Preface

Cavitation is the formation of voids or bubbles containing vapour and gas in an otherwise homogeneous fluid in regions where the pressure falls locally to that of the vapour pressure corresponding to the ambient temperature. The regions of low pressure may be associated with either a high fluid velocity or vibrations. Cavitation is an important factor in many areas of science and engineering, including acoustics, biomedicine, botany, chemistry and hydraulics. It occurs in many industrial processes such as cleaning, lubrication, printing and coating. While much of the research effort into cavitation has been stimulated by its occurrence in pumps and other fluid mechanical devices involving high speed flows, cavitation is also an important factor in the life of plants and animals, including humans.

Several books and review articles have addressed general aspects of bubble dynamics and cavitation in Newtonian fluids but there is, at present, no book devoted to the elucidation of these phenomena in non-Newtonian fluids. The proposed book is intended to provide such a resource, its significance being that non-Newtonian fluids are far more prevalent in the rapidly emerging fields of biomedicine and bioengineering, in addition to being widely encountered in the process industries. The objective of this book is to present a comprehensive perspective of cavitation and bubble dynamics from the stand point of non-Newtonian fluid mechanics, physics, chemical engineering and biomedical engineering. In the last three decades this field has expanded tremendously and new advances have been made in all fronts. Those that affect the basic understanding of cavitation and bubble dynamics in non-Newtonian fluids are described in this book.

It is essential to understand that the effects of non-Newtonian properties on bubble dynamics and cavitation are fundamentally different from those of Newtonian fluids. Arguably the most significant effect arises from the dramatic increase in viscosity of polymer solutions in an extensional flow, such as that generated about a spherical bubble during its growth or collapse phase. Specifically, polymers, which are randomly-oriented coils in the absence of an imposed flow-field, are pulled apart and may increase their length by three orders of magnitude in the direction of extension. As a result, the solution can sustain much greater stresses, and pinching is stopped in regions where polymers are stretched. Furthermore, many biological fluids, such as blood, synovial fluid, and saliva, have non-Newtonian properties and

can display significant viscoelastic behaviour. Therefore, this is an important topic because cavitation is playing an increasingly important role in the development of modern ultrasound and laser-assisted surgical procedures.

Despite their increasing bioengineering applications, a comprehensive presentation of the fundamental processes involved in bubble dynamics and cavitation in non-Newtonian fluids has not appeared in the scientific literature. This is not surprising, as the elements required for an understanding of the relevant processes are wide-ranging. Consequently, researchers who investigate cavitation phenomenon in non-Newtonian fluids originate from several disciplines. Moreover, the resulting scientific reports are often narrow in scope and scattered in journals whose foci range from the physical sciences and engineering to medical sciences. The purpose of this book is to provide, for the first time, an improved mechanistic understanding of bubble dynamics and cavitation in non-Newtonian fluids.

The book starts with a concise but readable introduction into non-Newtonian fluids with a special emphasis on biological fluids (blood, synovial liquid, saliva, and cell constituents). A distinct chapter is devoted to nucleation and its role on cavitation inception. The dynamics of spherical and non-spherical bubbles oscillating in non-Newtonian fluids are examined using various mathematical models. One main message here is that the introduction of ideas from theoretical studies of nonlinear acoustics and modern optical techniques has led to some major revisions in our understanding of this topic. Two chapters are devoted to hydrodynamic cavitation and cavitation erosion, with special emphasis on the mechanisms of cavitation erosion in non-Newtonian fluids.

The second part of the book describes the role of cavitation and bubbles in the therapeutic applications of ultrasound and laser surgery. Whenever laser pulses are used to ablate or disrupt tissue in a liquid environment, cavitation bubbles are produced which interact with the tissue. The interaction between cavitation bubbles and tissue may cause collateral damage to sensitive tissue structures in the vicinity of the laser focus, and it may also contribute in several ways to ablation and cutting. These situations are encountered in laser angioplasty and transmyocardial laser revascularization. Cavitation is also one of the most exploited bioeffects of ultrasound for therapeutic advantage. In both cases, the violent implosion of cavitation bubbles can lead to the generation of shock waves, high-velocity liquid jets, free radical species, and strong shear forces that can damage the nearby tissue. Knowledge of these physical mechanisms is therefore of vital importance and would provide a framework wherein novel and improved surgical techniques can be developed.

This field is as interdisciplinary as any, and the numerous disciplines involved will continue to overlook and reinvent each others' work. My hope in this book is to attempt to bridge the various communities involved, and to convey the interest, elegance, and variety of physical phenomena that manifest themselves on the micrometer and microsecond scales. This book is offered to mechanical engineers, chemical engineers and biomedical engineers; it can be used for self study, as well as in conjunction with a lecture course.

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