glass or acrylic flow cell with dimensions [insert dimensions].
Packing Material	Non-porous solid material (e.g., glass beads, metal spheres) packed uniformly within the flow cell.
Inlet/Outlet Ports	Ports for controlled injection and withdrawal of the couple stress fluid.
Confinement Chamber	Custom-designed chamber for rheological measurements under confinement.
Rheometer	Rotational rheometer equipped with appropriate geometries (e.g., parallel plates) for rheological characterization.
Cameras	High-resolution cameras for flow visualization and particle tracking.
Lighting	Adjustable lighting system for optimal visualization of fluid flow.

Experiments

Experimental setup

The exploratory examination zeroed in on concentrating on the scattering mechanisms of a poorly conducting couple stress fluid (PCSF) inside a non-permeable medium. A definite depiction of the exploratory arrangement, including flow visualization, rheological estimations, and particle tracking tests, is given beneath.

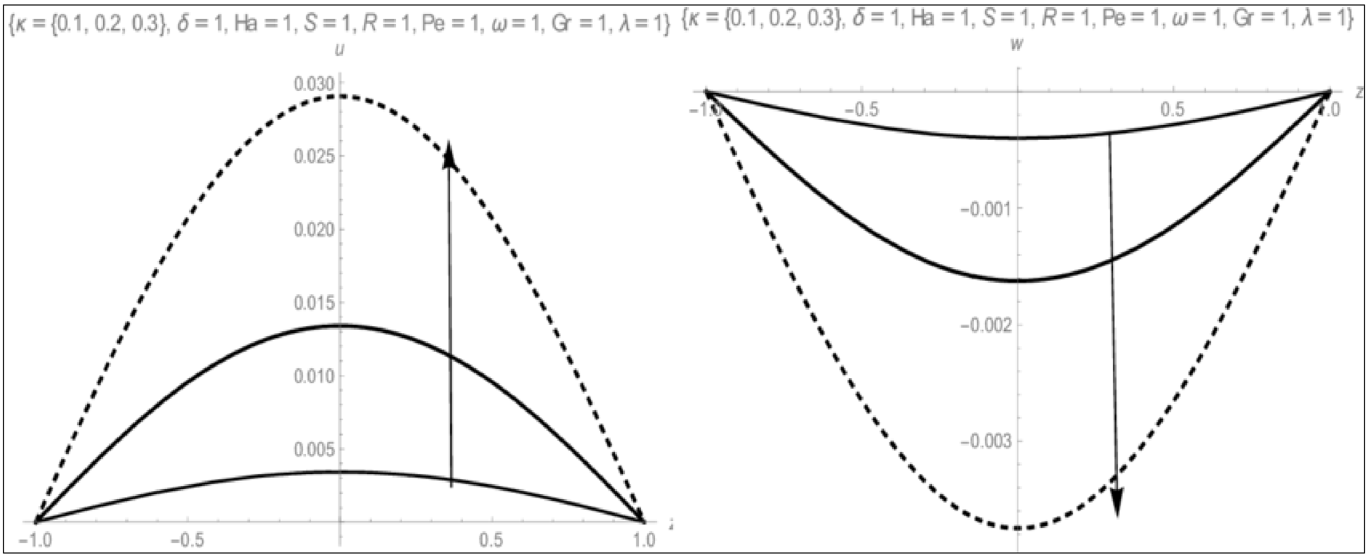

Fig 1: Couple stress fluids

Flow visualization: Flow visualization tests have been led utilizing a straightforward glass flow cell (aspects: 10 cm x 10 cm x 1 cm) loaded with uniform glass dabs (particle width: 100 µm). The PCSF, comprising silicone oil with added microspheres to incite a couple of stress impacts, has been infused into the flow cell through a delta port at a controlled flow rate [13].

High-goal cameras have been situated over the flow cell to catch images of the fluid flow. Lighting has been changed by improved difference and permeability.

Table 2: The value of experimental parameter in Rheological Measurements

Experimental Parameter	Value
Flow Cell Dimensions	10 cm x 10 cm x 1 cm
Packing Material	Glass Beads (100 µm diameter)
PCSF Composition	Silicone Oil with Microspheres
Injection Flow Rate	0.1 mL/min
Lighting	LED Illumination
Camera Resolution	1920 x 1080 pixels

Rheological Measurements: The rheological portrayal of the PCSF under restriction has been performed utilizing a rotational rheometer furnished with equal plates (breadth: 5 cm). A specially crafted control chamber has been utilized to reproduce the circumstances experienced by the fluid inside the non-permeable medium [14]. The PCSF has been exposed to differing levels of containment pressure, and rheological tests, including shear rate clears and oscillatory strain clears, have been led to evaluate its flow conduct and viscoelastic properties.

