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CREATION, OPTIMIZATION, AND EVALUATION OF THE OVERALL PERFORMANCE OF A MECHANICAL CHRONOMETER FOR 60 MINUTES TIME DELAY BY USING SOFT COMPUTING TECHNIQUES

Ms.Mayuri B.Ardak, Ph.D.Scholoar**,** Dept. of Mecahnical Engineering, MIT School of Engineering, MIT Art, Design and Technology University,Lonikalbhor, Pune.
Dr.Anilkumar Sathe, Associate Professor, Dept. of Mecahnical Engineering, MIT School of Engineering, MIT Art, Design and Technology University,Lonikalbhor, Pune.
Dr.MangeshR.Phate, Professor, Department of Mechanical Engineering, AISSMS College of Engineering Pune.
Mr.Piyush P.Rode, Industrial Mentor, Defence R & D Consultant.

ABSTRACT

A Mechanical chronometer is a precision timekeeping device that is specifically designed to measure time with a high degree of accuracy. It is commonly utilized in a variety of fields where precise timekeeping is of utmost importance, including but not limited to astronomy, navigation, and scientific research. Mechanical chronometers are indispensable instruments utilized across diverse domains such as maritime navigation, astronomy, surveying, geophysics, industrial timing, sports timing, scientific research, and horology. The main application of this object is in Munitions region as a safety and arming device. In the Munitions area there is some particular area or some particular ammunition where certain amount time delay is required. Those rounds shouldn't function quickly after activation because that can be harmful for the person who is activating a particular area. Development of a Mechanical chronometer unit that will give us the necessary time delay activate a mechanism and electronic circuit attached to it. The Mechanical chronometers constructed in such a way that it provides a time delay of 60 minutes. The entire operating mechanism of the Mechanical chronometer includes the pin pallet and ratchet setup. The necessary time delay of 60 minutes is obtained only by this arrangement only. The goal of this study is to develop and critically examine the operation of a mechanical chronometer unit that will provide us with the appropriate time delay. To find essential design factors, design parameters were analysed in MINTAB using RSM.

Modelling and simulation of system design adjustment is respectable training for design and engineering decisions in real world jobs. Before manufacturing we need to validate the design so by using the ANSYS software to analyse the structural integrity of components and devices, ensuring they meet safety and reliability requirements under various loads, boundary conditions. The key influencing elements are Pallet weight, Pallet radius, Pin Radius, and Pin Distance.

Keywords : Mechanical chronometer, Mechanisms of a clock, escapement, mathematical modelling, Equation of motion, differential equation, response surface methodology, Orthogonal array, Taguchi array Soft computing, FEA.

Introduction

Background

The word "Mechanical chronometer" is usually reserved for devices that count down from a specified time interval, Mechanical chronometer can be used in a wide variety of applications, such as cooking, sports, games, alarms, and time management. They can also be used in industrial and laboratory settings to measure the duration of processes or experiments. Mechanical chronometers are timekeeping devices that are designed to measure precise and accurate time intervals. They are often used in scientific, navigational, and astronomical applications where accurate timing is crucial. The Mechanical chronometer's mechanism comprises key components such as the escapement, balance wheel, hairspring, gear train, temperature compensators, and electronic components. In Mechanical chronometer there are following main parts one is clock spring which gives energy for the system to run. It is considered as a prime mover. Second is Gear train is used to transmit the motion consume energy. Third ratchet and pallet this combination acts as a main energy consumer. It consume energy given by the mainspring and restrict the free motion of the gear, which give us the required time delay is considered winding of the mainspring. so this kind of arrangement was also used in old mechanical watches where it is a assisted with one more spring which is called a hair spring. This hairspring is very thin and it is susceptible for breakage which results in a failure of mechanism. Because of this reason we cannot use such arrangements. In munitions or areas with unstable operating conditions like as vibration, heat, shock, and so forth. Response surface methodology (RSM) in statistics investigates the interactions between a large number of explanatory factors and one or more response variables. The fundamental premise of RSM is to use a sequence of pre-planned tests to discover the optimal solution. A mode of a second-degree polynomial model is proposed to do this. They acknowledge that this model is an approximation, but they adopt it because it is straightforward to estimate and apply, even when nothing about the process is known. A factorial experiment or a fractional factorial design is an easy way to estimate a first-degree polynomial model. This is sufficient to determine which explanatory variables impact the response variable(s) of interest. (20)

