Rotating Oscillations of Solar Cooker with A Permeable Bar Plate in A Couple Stress of Fluid Dynamics

D. Prabavathi, A. Selvaraj, E. Jothi, S. Shanmugan

Abstract: In this paper an attempt is made to study the flow of heat generated by rotary oscillations of a permeable bar plate in an immeasurable area of an incompressible couple stress fluid. The solar cooker heat flow generated is explained in Stokesian hypothesis for velocity field in the form of modified Bessel functions. The couple acting on the bar plate temperature due to external heat flow as well as internal heat flow is considered. The influence of solar cooker with in both relative couple stress parameter has been achieved and to different couple stress parameters are drawn to analyze the heat flow in bar plate area. The solar cooker heat flow for the couple stress to the particles move to near the area is thrown away with high velocity of the bar plate area.

***Keywords:** Solar Cooker, Couple stress, Rotary oscillations, Permeable bar plate*.

I. INTRODUCTION

Heat fluid is illuminated by couple-stress fluids theory of due to the heavy technical demand of industries. Rotational effects of the fluid particles, constitutive equations and basic theory for couple stress fluid theory was first recognized by stokes [1]. Stokes has planned couple stress fluid theory in the year 1966. Thus theory of Eringen [2] has established on micro structural effects present with in a fluid element. Srivarava [3] observed the flow due to rotation of axisymmetric body. The author deliberated the oscillatory and uniform flow of an incompressible couple stress fluid past permeable sphere previously and described [4, 5]. Parametric optimization of a box type solar cooker has studied in an inbuilt paraboloid reflector using Cramer's rule is verified [6]. Nano Particles using in Experimental work of Box-type Solar Cooker have analyzed by effective of cooking performances [7]. Ramakisson [8] derived a mathematical formula for drag experienced by sphere in couple –stress fluids in the form of stream function. The formula for couple, acting on a solid axisymmetric body in a rotary flow of viscous fluids, was derived by Jeffery [9]. Lakshmana Rao and Iyengar [10] analyzed the flow past a spheroid. The flow of a couple stress fluids past an approximate sphere was considered by Iyengar and Srinivasacharya [11]. Resonance type flow due to Rotary Oscillations of a sphere as well composite sphere in a micro-polar fluid was investigated and couple experienced by the fluid on the porous surface is obtained analytically [12,13]. Study of flow past sphere for viscous fluid was reported [14, 15, 16]. The solar cooker analysis of schematic diagram has following research theoretical reported usefully human and environmental condition [17, 18]. The solar cooker have been produced by a heat flow due to rotary oscillations of a permeable bar plate in a couple stress fluid is evaluated.

Revised Manuscript Received on June 12, 2019

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II. METHODOLOGY AND MATERIALS

2.1 System Description

In the solar cooker consists of inner and outer dimensions 120cm x120cm, bar plate (copper metal) area 100cm x 100cm and commercially available in bottom slide have been used in glass cover thickness 4mm. The copper plate area is assorted in *Nanoparticles* (Al_2O_3) using made black paint in covering the plate area and bottom side of the bar plate in welding for copper coil castoff of the PCM ($C_{18}H_{36}O_2$). The copper coil dia1.5mm inlet and outlet fixed the copper bar plate bottom side. The copper coil all place nanoparticles mixed made black paint all coating and more absorb solar radiation in the system. The insulations in between plywood outer and inner diameter of the cooker should be 5cm thickness occupied with the glass wool. The door of the system has been fixed top side area on 100cm x 100cm (glass cover). The thermal model heat increases through in very fast working of the cooker which that aid of the materials PCM and Nanoparticles for using inside the bar plate area more energy saving on heat conducted from a vessel. The vessel depth of dia is 10cm in amid top to bar plate should be used in more thermal conduct with the absor*bing* plate to obtain for *a* cooking point. The ambient temperature measure has thermometer use of the system. The solar radiation absorbs in the cooker per second change the ratios which expression the solar radiation monitor, schematic diagram as following
in Figure 1.