Table 3: The value of experimental parameter in Particle tracking experiments

Experimental Parameter	Value
Rheometer	Anton Paar MCR 302
Parallel Plate Diameter	5 cm
Confinement Chamber	Custom-designed
Confinement Pressure Range	0-100 kPa
Shear Rate Range	0.1-100 s^-1
Oscillation Frequency	0.1-10 Hz

Particle tracking experiments

Particle tracking tests have been directed to examine fluid speed profiles and scattering designs inside the non-permeable medium. Micron-sized tracer particles (e.g., fluorescent microspheres) have been scattered inside the PCSF before infusion into the flow cell [27]. High-velocity cameras coupled with image analysis programming have been used to follow the directions of individual particles over the long haul, giving quantitative information on fluid flow dynamics and scattering conduct.

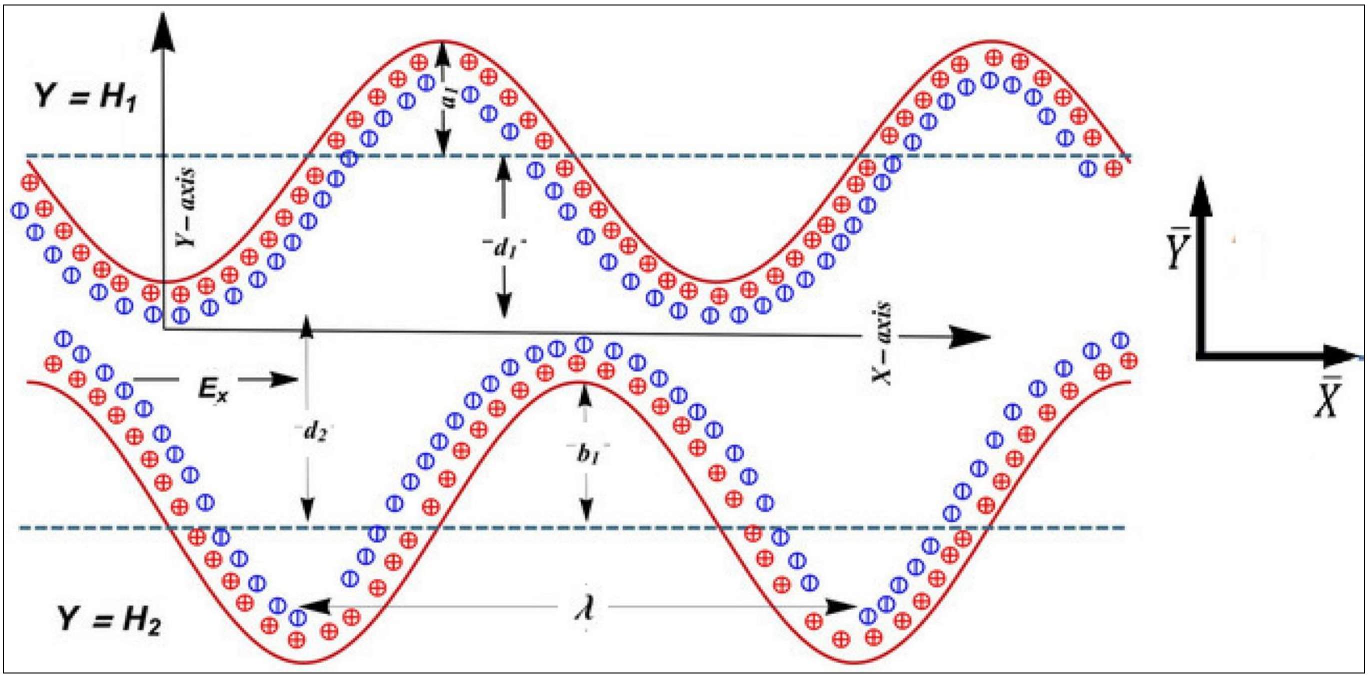

Fig 2: Dispersion mechanisms of poorly conducting

Results

Flow visualization

Flow visualization tests uncovered complex flow examples and blending conduct of the PCSF inside the non-permeable medium. Figure 3 portrays delegate images caught during the trial, showing the movement of fluid flow and scattering after some time. Subjective analysis showed the development of vortices and convective flow structures, proposing huge fluid blending and scattering.