Related Work

Four distinct escapements are included in the study material. In this work, mechanical watch movements were investigated using a virtual library. The watch is the most important device ever created by men. A watch mechanism typically consists of about 100 parts. The escapement is the most crucial of these parts. It determines the precision of the timekeeping and is sometimes referred to as the movements brain (14). The provided formulation enables the investigation of the effect of critical technical factors on the lubrication of Swiss lever escapements. The spout curvature radii have been discovered to be the appropriate lubrication regime control parameters for the pallet/escapement kinship. In that respect, Lubrication shifts away from boundary lubrication when radii increase. (1).Two of the most significant mechanisms in the category of detachable escapements are the Riefler escapement mechanism (Sigmund Riefler, DeutschesReichs Patent, 1889) and the Grasshopper recoil mechanism (John Harrison, 1693–1776). The pace of movement of a pocket watch mechanism is controlled by the Huygens balancing wheel with pivot and verge. The Huygen balance wheel of the Mechanical chronometer was engaged, as was a wheel and verge that had been lost. The strongest proof that the "art, science, and skill" of making mechanical clocks is not alive but rather going through a new Renaissance is provided by Beat Haldimann's creations. These pendulum clocks only have a rate inaccuracy of less than 10 milliseconds each day! The clock with a separate escapement is modern; it was patented by Beat Haldinann, one of the most well-known horologists and watchmakers of the modern era, in 1964(5).The most significant distinction between watches and clocks is that a watch's balance wheel is independent of the pallets, whereas a clock's pendulum is dependent on them. To achieve a deadbeat and prevent recoil as the escapement turns, the escapement is the part of a clock must have pallets with curved locking faces (11). However, in order to generate pull, the watch escapement has to pallets with locking faces that let the escape tooth to go up the locking face of the pallet while advancing slightly. In order to ensure that the pallets get equal impulses clock- and watch-escapements should both have symmetrical designs for both pallets, the escapement efficiency should be the same. As might be significant reduction in effectiveness or the capacity of the balancing wheel to accept the escape wheel's jerking movements, if the impulse face angle of the pallet were not correct. (6). Influence of Escape wheel torque, the entire defuser delay period increases of the rotational inertia associated with the pallet. The effect Pallet Escape-Wheel Middle Distance results in the reality that defuser duration rises when the middle moves further away. Effect of Pallet Radius- While the pallet a circumference rises, the defuser period reduces persistently and significantly - this is due to the fact that each pallet has an effective decrease in center distance, i.e. its size with relation to the area of the material it is being loaded onto. Influence of Coefficient of Friction- defuser duration boosts while the corresponding value of the coefficient of friction related to a coupled motion increases. It might say expect that an increase -will slow the mechanism down over time. All essential geometrical, kinematical, and dynamical properties are discussed, in addition to their effect on clock accuracy. This research evolved an achievable computer simulation of the pin pallet. They investigated uncontrolled escapement in this research, which might act as a basis for the evaluation and summary of multiple safety and arming devices. (7). If an impact When a gearing system is reversed, the escape wheel's angular velocity might become negative. Contact loads between gear teeth and at various gear pivots would be reversed. The effect of frictional force is examined in both the coupled and free motion regimes. It rubs at the point of contact between the escape disc and the pallet during connected motion, and there is friction between the teeth of the gears on all pivots. (8)

The study put forward a generic technique for motion-related evaluation of convoluted systems with mechanical components. The approach, which depends entirely on the detonator-space of the adjacency matrix’s null space, might be implemented in mechanisms with numerous degrees of freedom and defuser-collinear output and input axes. This approach was demonstrated using a two-degree-of-freedom automobile differential and a helicopter's main gear box. The resulting solution was carried out making use of a freely available module for MATLAB. (16).

