Overall Conclusions and Further Scope of Study

Overall Conclusions

The present thesis is concerned with flow dynamics of oesophageal swallowing. The formation of bolus and swallowing it are an integrated part of oral actions in eating process. It involves a series of simultaneous and coordinated contractions and inhibitions of responsible muscles of mouth, pharynx and oesophageal regions. The most important aspect to take care of during swallowing is the ease of swallowing and safety of oesophagus. Swallowing is affected by different classes of fluids, various types of peristaltic waves, different states of oesophagus. The present thesis is well equipped to investigate oesophageal swallowing to food stuff of Newtonian or non-Newtonian nature in normal and pathological states.

- In **Chapter 3**, we have investigated analytically the flow of Herschel-Bulkley fluid induced by peristaltic waves with progressively dilating amplitude in normal state of oesophagus. This model investigates the impact of swallowing of particularly single food bolus such as raisin paste, minced fish paste transported in oesophagus. The study shows that the spatial rate of change in the pressure difference is much greater when the wave originates at the inlet and terminates at the outlet of the oesophagus than when the wave travels in the middle. The conclusion derived from this that the pumping action does not take place along the entire length of the oesophagus uniformly. The rate of change is more in the vicinity of the inlet and the outlet. It is further concluded that the pressure difference at a given axial position is more for a dilatant fluid than that for a pseudo plastic fluid. The pressure-difference corresponding to a Bingham fluid falls in between these two values. As an

application it has been concluded in this chapter that feeding of pseudo plastic fluids are preferable to the patients suffering from achalasia.

- A theoretical analysis of swallowing of Herschel-Bulkley fluid through oesophagus which suffers from sliding hiatus hernia has been made in **Chapter 4**. The prime concern in this chapter is to examine the impact of bulging of the oesophagus at the distal end, which is formed by various combinations of divergence and convergence. From this study it may be concluded that when the bolus is nearing the cardiac sphincter, pressure-rise and pressure-drop are less in a diverging tube than that in a uniform tube. Therefore, the pressure requirement to deliver bolus in stomach is less if oesophagus diverges. Probably, this is the reason why patient is ignorant of sliding hiatus hernia. Moreover, tube diverges near the end only, its impact is seen on the pressure distribution right from the beginning of the oesophagus. The study has relevance to the physiological flow of food in pathological state of oesophagus.

- **Chapter 5** was devoted to the study of the impact of volume fraction of particles suspended uniformly in food items on pressure, pressure-gradient and velocity during oesophageal swallowing. It is inferred that an increment in volume fraction of suspended particles diminishes the pressure gradient and hence also the axial and radial velocities. The research endorses the advice of the doctors to the patients suffering from achalasia, oesophageal stricture and oesophageal tumors to consume liquid or food items with lesser solid contents.

- Peristaltic transport of food bolus through oesophagus has been investigated theoretically by considering the oesophagus as an elastic tube in **Chapter 6**. Impacts of increasing forcing amplitude on pressure, velocities and time averaged volume flow rate are examined and streamline patterns are also drawn. This study derive the conclusion that the presence of elasticity affect the pressure, pumping performance and velocity significantly. A rise in the forcing amplitude of inward radial force enhances the pressure, time-averaged volume flow rate and hence also the axial and radial velocities. Therefore, we conclude that the elasticity of oesophageal tube favours swallowing of a food bolus.

- In **Chapter 7**, a mathematical model for the study of heat transfer in swallowing of food bolus through the oesophagus is presented analytically. We infer from that smaller is the requirement of pressure to swallow when heat propagates in the oesophagus. Pressure-rise-per-wavelength increases with either of the Grashof number and the heat source/sink parameter before attaining a particular value of the time-averaged volume flow rate but the trend reverses beyond that. It is worthwhile to mention that the study of heat transfer effect on oesophageal swallowing is quite promising for oesophageal cancer treatment.

The overall conclusion we drew is that the problems presented through different chapters in this thesis have potential applications to the physiology of oesophageal swallowing. Oesophageal diseases such as achalasia, sliding hiatus hernia, oesophageal cancer, oesophageal motility disorders and Barrett's oesophagus have brought the human health under threat in the modern society. The oesophageal heat transfer device is used for temperature management of adult survivors of cardiac arrest. We have thrown light on some of these oesophageal diseases throughout our analysis. The problem presented for particle-fluid mixture is immensely useful for understanding a number of physical phenomena including transportation of solid particles by liquids, mixing operations, particulate suspension theory of blood, flow of food suspension through oesophagus and intestines, urine flow through the ureters, transportation of liquid slurries in chemical and nuclear processing etc. Several industrial food processes involve flow of food suspension in which the knowledge of flow properties is essential for assessing pumping requirements.

Further Scope of Study

Theoretical analysis presented in the thesis provide a framework to study oesophageal swallowing in normal and pathological states. In future, some models which can further be explored from the present analyses are indicated below.

- We have presented an analytical model for sliding hiatus hernia by considering it a combination of diverging and converging parts of the oesophagus. But in some cases of this pathological state some parts of oesophagus become curved. This may be another aspect of analysis.

- We have studied oesophageal swallowing of food suspension behaving as Newtonian fluid in normal state of oesophagus. Particulate suspensions may be in a non-Newtonian food.

- We have incorporated an inward radial force as sinusoidal wave forcing to reflect the elastic property of the tube wall. This analysis may be further explored for solitary waves with Gaussian forcing.

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