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CASE STUDY OF HYDROMAGNETIC STABILITY OF A FLOW THROUGH A POROUS SUBSTANCE

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Abstract

In this paper, I am going to discuss the various scenarios of stability problems when a fluid undergoes the effect of magnetic field, fluid passes through a porous substance or when heat is applied to flow of fluid. Instability of fluids under magnetic field is of great importance in physical sense in various phenomena related to atmospheric and oceanic activities. Investigation of stability of fluid flowing through porous media provides crucial information which is applied in various branches of engineering and technology. The fluid flowing with suspended particles are quite sensitive to variations in temperature. The study of these flows is very important in several industrial applications and in atmospheric sciences.

Keywords: thermal instability, atmospheric sciences, interface, visco-elastic.

1. HYDROMAGNETIC INSTABILITY

The subject of hydromagnetics associates itself with the ways in which the magnetic field may impact the fluid behaviour. A number of research workers have explored the stability of different types of flows under the impact of magnetic field to check the arrival of instability. The impact of magnetic field on the hydro magnetic Benard's problem is taken care of and the results show that the magnetic field induces the fluid stable (Chandrasekhar,1954). It is discussed how the flow of fluid between two plates placed parallel to each other and acted upon by magnetic field force behaves. Lundquist (1952) showed that how important the hydro magnetic flows are provided the dimensional less number $\sqrt{B_{mf} * L_{ch} * \frac{(\eta_e * \mu_m)^{1/2}}{\rho_f}}$ exceeds 1, where B_{mf} is the magnetic field, L_{ch} is the characteristic length, η_e the electrical conductivity, μ_m denotes magnetic permeability and ρ_f represents density of the fluid. An investigation was carried out suggesting that the applied magnetic field induces in the fluid a certain level of rigidity along with certain degree of elasticity which enables it to send out disturbances by new modes of propagation known as transverse waves (Bullared, 1949 and Batchelor, 1950). Moreover Lehnert (1954) concluded that the fluid having conducting nature behaves differently in the absence and in the presence of a magnetic field. These are some of the interesting features associated with magnetic field, which have attracted the research workers towards the study of this subject.

Therefore, the stability of such flows is of great physical importance. Many researchers have done investigations on the stability of different types of flows under the influence of magnetic field and they have shown that the application of magnetic field is a key technique to examine the dawn of instability.

2. STABILITY OF A HETEROGENEOUS FLOW WITH SHEAR FORCE

The stability of a heterogeneous shear flow of an incompressible, having almost zero viscosity, non-conducting fluid having zero electrical resistivity when a uniform magnetic field is applied in the streaming direction when the system is statically stable is discussed in detail (Agrawal & Agrawal,1969).

3. STABILITY OF NON-DISSIPATIVE HETEROGENEOUS SHEAR FLOW

Agrawal and Agrawal in 1970 carried out analysis of the stability patterns of heterogeneous shear flow having non-dissipative nature impacted by magnetic field having uniform intensity and acting in the direction of the flow. During the analysis, the density of the fluid is assumed to be the function of vertical co-ordinate and it increases in vertically upward direction.

4. STABILITY OF A STRATIFIED LAYER OF VISCOUS INCOMPRESSIBLE FLUID

Banerjee and others (1976) have investigated the stability of a continuously stratified layer component of viscous and incompressible fluid having finite electrical conductivity and at rest between two horizontal and perfectly conducting boundaries when a uniform vertical magnetic field acting opposite to the direction of gravity is applied. The initial process of layers formation which might be produced, for example, by a dissolved solute of negligible diffusivity is assumed to be a function of the form, $\rho_2 = \rho_1 \exp\ (-\delta_c z)$, δ_c is constant in value. A detailed mathematical analysis of the stability of generalized hydro magnetic thermal shear flows is provided (Gupta and Pathania, 1978). Further, results related to the validity of principle of exchange of stabilities (PES), existence of non-oscillatory modes and the bounds for the phase velocity of disturbance are mathematically established for certain differential streaming classes $V(z)$. The criteria that determines stability and instability in not dependent on the effects of viscosity and suspended particles. The Rayleigh-Taylor instability of visco-plastic fluid (like oil in petroleum industry) through porous medium has been investigated (Sharma and Kumar, 1993). Newtonian viscous fluids and visco-elastic fluids behave in a stable manner stable and also in unstable manner. Here uniform horizontal magnetic field is applied on the fluid layer and uniform rotation is given to fluid of layer. It was deduced that that the application of magnetic field induces stabilizing nature in certain wave number bands whereas its absence makes system unstable irrespective of wave numbers for the potentially unstable configuration of the system. In this work, it was further found that the system becomes unstable for a viscous fluid placed on an Oldroydian visco-elastic fluid passing through porous medium in the presence of a uniform rotation field.