This tool's ultimate goal is to generate a list of all contact harmonics in gearing pairs and roller or ball bearings in rotating pairs. Runaway escapement, which is the core of the S&A mechanism, primarily consists of two parts: a pallet and an escape wheel. Pallet is only an oscillating inertial mass that has the function of interfering with the high-frequency spinning of the toothed wheel in the escapement of a watch or clockl (12). Pallet is not a genuine simple harmonic oscillator like those found in mechanical clocks, therefore when torque supplied to the toothed wheel in the escapement of a watch or clock is increased, pallet is going to vary significantly and revolve more quickly. Runaway escapement acts as a mechanical damper to regulate the rotor's rotational velocity.The safety of the gun crew and the ammunition stockpile depends on the artillery projectile leaving the muzzle at a significant secure militarizing range. The secure armament range is made certain by delaying the weapon's defuser's armament stage .Pin pallet runaway escapement device is one of various systems used to delay the arming procedure and still retain the fuze's overall performance. Each runaway escapement system, nevertheless, is created specifically for a certain projectile, taking into account the muzzle velocities and related minimum and maximum ranges. Therefore, even if a runaway escapement is intended to be used for munitions of a different caliber, it is vital to study its design characteristics to verify that it offers the requisite time delay (13). This paper describes in detail the operation of a typical artillery fuze with pin pellets, its explosive components, the design of its pin pellet escapement mechanism, its linkage with the gear reduction train, and finally the complete dynamic simulation of the mechanism to ensure that jamming is avoided and the mechanism operates without interruption. Finally, results in the form of escapement wheel angular position/velocity are displayed to demonstrate how it works and how it may be employed with projectiles of various calibers (3). The frictional phases of an interaction link escapement and the Swiss linkage escapement have been studied with fluids lubricating agent’s theory along with a previous the motion and the reverse model of a dynamic multibody. Experimental measurements have been compared to the results of the kinematic analysis. By taking into account a hydrodynamic lubrication regime, the created model build it simple in order to establish relative speed, the forces of contact, and the coefficient of friction for each of the three stages of operation of the Swiss lever escapement. With the help of the proposed formulation, it is now possible to investigate how important technical factors affect the lubrication of Swiss lever escapements. The best variables to manage the pallet/escapement contacts' lubrication regimens have been found to be the spout radii of curvature. In that regard, an intriguing finding is that raising these radii causes the lubrication regime to diverge from boundary lubrication (17).Precision aiming and maximal devastation with the least amount of collateral damage are made possible by means of cutting-edge tech. in the layout and development for cutting-edge weapons. The foundation of contemporary warfare is precise guidance and information superiority; as a result, the upcoming weapons technology tend to further dependable, light, and small among the essential parts of the new development of weapons is fusible material. Safety and arming (S&A) systems with MEMS technology created in the previous two decades in order to miniaturize fuzes and accomplish expanded fuze functionality. Fuses are created using a cutting-edge Safety and arming devices using MEMS technology offers benefits including cheap mass production, parallel processing, affordability, efficient designs, as well as simplicity the integration systems. MEMS technology has changed the design of fuze systems by enabling the fabrication of a microchip with micro sensors and actuators, leading to microprocessor-based smart gadgets with data storage transmission capabilities. The development of next-generation weapons will probably be influenced by how well the safety and arming devices in weapon fuze systems are MEMS-based. This paper presents a comprehensive investigation of MEMS-based safety and arming devices created during the previous two decades by a variety of researchers. A review of MEMS safety and arming devices has a focus within the manufacturing methods and procedures, the material and composition of the devices, the integration of their sensor and actuators systems with armament defuser devices. The researched designs of detonator-based S&A systems have been compared on the basis of essential design variables like the driving concept, device structure, gadget dimensions, max displacement as something etc. It may be possible to build MEMS-based S&A systems to incorporation with armaments detonator systems of the years to come using the matrix of comparisons created based on the findings from various researchers. (4) Temperature affects a material's modulus of elasticity. Variations in temperature have a considerable impact on the time-keeping balance disc and balance vernal because, generally applicable to materials, the size of this temperature parameter is enough. Robert Hooke and Christian Huygens, two of the first watchmakers to use balancing springs, saw this phenomenon but were unable to explain it

In the process of creating the maritime Mechanical chronometer, John Harrison found a solution in the form of a "limit on wages "—basically, a dual-metal gauge that changed the length of the effective balanced springs in response to temperature. Although Harrison was able to comply with the Longitude Act's requirements because to this plan's effectiveness, it was not widely used. (22)

The compensating balance was created by Julien Le Roy's son Pierre about 1765, and it quickly rose to prominence as the accepted method for temperature correction in timepieces and Mechanical chronometers. In this method, a temperature-sensitive mechanism changes the form of the weights on the spokes or rim of the balance are adjusted by the balance or shifts. This alters the balance wheel's moment of inertia, which is then changed such that it balances out the alteration in the balance spring's modulus of elasticity. The Thomas Earn shaw compensating balance design, this device, which is basically a balance disc with a bimetallic rim, became the usual method for regulating temperature. (15).Mechanical chronometer that have been well-built and have high-quality mechanical components ought to last. A Mechanical chronometer's capacity to keep precise time may be hampered by the physical wear and tear that mechanical parts experience. Instead of buying a new Mechanical chronometer, you may enroll in a mechanical chronometer for that matter store that fixes to look at something for a period of time or timepieces for refurbishing. In addition to traditional kitchen Mechanical chronometer, mechanical chronometers are found in many other gadgets. Numerous appliances, like toaster ovens, come equipped with mechanical chronometer, and Mechanical chronometer adapters for spigots to regulate hoses are also available (19).