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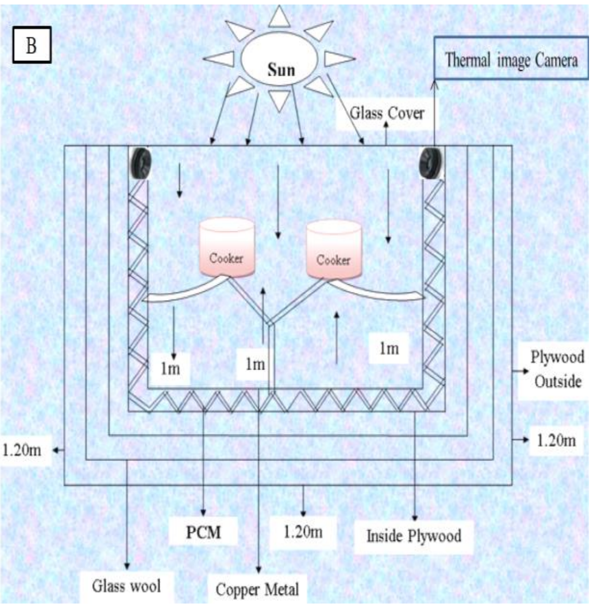

Figure1 Shown in solar cooker schematic diagram.

2.2 Solar Cooker use in Basic Equations and Design of the problem

The solar cooker has use in basic equations of motion of couple stress fluid which were introduced by Stokes [1] are

$$\rho\frac{d\vec{v}}{dt}=-\nabla p+(\lambda+\mu)\nabla(\nabla.\vec{V})+\eta\nabla^2\{\nabla(\nabla.\vec{V}\}\quad(1)$$

$$+\mu\nabla^2\vec{V}-\eta\nabla^4\vec{V}+\rho\vec{f}+(1/2)\nabla\times(\rho I)$$

Together with the continuity condition of the solar cooker as given by

$$\frac{d\rho}{dt}+\nabla.(\rho\vec{V})=0\ (2)$$

Since the heat fluid of the cooker is incompressible, the equation (2) decreases to

$$\nabla.\vec{V}=0\ \ (3)$$

The solar cooker is dodging the cooking moment, forces, following equation (1) as given by

$$\rho\frac{d\vec{V}}{dt}=-\nabla\rho-\mu\nabla\times\nabla+\vec{V}-\eta\nabla+\nabla\times\nabla\times\nabla\times\nabla+\vec{\vec{V}}\quad(4)$$

The solar cooker performance of the rotary oscillations of an incompressible couple stress heat fluid permeable bar plate having radius ‘a’ and angular velocity $\Omega e^{i\omega t}$ the amplitude Ω of the angular velocity is expected to be trivial so that stokes estimate can be adopted and the nonlinear terms in equation (4) can be deserted. We get

$$\rho\frac{\partial\vec{V}}{\partial t}=-\nabla\rho-\mu\nabla\times\nabla\times\vec{V}-\eta\nabla\times\nabla\times\nabla\times\nabla\times\vec{V}$$

(5)

$$\bar{V}=\vec{Q}e^{i\omega t}=\left(\frac{W}{h_3}e^{i\omega t}\right)\vec{e}_\phi\ ,P=Pe^{i\omega t}\qquad(6)$$

Substituting (6) in (3) we get,

$$\rho\omega q\vec{Q}=-\nabla P\times\nabla\times\vec{Q}=\nabla\times\nabla\times\nabla\times\nabla\times\vec{Q}\ \ (7)$$

Taking the components of toroidal direction e the equation for swirl W is gotten as below

$$\left[E_0^2=\frac{\lambda_1^2}{a^2}\right]\left[E_0^2=\frac{\lambda_2^2}{a^2}\right]W=0\qquad(8.1)$$

$$E_0^2=\frac{\partial^2}{\partial R^2}+\frac{1}{R^2}\left[\frac{\partial^2}{\partial\theta^2}-Cot\theta\frac{\partial}{\partial\theta}\right]\ (8.2)$$

$$\lambda_1^2+\lambda_2^2=\frac{\mu a^2}{\eta}=S\ \text{ and }\ \lambda_1^2\lambda_2^2=\frac{i\rho\omega a^4}{\eta}=i\sigma\ (8.4)$$

