Sudan University of Science and Technology

College of Engineering

School of Mechanical Engineering – Department of Production Engineering

Project Submitted to school of mechanical engineering as Partial Fulfilment of the Requirements for the Degree of BSC in Mechanical Engineering (Production)

Title:

Modeling and Simulation of a MEMS gyroscope using Analysis

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DEDICATION

All praise to Allah, today we fold the days' tiredness and the errand summing up between the cover of this humble work.
To the utmost knowledge lighthouse, to our greatest and most honored prophet Mohamed - peace and grace from Allah be upon him.
To the spring that never stops giving, to my mother who weaves my happiness with strings from her merciful heart... to my mother.
To whom he strives to bless comfort and welfare and never stints what he owns to push me in the success way who taught me to promote life stairs wisely and patiently, to my dearest father.
To whose love flows in my veins and my heart always remembers them, to my brothers and sisters.
To those who taught us letters of gold and words of jewel of the utmost and sweetest sentences in the whole knowledge. Who reworded to us their knowledge simply and from their thoughts made a lighthouse guides us through the knowledge and success path, to our honored teachers and professors. To Our supervisor Dr.Musaab Hassan Zarroug

Abstract:

Micro electro mechanical systems refer to devices or systems integrated with electrical and mechanical components that are in Micro scale. With its small size, low cost and efficiency the technology has been widely used in various fields.

In this research, several models of various concepts are studied, modeled and proposed. First, an introduction to Micro electro mechanical systems will be discussed in chapter I. A briefing of previous recent studies and various models will be given in chapter II. Chapter III will explain in details the theoretical concept from explaining the Coriolis Effect till the resulted capacitance sensing of the gyroscope background. Then the various design parameters proposed and concepts and processes will be presented in chapter IV. Then results and the ideas concluded in chapter V.

The gyroscope is a device that is used in orientation and tilting measurement according to reference. A micro electro mechanical version of the device was invented and it made a breakthrough in the market for its size and efficiency.

ملخص:

الأنظمة الميكانيكية الكهربائية الدقيقة تشير إلى أجهزة أو أنظمة متكاملة مع المكونات الكهربائية والميكانيكية التي هي في النطاق الصغير. مع صغر حجمها، وانخفاض التكلفة والكفاءة والتكنولوجيا قد استخدمت على نطاق واسع في مختلف المجالات .

في هذا البحث تم دراسة عدة نماذج من مفاهيم مختلفة، وعلى غرار المقترح. أولا، مقدمة لمايكرو الأنظمة الميكانيكية والكهربائية سيتم مناقشتها في الفصل الأول ستعطى إحاطة من الدراسات الحديثة السابقة ونماذج مختلفة في الفصل الثاني. والفصل الثالث يشرح بالتفصيل مفهوم النظرية من شرح تأثير كوريوليس حتى الاستشعار السعة أدى الخلفية جيروسكوب. ثم اقترحت مختلف المعلمات تصميم وستعرض المفاهيم والعمليات في الفصل الرابع. ثم النتائج والأفكار وخلصت في الفصل الخامس .

وجيروسكوب هو الجهاز الذي يستخدم في قياس التوجيه وإمالة وفقا لمرجعية. اخترع نسخة الميكانيكية والكهربائية الصغيرة من الجهاز وانها حققت اختراقا في السوق لحجمها وكفاءة

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Symbol	Definition
X_a	The object that exists in frame A
X_b	The object that exists in frame B
u_j	The figure above the axis of frame B
a_A	The acceleration of the object in frame A
a_B	The acceleration of the object in frame B
$\boldsymbol{\alpha}$	The angular velocity
$\mathbf{v_B}$	The velocity of the object in frame B
$F_{coriolis}$	The coriolis force
F_{Euler}	The Euler force

$F_{centrifugal}$	The centrifugal force
m	The mass
F_o	The electrostatic force
Cx	The co-efficiency of air surrounding for drive mode
Cy	The co-efficiency of air surrounding for sense mode
Kx	The spring constant for drive mode
Ky	The spring constant for sense mode
Q_x	The equality factor of X direction
Q_y	The equality factor of Y direction
X_m	The amplitudes for X direction
y_m	The amplitudes for Y direction
θ	The angular displacement
ω_x	The radial velocity for the drive mode
ω_y	The radial velocity for the sense mode
S_{dn}	The normalized displacement sensitivity

q1 q2	The electrical charges
R	The distance between the charges
F	
ε_o	The relative permittivity of a vacuum
W	The width of the comb finger
L	The length of the comb finger
C	The capacitance
V_d	The battery voltage
Q_c	The storage of the electrical charge
E_c	The energy stored in the capacitor
E_o	The original energy in the capacitor
E_B	The reduced energy of the capacitor
F_{en}	The electrostatic force on the movable plate of the capacitor
F_k	The elastic recovery force
d	The gap distance
x	The overlapping distance

F_{el}	The lateral electrostatic force
t	The thickness of the comb finger
N	The no. of comb fingers
V_o	The applied AC voltage
S	The overlap area of the two surfaces
C_o	The static sensing capacitance
E	The dielectric constant

d_o	The static capacitance gap
M	The proof mass of the system
E	Young's Modulus
I	Moment of Inertia
Fx	The frequency in the drive mode
Fy	The frequency in the sense mode
ωx	The radial velocity in the drive mode
ωy	The radial velocity in the sense mode
mx	The driving mass
my	The sensing mass

1.1.Importance of this research:

As mentioned earlier, MEMS technology will improve the performance in many applicable sciences, so to be able to contribute and manufacture, we first need to understand the basic concept and grasp the theoretical side of the industry, for this research a stepping stone for maybe manufacturing locally in the future. And even improve and contribute scientifically to a global level.

1.2. Objectives:

1. Is to design and modify multiple designs of the mechanical component of the MEMS gyroscope

2. To simulate the designs and measure then compare the output from each design and compare them with each other.

1.3. Methodology:

The methodology taken in this research is to design several models and putting every parameter that might affect the performance of the gyroscope. The designs were modelled based on the equations in chapter 3 and dimensions were estimated based on what might lead to better results. Then multiple simulation processes were applied to each model to compare which choice of parameters was better than the other. The models were compared. Also the results of the simulation processes were compared to the equations governing the design.