© 2017 IJEDR | Volume 5, Issue 2 | ISSN: 2321-9939

Variation of resonant frequency due to thermal and loading conditions on torsion bar dither mechanism in Ring laser gyroscope

[1]K.Venkata Rao,[2]K.Veladri,[3]C.Narashima Reddy

[1]M.E student, [2]Associate professor, [3]Senior Technical Manager
[1,2]Department of Mechanical,Vasavi college of Engineering, Hyderabad,India
[3]Eloria, Research Centre Imarat, Hyderabad, India

***Abstract*——Ring laser gyro is used in inertial navigation system. It works on the principle of sagnac effect. It has the inherent property to go out of operation at low rotation rates as it goes into dead (lock-in) band. The performance of RLG can be enhanced by keeping it out of dead band. A peizo driven mechanical actuator commonly known as mechanical dither in RLG is engaged to avoid the dead band.This paper presents the selection of material, model and analysis of the mechanical dither in RLG. Structural, thermal analysis is analyzed in the range of -30 to 70 degree centigrade by using finite element analysis. Finite element analysis is also used to find the different resonant frequencies, stresses and strains.**

***IndexTerms*—Navigation, Rlg, mechanical dither, lock-in, sagnac effect, beat frequency.**

I. INTRODUCTION

Navigation is the term used for monitoring and controlling the movement of a vehicle from one place to another. Inertial Navigation Systems (INS), unlike other navigation systems, it does not depend on external (radio) measurements. INS keeps track of its position by accurately measuring motion sensors (accelerometers) and rotation sensors (gyroscopes).A gyroscope works on the principle of conservation of angular momentum. Gyroscopes are useful for measuring orientation. Different types ofGyroscopes are electronic, microchip-packaged MEMS gyroscopes, solid-state ring lasers, fibre optic gyroscopes, and the extremely sensitive quantum gyroscope**.**

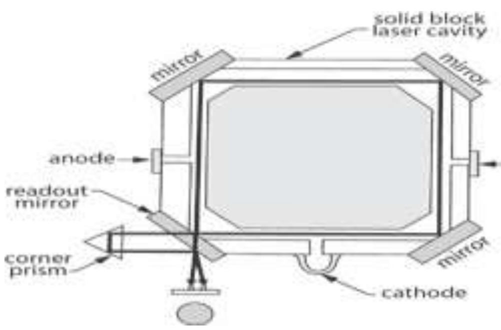
.

II. RING LASER GYROSCOPE

Ring laser gyroscope (RLG) has high sensitivity and stability. It operates on the principle of the Sagnac effect which shifts the nulls of the internal standing wave pattern in response to angular rotation. Interference between the counter-propagating beams, observed externally, results in motion of the standing wave pattern, and thus indicates rotation.

Sagnac-effect

Two wave trains, created by a beam splitter, are travelling around the ring interferometer in opposite directions[3].If the beams are combined (superposed) after one circle they form interference fringe pattern, which is made visible on a screen by means of a photo detector. The light source, the beam guiding system (mirrors or prisms), combining optics, screen and/or photo detector, - all these elements are mounted on a platform (Fig.1). If the whole system rotates around an axis perpendicular to the plane of the counter propagating wave trains, the fringe pattern will be shifted proportional to the rotation rate Ω.



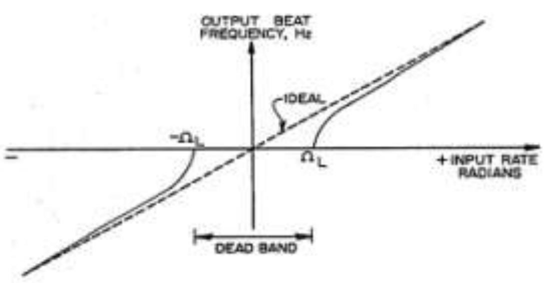


Figure: 1 Figure: 2

Ring laser gyroscope equation

The fundamental RLG equation[5] is $\Delta f = \frac{4A\Omega}{L\lambda}$

Above equation shows the RLG frequency difference, commonly called beat frequency (Δf), to be proportional to the product of the geometric area enclosed by the light beams (A) and the angular rate of cavity (Ω). The beat frequency is also inversely proportional to the product of the vacuum wavelength of the laser (λ) and the optical path of cavity (L). The ratio (4A/L**λ**) is called the scale factor of the ring laser gyroscope.