Non-dimensional form

$$R=ra,W=\Omega a^2w,P_1=\mu\Omega p,S=\frac{\mu a^2}{\mu},\qquad(9)$$

$$Re=\frac{\rho\Omega a^2}{\mu},\sigma=\frac{\rho\Omega a^2}{\eta}=Re.S,E_0^2=\frac{1}{a^2}E^2$$

Using (9) in (8) we get

$$\left(E^2-\lambda_1^2\right)\left(E^2-\lambda_2^2\right)W=0.(10)$$

2.3 The cooker solution of the problem

The solution of equation (10) can be written in the following formW=W_1+W_2 (11)

Where $\left(E^2-\lambda_1^2\right)w_1=0,\left(E^2-\lambda_2^2\right)w_2=0$

The solution of explain (10) by separation of variables cooking method which satisfies condition is given by (i)

$$W_e=\sqrt{r}\left(a_1K_{3/2}(\lambda_1 r)+b_1K_{3/2}(\lambda_2 r)\right)G_2(x)\ (12)$$

$$W_i=\sqrt{r}\left(a_2I_{3/2}(\lambda_1 r)+b_2I_{3/2}(\lambda_2 r)\right)G_2(x)\ (13)$$

where $G_2(x)=\frac{1}{2}(1-x^2),x=\cos\theta,I_{3/2}(\lambda_1 r),I_{3/2}(\lambda_2 r)$

and $K_{3/2}(\lambda_1 R)$, $K_{3/2}(\lambda_2 r)$ are modified Bessel’s function.

The constants a_1, b1, a2, b2are to be
Found by using above boundary condition (ii) and (iii).

$$a_1^{'}=a_1K_{3/2}(\lambda_1),b_1^{'}=a_1K_{3/2}(\lambda_2),$$
$$a_2^{'}=a_2I_{3/2}(\lambda_1),b_2^{'}=b_2I_{3/2}(\lambda_2).\qquad(14)$$

$$\Delta_1(\lambda_1)=1+\frac{\lambda_1K_{1/2}(\lambda_1)}{K_{3/2}(\lambda_1)},\ \Delta_2(\lambda_1)=1-\frac{\lambda_1K_{y}(\lambda_1)}{K_{3/2}(\lambda_1)}\ (15)$$

where $a_1^{'}+b_1^{'}=2,\ a_2^{'}+b_2^{'}=2,$ the flow similar to micro-polar heat fluid, where the heat flow is pretentious by the permeability of the cooker. This (6) shows that, under Stoke’sian estimate, In spite of the element that the cooker is permeable.

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2.4. Couple on the cooker absorbs heat flow by bar plate

The couple acting on bar plate is given by

$$C = 2m^3 \int_0^{\pi} T_{r\Phi} \sin^2 \theta d\theta. \qquad (16)$$

The constitutive equation for stress T, for couple stress heat fluid is given by

$$T = -pI + \lambda(\Delta.\vec{V})I + \mu\left\{\nabla\vec{V} + (\nabla\vec{V})^T\right\} \text{(17) form which}$$

$$+\frac{1}{2} I \times (\mathrm{Div}M + \rho\vec{c})$$

$$T_{r\Phi} = \mu\left\{\frac{1}{R\sin\theta}\left(\frac{dW}{dR} - \frac{2W}{R}\right) - \frac{1}{R\sin\theta}.\frac{d}{dR}E^2 W - \frac{1}{2R}.\frac{\partial m}{\partial \theta}\right\}^{i\omega t} \qquad (18)$$

2.5. Couple due to couple stress of cooker

The couple due to couple stress of the cooker disappears on the boundary the couple C_m due to couple stress is

$$C_m = 2\pi a^2 \int_0^{\pi} M_{rr} \cos\theta - M_{r\theta} \sin\theta) d\theta \qquad (19)$$

