INDIAN INSTITUTE OF TECHNOLOGY GUWAHATI
SHORT ABSTRACT OF THESIS

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Programme of Study	:	Ph.D.

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SHORT ABSTRACT

Hemispherical Resonator Gyroscope (HRG) is a state-of-the-art inertial navigation sensor proposed for the future high valued long duration interplanetary satellite missions. HRG is a kind of Coriolis Vibratory Gyroscope (CVG). Mechanical resonator is a very critical functional part of the HRG. The performance of the HRG sensor is decided by the resonating structures Quality factor (*Q* factor) which is a measure of damping. High *Q* factor means low energy loss from the resonator. Ultra high *Q* factor is a mandatory requirement for very fine resolution and accurate resonant frequency reference based sensors like HRG.

In the present work, the quantitative requirement of Quality factor is arrived for the mechanical resonator of HRG. The *Q* factor requirement is estimated based on TNER (total noise equivalent rate) for the very fine resolution. Specification of resonator is arrived based on other different functional requirements and design constraints. Different damping mechanisms such as thermoelastic damping, anchor loss, surface loss, material internal friction, fluid damping and electronics damping are addressed. Study of various damping mechanisms is done using finite element simulations. Hemispherical geometry is considered for the design of the resonator. The basic size of the resonator is arrived based on achieving high Q_{TED}. Effect of different resonator dimensions on Q_{TED} is simulated. The sensor operating frequency is decided by this sensitivity study. The specific advantages of hybrid resonator configuration are brought out in terms of improved effective mass and angular gain for lower TNER and this hybrid configuration is used for further simulations. The selection of the $N = 2$ mode as the functional mode is also justified considering the performance parameter. Then, a detailed study of TED with thin film electrically conductive coating, effect of coating variations and configurations on TED is carried out. A sensitivity study of the effect of different dimensional parameters such as shell mean radius, shell thickness, stem radius, stem height on the Q_{Anchor} is carried out. Effect of geometric imperfections due to fabrication such as shell offset, shell tilt, shell thickness variation, mass unbalance is studied in detail and arrived at the fabrication tolerances.

Fused silica material is chosen for the hemispherical resonator. The fabrication procedure of fused silica brittle material and its effect on $Q_{Surface}$ is discussed. Hemispherical resonator is realized using high precision machines. Characterization facilities for frequency, *Q* factor and surface defects have been established. Then, detailed metrology measurements of realized resonators are done for assessing the precision of the fabricated resonators. Surface characterization has been carried out after machining and after chemical etching using nanoindentation technique. *N* = 2 mode resonance frequency measurement is carried out for resonators and compared with the simulation results. The effect of the measured dimensional and geometric deviations on the frequency and frequency split is analyzed. Coarse and fine methods of balancing are arrived. These balancing procedures have been established for correcting the frequency split of realized resonators. *Q* factor estimation from internal friction and surface loss is also discussed. *Q* factor measurement is carried out using Laser Doppler Vibrometry (LDV) for uncoated resonator. Experiment is carried out to estimate the effect of fluid damping and arrived at the sensor operating pressure level for the present resonator design. *Q* factor measurement of the thin film coated resonator is also carried out. *Q* factor of few millions and other functional specifications are achieved in the final functional hybrid configuration of the resonator.