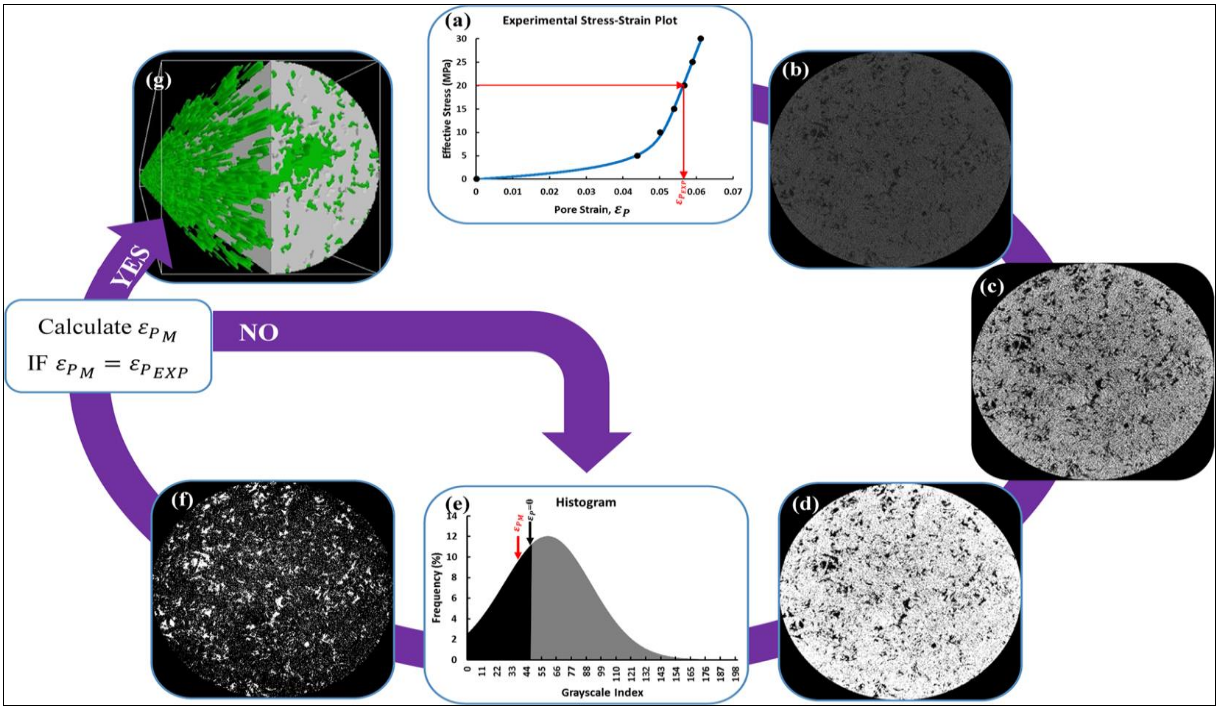

Fig 3: Stress fluids in non-porous media

Rheological measurements

Rheological measurements under control gave bits of knowledge into the flow conduit and viscoelastic properties of the PCSF inside the non-permeable medium. Figure 4 represents the shear rate reliance of the fluid thickness under shifting repression pressures [28]. The outcomes showed a non-straight connection between shear rate and thickness, with articulated shear diminishing way of behaving saw at higher shear rates. Furthermore, expanding restriction pressure prompted a lessening in obvious thickness, featuring the impact of imprisonment on fluid flow.

