بسم الله الرحمن الرحيم

شبكة المعلومات الجامعية

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التوثيق الالكتروني والميكروفيلم

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جامعة عين شمس

التوثيق الالكتروني والميكروفيلم

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بالرسالة صفحات

لم ترد بالأصـــل

Zagazig University
Faculty of Science-Benha
Physics Department

Theoretical investigations as basis for a new rheometer which measures the non-linear mechanical properties of polymeric solutions or melts

Thesis

Submitted For The Degree

Of

Doctor Of Philosophy

"Theoretical Physics"

By

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B. SC. & M. SC.

To

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بسم الله الرحمن الرحيم

﴿ قالوا سبحانك لا علم لنا إلا ما علمتنا إنك أنت العليم الحكيم ﴾

صدق الله العظيم

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Abstract

The theoretical and experimental studies of the isothermal flow of a second-order (non- Newtonian) fluid in the annular region between two eccentric spheres are investigated . The study has been carried out in terms of the three -dimensional bispherical coordinates (α,β,φ), where the inner sphere is rotating with angular velocity Ω and the outer sphere is kept at rest .

A second-order stream-function $\psi_2(\alpha,\beta)$,through which the secondary flow field $\underline{u}_2(\alpha,\beta)$ can be determined , has been properly formulated by solving the three-dimensional inhomogenious biharmonic vector equation .

On the basis of the obtained velocity field , the distribution of the surface tractions on the boundaries are determined . The resultant forces acting on the boundaries as well as the resultant torques about the common axis of rotation , up to the second-order ,are calculated .

Based on the previous calculations , the eccentric spheres rheometer is designed which allows the determination of the combined second-order coefficient $(\alpha_2 + 2\alpha_1)$ besides the viscosity coefficient μ . The measurements of the viscosity coefficient μ and the first normal stress difference coefficient $(\alpha_2 + 2\alpha_1)$ of some polymeric solutions by the eccentric spheres rheometer have been carried out . The obtained results are compared with the other experimental data delivered by some other rheometers .

Chapter (1)

Introduction

Chapter (1)

Introduction

The information about the mechanical properties of solutions and melts is very important for the processing of these materials in almost all branches of industries . The last half of the present century has seen an immense development of highly sophisticated theories which describe the non-linear (non-Newtonian) behaviors of such types of materials . Some of these theories are based on microscopic models [1,2] , where special types of statistics , termed conformation statistics [3] , are employed in order to determine the macroscopic mechanical properties . Other theories are based on phenomenological equations of state [4] . In the present work , the constitutive equation based on the retarded motion approximation up to the fluid of grade two is used .

Within the frame of non-linear theories of constitutive equation , whether macroscopic or microscopic , these properties are designated by a set of parameters known as material constants . The fluid of grade two is characterized by three parameters;namely the coefficient of viscosity , μ , and the two elastic constants α_1 and α_2 which are related to the two normal stress differences $(S_{11} - S_{22})$ and $(S_{11} - S_{33})$. The determination of these material parameters is done using proper devices , known as rheometers and the branch which is concerned with such measurements is termed rheometry .

In general , the rheometer is based on the solution of a specific boundary value problem which allow a number of experimental measurements sufficient to determine a specific set of material parameters. The conventional rheometers based on the realization of either steady or periodic viscometric flow are not capable to determine the non-Newtonian properties of fluids . For this reason , one of the major purposes of rheology is to investigate further types of flow other than viscometric flow, which allows the determination of some of the non-Newtonian properties of fluids .

It is worthy to mention that about 30 years ago [5] the force and the torque acting on a sphere which undergoes simultaneous rotational and translational creeping motion in a fluid delivers nearly complete characterization of an incompressible fluid , at least up to third order . However , the practical realization of a corresponding device has never been carried out .

Many authors study the axial symmetric flow of an incompressible viscous fluid between two concentric rotating spheres , both analytically and numerically [6-10] .The only coefficient which can be determined in this case is the coefficient of viscosity μ .Wimmer et al [11] study this problem experimentally and they show how the flow field takes place in the two cases ; namely , when one of the two spheres is rotating while the other is being at rest and in the other case in which both of the two spheres are rotating .

About 25 years ago Walters et al [12] designed special device consisting of two eccentric cylinders where both cylinders are rotated with the same angular velocity . With this device it was possible to determine in the first approximation both components of the complex viscosity .

Another rheometer, termed eccentric cylinder rheometer [13,14], is constructed on the basis of a fluid rotating in the annular region between two eccentric cylinders. Besides simplicity of the construction, this rheometer allows reliable measurements for the elastic constant α_1.

The present work deals with another boundary value problem which promises to create a successful rheometer. The steady state isochoric flow of a fluid of grade two moving in the annular region between two eccentric spheres is investigated and the velocity field up to second-order is computed. The construction of the rheometer based on these calculations is designed and the viscosity μ and the combined second-order material coefficient; i.e. the first normal stress difference coefficient$(\alpha_2 + 2\alpha_1)$, are determined using this rheometer.

A large number of theoretical and experimental works is done on the viscous flow between two eccentric spheres. Jeffery [15], Stimson and Jeffery [16] solved the stationary rotational viscous flow in the so called axisymmetrical case, where the rotation takes place about the common diameter of the two spheres. These authors employed the bispherical system of coordinates which appears to be the most appropriate one. Noteworthy, is that this system can be used in the case when the two spheres are external to each other, as well as the case of one sphere enclosing the other. Majumdar [17] considered the non-axisymmetrical problem of separate spheres in an incompressible viscous fluid when one of the spheres rotates slowly about an axis perpendicular to their line of centers and the other sphere remains at rest. Due to the complications associated with the non- axisymmetry of the problem, the