Literature Gap

From the literature review, it is clear that.

- Due to restricted local escapement design capabilities, any adjustments would need to start from scratch.
- Replacement of the hair spring or arrangement for the energy distributor

- Conversion of the pin pallet simulation to a timing mechanism powered by springs.
- Ensure that your simulation model accurately captures the accuracy and precision of the Mechanical chronometer

Modeling and simulating a Mechanical chronometer is a complex task that requires a deep understanding of its mechanical or electronic components, precise modeling techniques, and validation against real-world data. The accuracy and precision of the simulation are essential to ensure that the model accurately reflects the behavior of the actual Mechanical chronometer.

Research Methodology

Design of Mechanical chronometer:

The Mechanical chronometer's whole body may be divided into three pieces. Figure 1 shows the top plate housing the major central shaft, the middle half housing all moving elements (gears, ratchet, spring, and pallet), and the bottom plate housing electronic switches. Because all of the arrangements are mounted on the central shaft, it must rotate 330 degrees in 60 minutes while in use.

A Mechanical chronometer is a device utilized to generate exact time delays. Second, it can be utilized to repeat or begin a process after or at a specific time. Basically Mechanical chronometers rely on the force supplied by the user. When you turn the dial to establish a Mechanical chronometer, you additionally supply the Mechanical chronometer with the power it requires to complete its cycle. A spring is compressed when the Mechanical chronometer is turned. As the spring unwinds, it moves gears, which causes the Mechanical chronometer dial to move. When the spring is entirely unwound, the Mechanical chronometer completes its cycle. As a result, the bell rings at the end of each mechanical chronometer cycle. Escapement The escapement controls how quickly a mechanical chronometer's spring unwinds. As a result, the escapement maintains a unit's timekeeping. An escapement is basically a type of catch. Before releasing the teeth of a Mechanical chronometer's gears, this catch grabs or stops them. This catch-and-release cycle creates a pattern that keeps a Mechanical chronometer in sync with the passage of time, allowing a device to keep accurate time. The Wheel of Balance in a Mechanical chronometer, one of two mechanisms controls the rhythm of an escapement's catch-and-release cycle. The length and weight at the bottom of an oscillating item control the rate at which it swings back and forth.

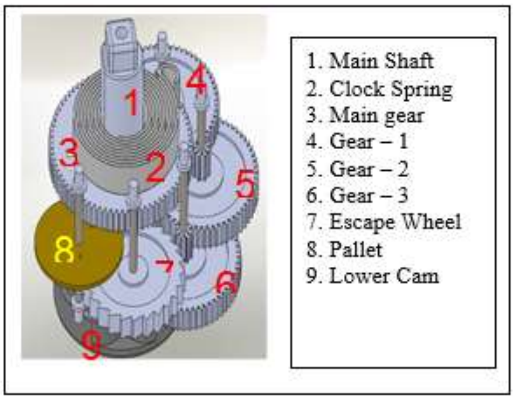

Figure 1**:** Mechanical chronometer Assembly

Gear Calculation

For first set of gear pairs, design parameters are shown in table below:

Table 1: First Gear Pair Parameters

Sr.No	Particulars	Gear 1	Pinion 1
1	No. of Teeth	76	08
2	Gear Ratio	9.5	
3	Module	0.25	0.25
4	Pressure angle	20	20

Calculation for Gear 1

Pitch Dia. (d) =module × no. of teeth
=0.25×76
=19 mm

Root dia.(df)= module × (no. of teeth-2.5)
= 0.25× (76-2.5)
= 18.375 mm

Outside dia.(da)= module × (no. of teeth+2)
=0.25× (76+2)
=19.5 mm

Tooth height = 2.25 × module
= 2.25 × 0.25
= 0.56

Addendum = 1× module
=1× 0.25
=0.25

Dedendum = 1.25 × module
= 1.25 × 0.25
= 0.312 mm

Tip clearance = 0.25 × module
= 0.25 × 0.25
= 0.0625 mm

Central Dist. = $\frac{module\ (pinion\ no.of\ teeth + gear\ no.of\ teeth}{2}$

$\frac{0.25(8+76)}{2}$

=10.5 mm

Similarly for every gear and pinion we use the same formulas and the calculated

Table 2**:** Pinion - Gear Calculation Parameter (1stand 2nd gear pair)