5. ACCELERATION OF TWO SUPERPOSED FLUIDS

Taylor (1950) derived that if we take two fluids placed one above the other, having different densities and negligible viscosities and accelerate these fluids in a direction which is normal to their plane, then this surface shows stability if the acceleration is guided from the fluid which is more dense to the fluid which is less dense. Moreover the surface becomes unstable for small perturbations in the opposite scenario. Similar patterns of instability are visible when two fluids placed one above the other, viscous in nature and passing through a porous medium are enacted by gravitational force and pressure gradient administered. Analyzing the stability of such fluids flowing through a porous medium is of utmost importance to conduct studies related to movement and occurrence of ground water, production of petroleum products, construction of buildings etc. It is because of this fact that the extensive studies have been conducted on the stability of interface between two fluids through porous media when there is movement or displacement parallel to the interface as well as perpendicular to the interface.

6. STABILITY OF THE INTERFACE SEPARATING TWO SEMI-INFINITE IMMISCIBLE FLUIDS

An investigation regarding the stability of the interface separating two semi-infinite immiscible fluids moving with a uniform velocity in porous media by neglecting surface tension between the fluids was carried out (Saffman and Taylor, 1958). They have carried out experiments on two immiscible fluid interface using Hell-Shaw model and observed this is mathematically similar to the flow in two dimensions in a porous medium. The Kelvin-Helmhotz (K-H) instability for flow in a porous medium is also studied for fluid flowing under Darcy conditions (Raghavan and Marsden, 1973).Using linear stability analysis, it was concluded that the K-H instability is possible only if the heavier fluid is lying above the lighter fluid. The K-H instability of parallel flow in a porous media for statically stable situation is also discussed (Halm, 1982).

7. RESULTS

Following findings are observed during the investigation:

i) The wave disseminating in the direction similar to the streaming direction are the most unstable in nature and hence the two dimensional analysis is taken into account.

ii) The complex wave velocity of an arbitrarily unstable mode must be bounded by a semi-circle lying in the upper half plane. This semi-circle has radius less than radius of Howard's semicircle.

iii) If magnetic force number exceeds certain quantity which depends only upon the streaming velocity, the system becomes stabilized in all respects. Also, the analysis has also been carried under the assumption that the applied magnetic field not too strong.

iv) It is shown that the perturbations moving with short wavelength are moderated in the presence of magnetic field while the instability for long wavelengths remains unaffected and unchanged.

v) It is shown that the marginal state, if found, is definitely oscillatory in nature. Further for $\delta_c < 0$, the system is unstable while for $\delta_c > 0$, the Rayleigh number and the frequency of oscillation are calculated at the borderline state and the stabilizing nature of the magnetic field is signified in situations where the magnetic Prandtl number is having value less than the thermal Prandtl number.

vi) The magnetic field has a stabilizing effect on the system which is otherwise unstable when there is no magnetic field. It is noticed that under different situations the growth rates increase or decrease with the increase in viscosity and increased number of suspended particles in the fluid.

vii) K-H instability may appear provided the ratio of the viscosities of two fluids fulfills certain conditions. In this respect the K-H instability for fluids flowing through a porous medium differs from the instability problem of the flows which is a function of the magnitude of the velocity vector only under the constraint that inertia velocity may be on the higher side and exceeds the range in which Darcy's law holds good.

8. CONCLUSION

During the investigation the hydro magnetic instability, stability of a heterogeneous flow with shear force, stability of non-dissipative heterogeneous shear flow, stability of a stratified layer of viscous incompressible fluid, acceleration of two superposed fluids and Stability of the interface separating two semi-infinite immiscible fluids is discussed. The stability of a mixture of a fluid and immersed particles having variable density and viscosity are carried out under a magnetic field acting in horizontal direction and having variable intensity. It is also observed that the behaviours of Newtonian viscous fluids and visco-elastic fluids follow the stability as well as instability patterns. It is also deducted that there are certain wave number bands that show stable patterns when a uniform magnetic field is applied and these bands otherwise behave in an unstable manner.

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