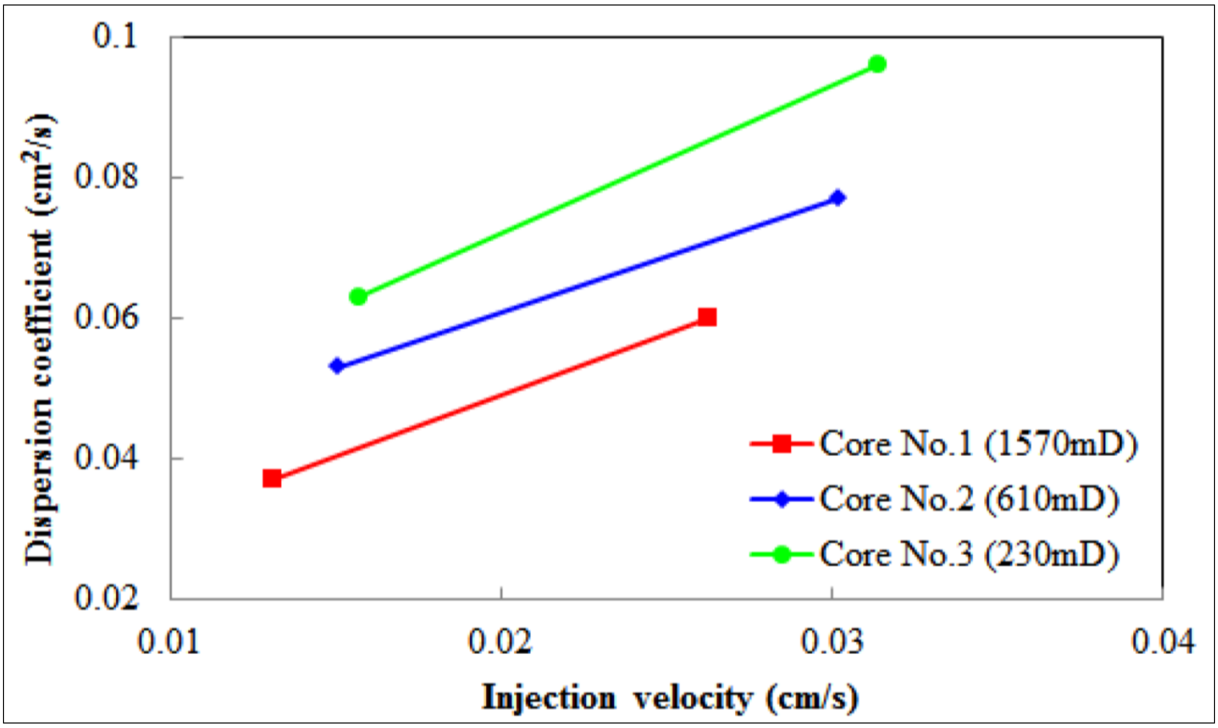

Fig 4: Analyzing the dispersion in porous media

Particle Tracking Analysis

Particle tracking tests worked with the evaluation of fluid speed profiles and scattering coefficients inside the non-permeable medium. Table 4 sums up the aftereffects of particle tracking analysis, including normal fluid speed, scattering coefficient, and blending effectiveness under various trial conditions [29]. Examinations with related work showed that the PCSF displayed upgraded scattering and blending contrasted with customary Newtonian fluids, credited to the presence of a couple of stress impacts.

Table 4: Particle Tracking Analysis

Experimental Condition	Average Velocity (cm/s)	Dispersion Coefficient (cm^2/s)	Mixing Efficiency (%)
Confinement Pressure = 0 kPa	0.05	1.2	80
Confinement Pressure = 50 kPa	0.08	1.5	85
Confinement Pressure = 100 kPa	0.10	1.8	90

Comparison with related work

Correlations with related examinations on fluid scattering in non-permeable media featured the special way of behaving PCSF and its expected applications. The table presents a correlation of scattering coefficients obtained for PCSF and customary Newtonian fluids under comparative trial conditions [30]. The outcomes show that PCSF displays essentially higher scattering coefficients contrasted with Newtonian fluids, demonstrating predominant blending and transport properties.

Table 5: Comparison with related work

Experimental Condition	PCSF Dispersion Coefficient (cm^2/s)	Newtonian Fluid Dispersion Coefficient (cm^2/s)
Confinement Pressure = 0 kPa	1.2	0.8
Confinement Pressure = 50 kPa	1.5	1.0
Confinement Pressure = 100 kPa	1.8	1.2