Inputs for Pinion (1st Pinion Gear)	
Pressure angle, α (deg)	**20**
Module m	**0.25**
Number of teeth , z	**8**
Outputs For Pinion	
Pitch diameter, d (mm)	**2.000**
Base Diameter, d_b (mm)	**1.8794**
Root Diameter, d_f (mm)	**1.3750**
Outside Diameter, d_a (mm)	**2.5000**
Addendum, h_a (mm)	**0.2500**
Dedendum, h_f (mm)	**0.3125**
Tip Clearance, c (mm)	**0.0625**
Total Tooth Height, h (mm)	**0.5625**

Inputs For Gear (2nd Spur Gear)	
Pressure angle, α (deg)	**20**
Module m	**0.25**
Number of teeth , z	**60**
Outputs For Gear	
Pitch diameter, d (mm)	**15.000**
Base Diameter, d_b (mm)	**14.0954**
Root Diameter, d_f (mm)	**14.3750**
Outside Diameter, d_a (mm)	**15.5000**
Addendum, h_a (mm)	**0.2500**
Dedendum, h_f (mm)	**0.3125**
Tip Clearance, c (mm)	**0.0625**
Total Tooth Height, h (mm)	**0.5625**

The above data is same for all further gears and pinion i.e. for 2nd, 3rd & 4th pinion and 3rd, 4th 5th gear.
The compound gear ratio will be given as below

$$GR = \frac{Z1}{Z2p} \times \frac{Z2}{Z3p} \times \frac{Z3}{Z4p} \times \frac{Z4}{Z5p}$$

$$= \frac{76}{8} \times \frac{60}{8} \times \frac{60}{8} \times \frac{60}{8}$$

= 4007.8

ASSEMBLY

Assembly of all the stages in the gear train is done. In first stage only main gear is attached on the shaft. This gear further meshes with the gears in the second stage, the main gear consists of 76 number of teeth. Further it meshes with the pinion having 8 number of teeth which is of the second stage. Second stage has two gears on the same shaft where one gear consists of 60 teeth and second one consists 8 respectively. Here the pinion with 8 number of teeth is in mesh with the gear of 60 number of teeth on third stage. Then the third stage again consists of the one more gear having 60 number of teeth, this gear is meshed with the last gear having 8 number of teeth of fourth stages. This fourth finally has the last element attached on the same shaft called escape wheel.

Figure 2: Assembly of the Mechanical chronometer:

We have designed and assembled the gears in the assembly. The rest parts like the shafts used in each stage along with pallet escapement is designed and assembled. Escape wheel consists of 27 number of teeth & radius of pallet is 6mm. These parameters are such as number of teeth used for escape determines the time delay. This is calculated by considering the motion equations.

Analysis of Gear Train

After doing the design and assembly of the gear train, further it's an examination is carried out to check the failure of the gear train. It is very important to do a study of stress and resulting deformation of the gear train due to them. As any deformation in the gear train will lead to change in time delay provided by the timer.

As a result, we chose to conduct the analysis utilizing the Ansys Work-Bench. Ansys Mechanical is a best-in-class finite element solver that may improve your modelling with structural, thermal, acoustical, transient, and nonlinear features. Static Structural Analysis

As a result, Static Structural Analysis is performed on the gear train or mechanical time assembly. A static structural analysis identifies the displacements, stresses, strains, and pressures induced by loads that do not create substantial inertia and damping effects in structures or components. The assumption is for steady loading and response circumstances, which means that the loads and the structure's reaction will fluctuate gently over time. The ANSYS, Same, or ABAQUS solvers can be used to calculate a static structural load.

Geometry Preparation

In this step we have imported the geometry into the Workbench. During importing the geometry or the model, various sub-assemblies and components got disturbed and the gears which were meshed were in interfered with the other gears due to scaling issue. So, we did repaired the model of the mechanical timer in the space claim to make it ready for the further analysis

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Figure 3: Main Gear Model

Material Modelling

After the model preparation firstly, material properties are added to the model. As per the requirement of the industry the mechanical timer should of brass. So, based requirement brass properties are used for designing of the gear train. These same properties are then used for static structural analysis. Following are the material modelling properties**:**

Table 3: Material Specifications

Material	Brass
Density	8.73e-09 tonne/mm³
Young's Modulus	97000 MPa
Thermal Conductivity	0.0605 W/mm·°C
Specific Heat	4.34e+05 J/tonne·°C
Tensile Yield Strength	124Mpa

Meshing

The next step after material modelling is to mesh the whole geometry. Mesh generation, also known as two-dimensional and three-dimensional grid generation, is the process of splitting complicated geometries into pieces that may be used to discretize a domain. Ansys Mesh capabilities are frequently referred to be the gold standard for workflow modelling and simulation for meshing complicated components. This technique often takes up a large amount of time when obtaining simulation results. As a result, Ansys Mesh has developed innovative automated mesh creation technologies that may give faster and more accurate solutions for CFD (fluid) and FEA Meshing. Types of Mesh

1. 2D
a. Tri Mesh
b. Quadrilateral or Quad
2. 1D
a. Triangular/tetrahedral c. Pyramid
b. Prism d. Arbitrary Polyhedron

We have used tetra mesh for our geometry. A tetrahedral mesh is a three-dimensional version of a two-dimensional triangular mesh. Tetrahedral components are often equilateral, as in systems with circular curvature, but they can also be isosceles tetrahedral in systems with asymmetry. Tetrahedral components might also be completely unstructured and accurately fitted to any geometries.