Mode-locking (Dead Band)

The most limiting factor in the RLG performance is the dependence of the scale factor K on the rotation rate Ω. It arises from lock-in or frequency synchronisation of the counter propagating waves at low rotation rates [1,2,7].When the beat frequency Δf is below a critical value, mutual coupling of the waves locks them together and causes them to oscillate at the same frequency, making Δf=0.The coupling between the counterpropagating waves arises mainly from backscattering produced by mirrors or intracavity optical elements.One of the methods by which mode-locking (Fig.2) can be avoided is mechanical dithering[4].

III. MATERIAL SELECTION TABLE

The materials which have been chosen for modeling of the ring laser gyroscope are given in the table below. The materials which have been chosen are having low thermal coefficient of expansion. Glass cavity and mechanical dither have alow co-efficient ofthermal expansion of 0, 1.2x10^{-6}/^{o}C respectively.

Material selection table

Component	**Material**	**Density (kg/m^3)**	**Young's modulus (Gpa)**
Glass cavity	zerodur	2530	90
Mechanical dither	Super invar	8100	141
Anode	copper	8960	129
Cathode	aluminum	2800	72

Components of ring laser gyroscope

The torsion bar is the main component in the RLG which is responsible for avoiding the mode-locking. The torsion bar as shown in Fig.3 is made of super invar. The torsion bars which are opposite to each other acts as couple and a twisting moment takes place due to this the RLG goes out of locking mode. Fig. 4 is the sub-assembly where casing, glasscavity, anode and cathode are hidden and Fig. 5 is the complete assembly of the RLG.

Figure: 3

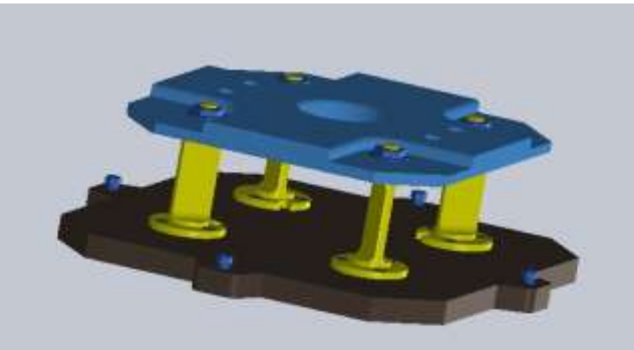


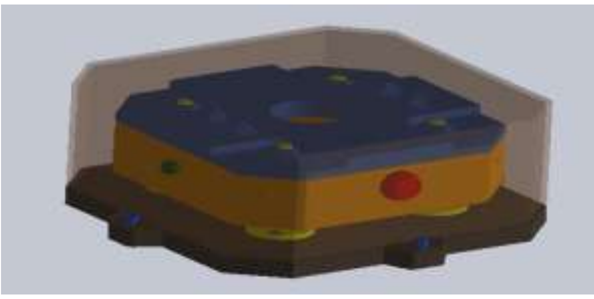
Figure: 4

IV. FINITE ELEMENT ANALYSIS

The numerical simulation consists of three stages by using ANSYS WORKBENCH 16.0. In the first stage, a modal analysis is performed to determine resonant frequencies and mode shapes which are important parameters in the design of structure for dynamic loading conditions. In the second stage, pre-stress is given for torsion bar and bolts of glass cavity to find stresses, strains at ambient temperature. In third stage, steady state thermal analysis is carried out in the range of -30 to 70°C to calculate temperature, total heat flux and then overall modal analysis is carried out.

Modal analysis

The modal analysis is carried out on the RLG and the typical modal results are shown in Fig.6.The first mode is the dithering mode as the glass cavity rotates in back and forth around central axis at 419.6Hz.The base plate moves up and down in second mode 744.8Hz.The third and fourth modes (756.9Hz and 757.4) are bending modes in two different directions.