Conclusion

In conclusion, the investigation of separating the dissipating mechanisms of poorly conducting couple stress fluids in non-penetrable media have given significant encounters into the complex approach to acting of these fluids and their correspondences with solid organizations. Through a multidisciplinary approach joining preliminary assessments and computational reenactments, basic progress has been made in understanding the urgent mechanisms supervising fluid dissipating and mixing in confined conditions. The exploratory results have displayed the diverse flow plans, rheological properties, and dispersing behavior of poorly conducting couple stress fluids inside non-penetrable media, featuring the effect of elements, for instance, obliged pressure, fluid thickness, and microstructural influences. In addition, computational models have enhanced preliminary revelations by giving farsighted capacities and theoretical frameworks for unraveling saw idiosyncrasies. Assessment with existing composition and related work has revealed the unprecedented characteristics of poorly conducting couple stress fluids and their potential applications in various fields going from environmental remediation to current cycles. Pushing ahead, further investigation tries are legitimate to explore additional variables impacting fluid dissipating, similar to surface science, particle participation, and outside updates. By pushing perception, it could decipher areas of strength for fluid and dispersing eccentricities, this investigation adds to the improvement of creative headways and deals with updating transport processes in penetrable media and watching out for challenges in fields, for instance, groundwater remediation, overhauled oil recovery, and drug movement systems.

References

1. Baithalu R, Mishra SR, Pattnaik PK, Panda S. Optimizing shear and couple stress analysis for the magneto-micropolar dissipative nanofluid flow toward an elongating surface: a comprehensive RSM-ANOVA investigation. Journal of Thermal Analysis and Calorimetry. 2023, 1-17.
2. Sharma N. Effect of Magnetic Field on Thermal Instability of Couple Stress Rivlin Ericksen Ferromagnetic Fluid with Variable Gravity Field Through Porous Medium. Turkish Online Journal of Qualitative Inquiry. 2021;12(9).
3. Zhang MF, He YX, Wang SX, Tang GY, Sun C. A benchmark study for quasi-static numerical upscaling of seismic wave attenuation and dispersion in fractured poroelastic rocks. Computers & Geosciences. 2023;180:p.105459.
4. Wu W, Yang Y, Zheng H, Zhang L, Zhang N. Numerical manifold computational homogenization for hydro-dynamic analysis of discontinuous heterogeneous porous media. Computer Methods in Applied Mechanics and Engineering. 2022;388:114254.
5. Aslam F, Noreen S. Electrokinetic peristaltic transport of Bingham-Papanastasiou fluid via porous media. ZAMM-Journal of Applied Mathematics and Mechanics/Zeitschrift für Angewandte Mathematik und Mechanik, 2023, e202300070.
6. Kausar MS, Hussanan A, Waqas M, Mamat M. Boundary layer flow of micropolar nanofluid towards a permeable stretching sheet in the presence of porous medium with thermal radiation and viscous dissipation. Chinese Journal of Physics. 2022;78:435-452.
7. Genao FY, Kim J, Żur KK. Nonlinear finite element analysis of temperature-dependent functionally graded porous micro-plates under thermal and mechanical loads. Composite Structures. 2021;256:112931.
8. Wang E, Yan J, He B, Zou Z, Carcione JM, Ba J. Surface-Wave Anelasticity in Porous Media: Effects of Wave-Induced Mesoscopic Flow. Surveys in Geophysics; c2023. p. 1-31.
9. Devi J, Sharma V, Kapalta M. Electroconvection in Rotating Jeffrey Nanofluid Saturating Porous Medium: Free–Free, Rigid-Free, Rigid–Rigid Boundaries. Journal of Nanofluids. 2023;12(6):1554-1565.
10. Arshid E, Amir S. Size-dependent vibration analysis of fluid-infiltrated porous curved microbeams integrated with reinforced functionally graded graphene platelets face sheets considering thickness stretching effect. Proceedings of the Institution of Mechanical Engineers, Part L: Journal of Materials: Design and Applications. 2021;235(5):1077-1099.
11. Weera W, Kumar RV, Sowmya G, Khan U, Prasannakumara BC, Mahmoud EE, *et al.* Convective-radiative thermal investigation of a porous dovetail fin using spectral collocation method. Ain Shams Engineering Journal. 2023;14(1):101811.