External heat flow to absorb internal heat by bar plate is given by

$$C_{mx} = \frac{8}{3}\frac{\pi\mu\Omega a^3}{S}\left(\lambda_1^2 a_1^{'} + \lambda_2^2 b_1^{'}\right)e^{i\xi t} \quad \text{for external flow} \quad (20)$$

$$C_{mn} = \frac{8}{3}\frac{\pi\mu\Omega a^3}{S}\left(\lambda_1^2 a_2^{'} + \lambda_2^2 b_2^{'}\right)e^{i\omega t} \quad \text{for internal flow(21)}$$

The steady heat flow internal and external occupied of the cooker region as following in Eq.(20) and Eq.(21)

III. RESULT AND DISCUSSIONS

In this analysis of finding heat flow field and couple stress with the values of length cooker parameters λ_1 and λ_2 are found by taking suitable values to S and σ and solving the quadratic equation, $x^2 - Sx + i\sigma = 0$ where $x = \lambda_1^2$ or λ_2^2. The velocity of the field in form of swirl '*w*' is found from equation (11). The equation (19) is helpful for calculating couple stress. The effects of different solar cooker parameters on couple stress and swirl are presented in the form of diagrams.In fig 3.1, Velocity at different values of couple-stress parameter increases (S) is shown and boundary conditions swirl decreases. Swirl is at any distance 'r' is less than the swirl on the surface (r=1) of the bar plate. The swirl near to the bar plate is more that the swirl on the surface of the cooker.

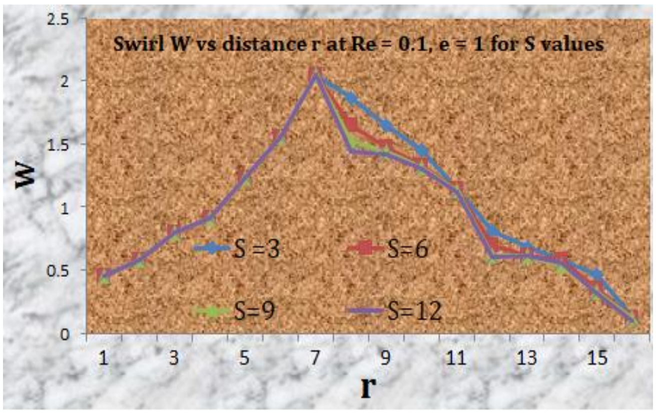

Fig. 3.1. Variation of swirl for various values of couple stress parameter 'S'

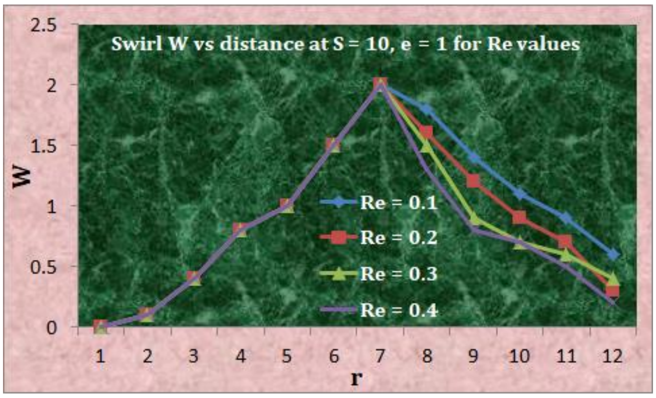

Fig. 3.2. Swirl for various values of Reynold's number Re

In figure3.2, variation of swirl for various values of Reynold's number Re for cooker conditions is shown. As Re increases, swirl decreases and goes to zero drastically as 'r', increases. This implies that oscillations of bar plate increases, the particles of fluid confines to the region near to the cooker. In figure 3.3, it is shown that as θ increases, swirl decreases. In figure 3.4, the variation of couple for external and internal heat flows at different values of relative couple stress parameter e is shown for cooker condition. As 'e' increases, the value of couple decreases and as S increases, couple tends to reach a constant value near to 6.