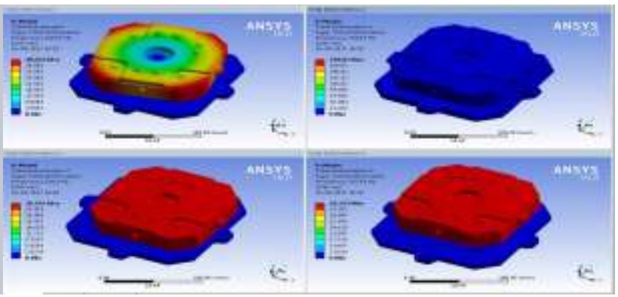


Figure: 5 Figure: 6

Static-Structural analysis

When tightening the nutson torsion bar and bolts of glass cavity, stresses get induced. So the torsion bar on the RLG is given prestress and then stresses (Fig.7), strains (Fig.8) which acts on the glass cavity and torsion bar are calculated. The maximum stresses are generated on the top plate and torsion bar at ambient temperature conditions. As the torque applied increases on the bolts and torsion bar, the resonant frequencies also changes accordingly.

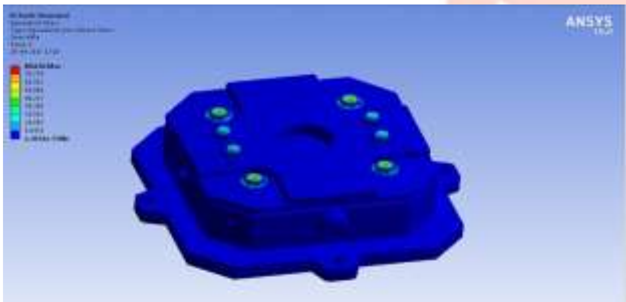


Figure: 7

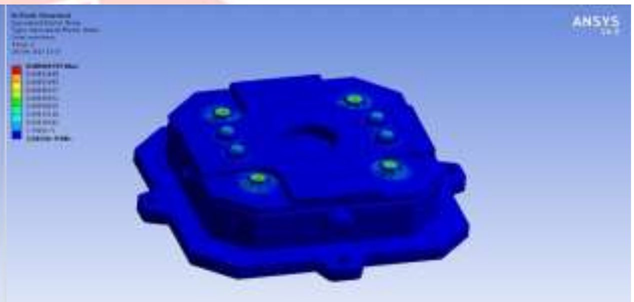


Figure: 8

Steady state thermal analysis

The prisms contacted near gain medium get heated up due to self-heatingin comparison to prisms contacted opposite side of the active medium. As the electrode size increases the temperature also increases accordingly[8].The external disturbances also effect the RLG[6].So a steadystate thermal analysis is carried out in the range of -30 to 70°C to find the temperature (Fig.9) and total heat flux (Fig.10) on the RLG.The maximum temperature and heat flux is found in the laser cavity where electrodes are placed at-30°C and at 70°C it is foundat place where the electrodesdon't exit.

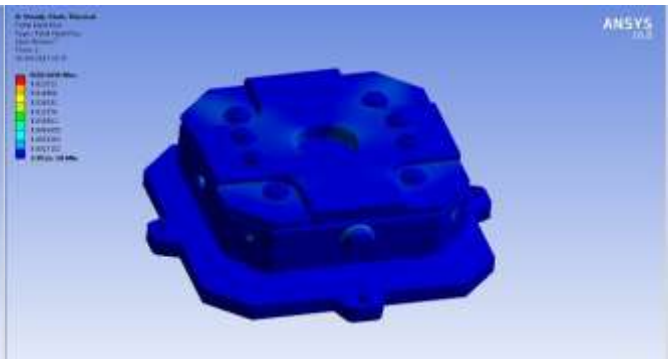


Figure: 9Figure: 10

Overall Modal analysis

In the overall modal analysis, first steady state thermal analysis is carried out, the data is transferred into static structural analysis and then analysed. After performing these analyses, modal analysis is done on the analysed RLG (Fig.11). It was found that there is a change of 8Hz in its resonant frequency.