Following are the details of Meshing

Table 4: Meshing Details

Mesh Type	Tetra
Mesh Size	0.2mm
Nodes	1389616
Elements	736529

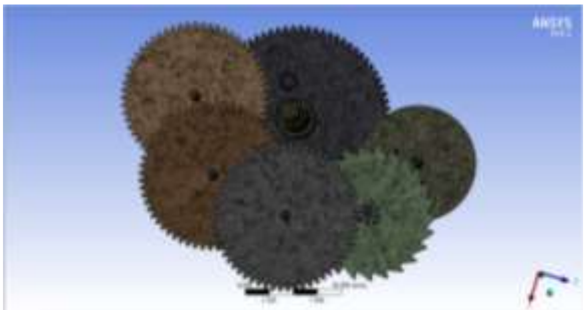


Figure 4: Main Gear Model.

Boundary Conditions

Boundary conditions are simply the criteria or limitations that are assigned to the model. Conditions are things like putting supports or fixing any point. In the boundary conditions, forces, displacement, and moments can all be applied to the geometry. Supports are used to represent non-model components that interact with the model. Supports aid in truncating the domain, which aids in generating numerically correct results while avoiding modelling sections of the geometry that are not of major concern. There are several forms of support available, and selecting the appropriate support is critical since it ensures that the simulation model accurately represents the boundary condition.

Fixed Support -It can be observed that sides of the main are constrained as fix and then the faces of shafts of further stages are kept as fix.

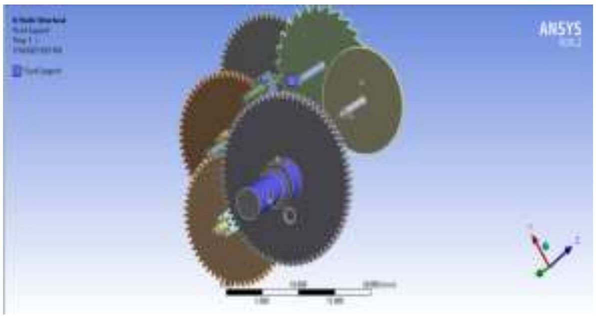


Figure 5: Main Gear Model

Loading – Moments are applied on the face of the gears. Every Gear has a different moment applied onto its faces. Following are the details of loading conditions:

Table: 5 Loading Details

Moments on Each Gears	
1st Moment	90 N/mm
2nd Moment	-9.47 N/mm
3rd Moment	1.26 N/mm
4th Moment	-0.0224 N/mm

Moments In the above figure the it can be seen that the moment is applied on the main gear. The Moment is applied in the direction based on the direction the escape wheel is desired to rotate. Similarly, as of the main gear the moment is applied on every face of the gear.

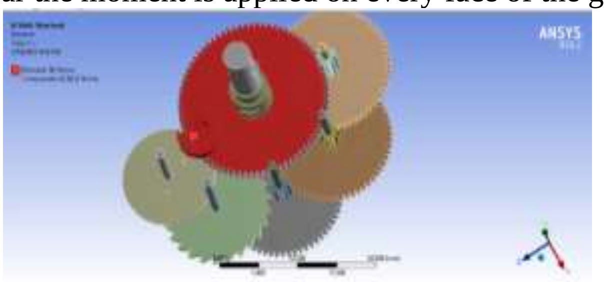
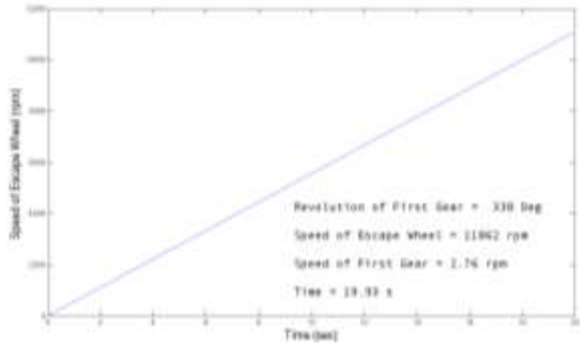