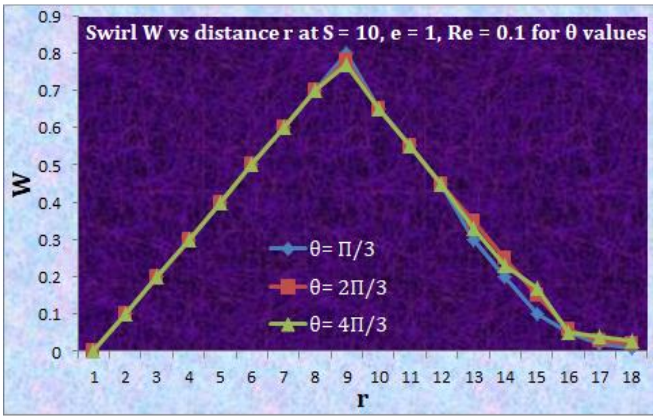

Fig. 3.3. Swirl w at different values of angles of θ

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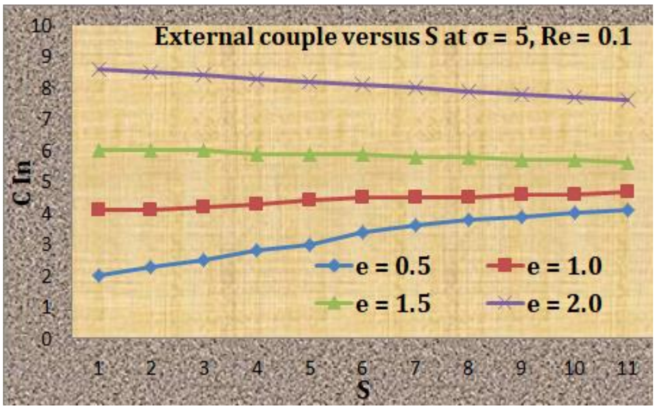

Fig. 3.4. Variation of couple for external and internal flows at different e values

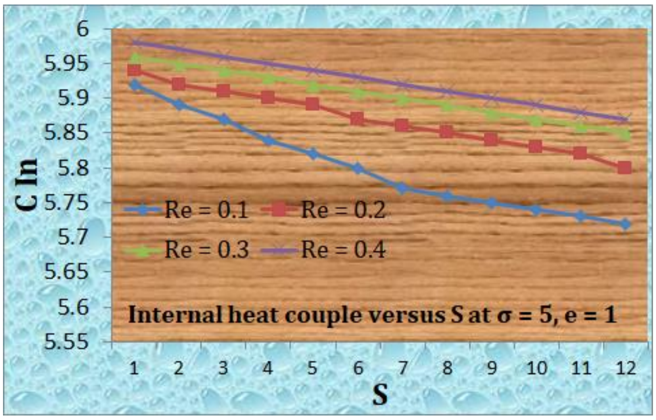

Fig. 3.5. Variation of Couple due to internal heat flow at changed values of Reynold's numbers Re.

From figure 3.5. cooker can observe that as Re increases. Couple due to internal flow decreases for type bar plate condition. But the values are near to 6 and less than 6 for small values of frequency parameterσ.

IV. CONCLUSION

In the present work, flow of heat generated by rotational motions of a permeable bar plate a way to deal with explore the impact of temperature on the solar cooker heat flow of a Stokesianthrough an incompressible couple pressure liquid is displayed. There is ideal understanding betweenthe present work and the solar cooker case researched to Reynold's numbers (Re 0.1 to 0.4) is explained in Stokesian hypothesis for velocity field in the form of modified Bessel functions.In the present work, it presume that expanding 'Re' number and radiation ingest solar powered cooker parameter effectsly affect both temperature and speed profile while increment in Reynold's number prompts an expansion in the stream speed; at long last, expanding the radiative solar motion parameter diminishes both the temperature and the speed profile of the solar oriented cooker. Moreover, Reynold's number the outcomes demonstrate that an expansion in the two modes to radiation retain solar based cooker parameter decreases on the heated wall.

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