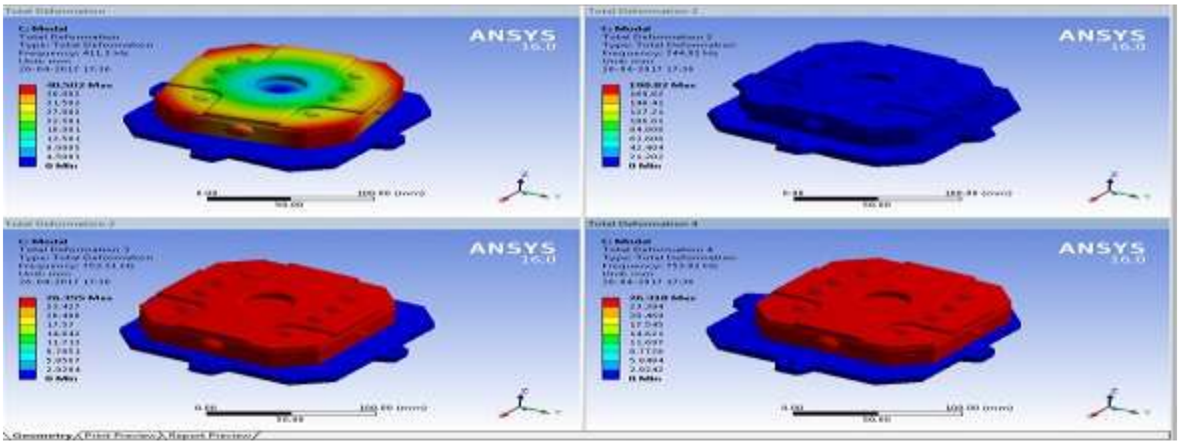


Figure: 11

V. CONCLUSION

Adesign method based on FEA is proposed for dither mechanism in RLG.The Torsion bar in RLG is given pre-stress, the stresses and strains at ambient temperature are determined. The steady state thermal analysisis carried out in the range of -30 to 70^{o}C and temperature, total heat flux are calculated. Then overall modal analysis is carried out in the range of -30 to 70^{o}C temperature at pre-stress condition. It was found that there is a change of resonant frequency of about 8Hz when compared with the modal analysis which has no loads and thermal effect. The performed analysis gives the actual resonant frequency of the RLG.

VI. ACKNOWLEDGMENT

[1]Authorconveys his deep sense of gratitude to Mr.G.KrishnaRao, DEAN OF ELOIRA (ELECTRO OPTICAL INSTRUMENT RESEARCH ACADEMY) for his valuable support in various ways. [1]Authoris very much thankful to [2]Author for his continuous and valuable guidance throughout the project work and suggestions. [1]Authorlikes to thank Project Co-ordinator[3]Author, Senior Technical Manager, ELOIRA for cooperating all through the project.

REFERENCES

[1] M Faucheux, D Fayoux and J J Roland, "The ring laser gyro", Journal of Optics, Volume 19, Number 3,pp.101-115.
[2] Thomas M.Wirt, "Dither suspension for ring laser gyroscope and method", United states Patent: 4,779,985,oct,1988.
[3] ApotinV.S., "Ring laser gyroscope and their Uses", 30, Lenin Avenue, Tomsk, 634050, Russia.
[4] D.C. Lee, G. Moon and J.C. Lee, Mechanical dither design for ring laser gyroscope, KSME International Journal,vol. 16-No.4 (2002), 485–491.
[5] Mohammad-Nejad, M.Pourmahyabadi and A.Lajevardizadeh, "Performance Modeling of Ring Laser Gyro in Inertial Navigation System", Iranian Journal of Electrical and Electronic Engineering,Vol.2,Nos.3&4,July 2006.
[6] Ayswarya P R, Pournami S S and Ravi Nambiar, "A Survey on Ring Laser Gyroscope Technology," International Journal of Computer Applications (0975 – 8887) ,Volume 116 – No. 2, April 2015.
[7] Dr. Frederick Aronowitz, "Fundamentals of the Ring Laser Gyro", 11430, Manzanita Trail, Dewey, Az 86327, U.S.A..
[8] A.RamchanderRao ,G.Laxminarayana,M.K.Gupta,I.M.Chhabra and C.Vishnuvardhan Reddy, "Analysis and optimization of electrodes for improving the performance of ring laser gyro", International Journal of Research in Engineering and Technology, Volume: 04 Issue: 05 | May-2015.