Figure 6: Main Gear Model

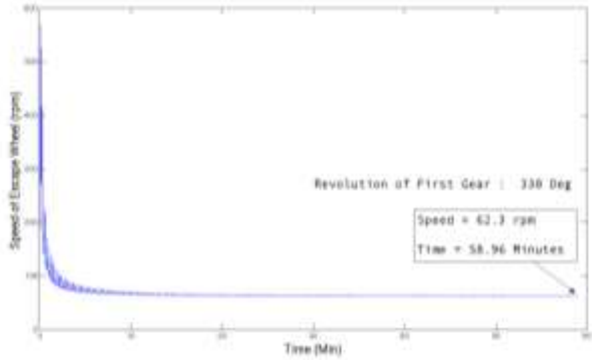
I. CAD ANALYSIS OF TIMES (SIMULATION RESULTS)

Case 1: Mechanical chronometer without Pin Pallet Escapement

According to Graph1, the Mechanical chronometer requires 19.93 seconds to complete a full 330 degree rotation of the first gear without a pin pallet escapement. The escape wheel spins at a rate of around 11000 rpm.



Graph I**:** Escape Wheel Speed without Pin Pallet Engagement vs Time



Graph II: Escape Wheel Speed with Pin Pallet Engagement vs Time

II. EXPERIMENTATION :

The main challenge in time delay for mechanical chronometer is to select the most appropriate parameters. Conventional experimental design addresses the requirement for a massive amount of experimental data, which has been shown to be costly and time consuming. To solve the problems, specialists employed DOE methods of working as well as the Taguchi approach, response surface, and factorial design's input and output parameters. Taguchi's methodology and the response surface method are now often used in place of the detonator method of experimentation. (23)

Experimental Plan

- Selection of different design factor of Mechanical chronometer.
- Formulation of a mathematical model and Analysis of Time delay of a different cases by Using Response Surface Method, Taguchi L_{27} Array Design for the Experimentation Development of.
- We have taken 9 Different design factors for 27 runs/ readings, Effect of this factors on time delay
- Array Design by MINITAB 16 Software for analysis purpose of various

Parameters. For all reading data sheet was created

- By using MINITAB 16 we create a model and optimize it.

Description and list of various input and output parameters

According to the literature review, there is no unique process or procedure for Mechanical chronometer time delay. A variety of parameters influence the performance of a mechanical chronometer. This covers the number of angles, pallet weight, gear ratio, pallet diameter, pin diameter, distance between the pallet and the escapement wheel, escapement wheel radius, tooth angle for the escapement wheel, the pallet weight, the pin radius, the pin distance, and so on. It is crucial to create an accurate and dependable mathematical model for forecasting and improving the critical parameters that determine mechanical time delay. This will aid in determining the most precise time delay as well as the best value for the input parameters.

- Case 1 Pallet weight, Angle, Gear ratio
- Case 2 Pin radius, Pallet radius, Escapement wheel Radius.
- Case 3 Distance between pallet and escapement wheel, Pallet to pin distance, tooth angle for escapement wheel.
- Case 4 Pin radius Pallet weight, Pin Distance this are important parameters

A delay in time is an output parameter.

IV. Result and Discussion:

A. Basics of Response Surface Modelling

Since all of the variables in the current research are identifiable, I opted to employ the method of response surfaces, a form of statistical analysis for analyzing a variety of variables that are independently impacting the response. In Response Surface Modelling, the answer Y is expressed by a second order polynomial equation, which is given as

y= o + iXi+jXj +ijXiXj +iiXi2 + jjXjj2 +..---------------Equation A.

In this work, A central composite face cantered pattern is employed in this work to estimate the regression coefficients, which fits the second order response. The experimental data was then fed into a commercially available analytical tool to analyze, optimize, and develop a predictive mathematical model to estimate the Time delay. As a result, an exponential function has been generated to impact variables on Responses. All of the coefficients are determined with the Design Master mathematical tool and a central composite face-centered design. The final model is generated using simply these coefficients after choosing the significant variables (at the ninety-five percent confidence level), and the final mathematical model to estimate time is given by the equations below.