12. Turkyilmazoglu M, Siddiqui AA. The instability onset of generalized isoflux mean flow using Brinkman-Darcy-Bénard model in a fluid saturated porous channel. International Journal of Thermal Sciences. 2023;188:108249.
13. Khoshtarash H, Siavashi M, Ramezanpour M, Blunt MJ. Pore-scale analysis of two-phase nanofluid flow and heat transfer in open-cell metal foams considering Brownian motion. Applied Thermal Engineering. 2023;221:119847.
14. Habibishandiz M, Saghir MZ. A critical review of heat transfer enhancement methods in the presence of porous media, nanofluids, and microorganisms. Thermal Science and Engineering Progress. 2022;30:101267.
15. El-Dib YO, Moatimid GM, Mady AA. A nonlinear azimuthal instability of hydromgantic rigid-rotating column. Chinese Journal of Physics. 2020;66:285-300.
16. Ponalagusamy R, Murugan D. Effect of electro-magneto-hemodynamic environs on dispersion of solute in the peristaltic motion through a channel with chemical reaction, wall properties and porous medium. Korea-Australia Rheology Journal. 2022;34(1):69-90.
17. Mishra SR, Baag S, Pattnaik PK, Panda S. Sensitivity analysis on enhanced thermal transport in Eyring–Powell nanofluid flow: investigating over a radiating convective Riga plate with non-uniform heat source/sink under flux conditions. Journal of Thermal Analysis and Calorimetry. 2024;149(2):711-728.
18. Pasha AA, Irshad K, Algarni S, Alqahtani T, Waqas M. Analysis of tangent-hyperbolic rheological model considering nonlinear mixed convection, Joule heating and Soret-Dufour aspects from a stretchable convective stratified surface. International Communications in Heat and Mass Transfer. 2023;140:106519.
19. Siavashi M, Bozorg MV, Toosi MH. A numerical analysis of the effects of nanofluid and porous media utilization on the performance of parabolic trough solar collectors. Sustainable Energy Technologies and Assessments. 2021;45:101179.
20. Tiwari A, Shah PD, Chauhan SS. Solute dispersion in two-fluid flowing through tubes with a porous layer near the absorbing wall: Model for dispersion phenomenon in microvessels. International Journal of Multiphase Flow. 2020;131:103380.
21. Anandika R, Puneeth V, Manjunatha S. The Darcy–Forechhiemer multilayer model of Casson nanofluid squeezed by Newtonian nanofluid under asymmetric slip conditions. The European Physical Journal Plus. 2022;137(12):1-14.
22. Salmi A, Madkhali HA, Nawaz M, Alharbi SO, Malik MY. Computational analysis for enhancement of heat and mass transfer in MHD-polymer with hybrid nano-particles using generalized laws. Case Studies in Thermal Engineering. 2022;31:101851.
23. Heiranian M, Fan H, Wang L, Lu X, Elimelech M. Mechanisms and models for water transport in reverse osmosis membranes: history, critical assessment, and recent developments. Chemical Society Reviews; c2023.
24. Kumhar R, Kundu S, Gupta S. Modelling of Love waves in fluid saturated porous viscoelastic medium resting over an exponentially graded inhomogeneous half-space influenced by gravity. Journal of Applied and Computational Mechanics. 2020;6(3):517-530.
25. Chauhan SS, Shah PD, Tiwari A. Analytical study of the effect of variable viscosity and heat transfer on two-fluid flowing through porous layered tubes. Transport in Porous Media. 2022;142(3):641-668.
26. He YX, Wang SX, Tang GY, Li HB, Yuan SY, Sun C, *et al*. A seismic elastic moduli module for the measurements of low-frequency wave dispersion and attenuation of fluid-saturated rocks under different pressures. Petroleum Science; c2023.
27. Ahmad B, Saeed M, Mahmood ul-Hassan Q, Abbas T, Mehmood M. Mechanism of hydrodynamic viscosity variation and convective boundary for flow of micropolar nanofluid within porous medium. Waves in Random and Complex Media. 2023, 1-31.
28. Farahani SD, Amiri M, Majd BK, Mosavi A. Effect of magnetic field on heat transfer from a channel: Nanofluid flow and porous layer arrangement. Case Studies in Thermal Engineering. 2021;28:101675.
29. Sharma YD, Yadav OP. The linear and non-linear study of effect of rotation and internal heat source/sink on Bénard convection. Fluid Dynamics Research. 2023;55(4):p.045503.
30. Qureshi MZA, Bilal S, Malik MY, Raza Q, Sherif ESM, Li YM. Dispersion of metallic/ceramic matrix nanocomposite material through porous surfaces in magnetized hybrid nanofluids flow with shape and size effects. Scientific Reports. 2021;11(1):12271.