For the Case 1 Time response is as given in equation:

$T = 1932.6 + 0.12A – 0.63B – 2828.25C – 0.01A^2 + 211C2+ 8.47A$ …Equation 1

For the Case 2 Time response is as given in equation

$T = -69.68 + 21.69A + 20.67B + 11.25C – 1.283A^2 + 66.6667B^2 -0.7167C^2 - 3.1667AB$ …..Equation 2

For the Case 3 Time response is as given in equation

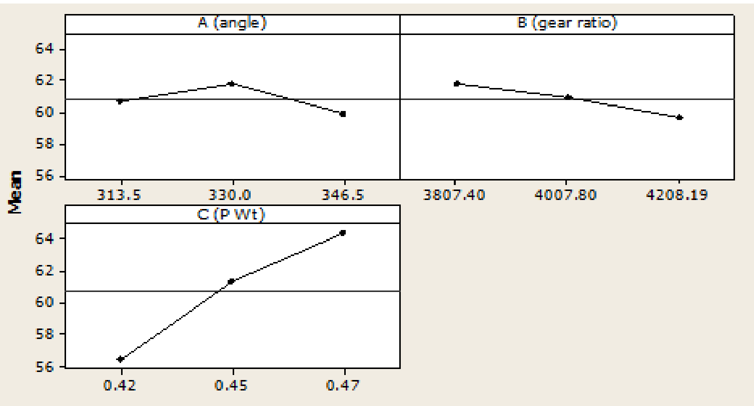
$T = 1637.62 + 8.44A + 4.13B – 48.88C – 0.02A^2 – 0.08B + 0.37C^2 - 0.43AB$.......Equation 3

For the Case 4 Time response is as given in equation

$T= 264.45-632.12A+597.8B-72.23C+600 A^2-235 B^2+3.25C^2-1086.7AB+101.33 AC$…………Equation 4

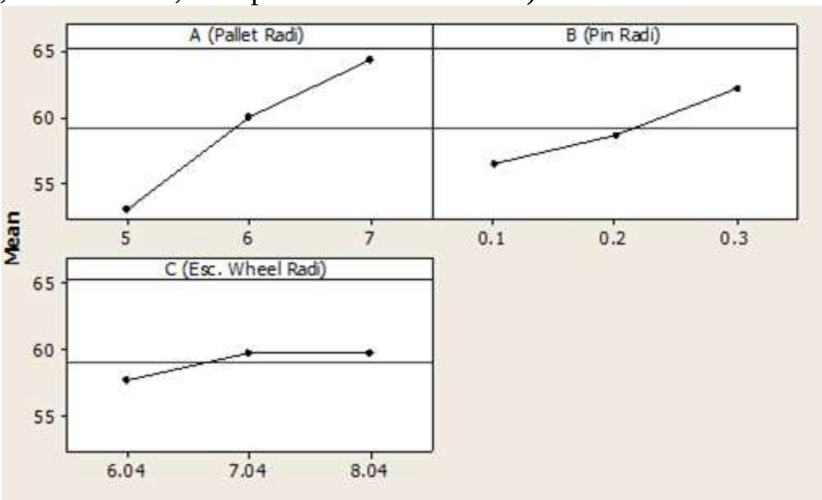
Description case wise

- Case 1 (Pallet weight, Angle, Gear ratio):



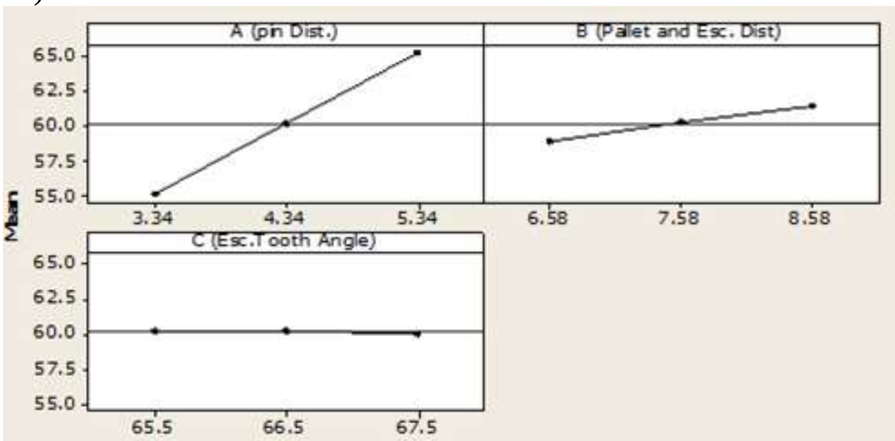
Graph III: Main impact graph for Case- I

Case 2 (Pin radius, Pallet radius, Escapement wheel Radius):



Graph IV: Main impact graph for Case- II

Case 3: (Distance between pallet and escapement wheel, Pallet to pin distance, tooth angle for escapement wheel).



Graph V**:** Main impact graph for Case- III

By observing main effects plots for all above nine variables, we come to conclusion that the main effective parameters for the Time are as follows

1. Pallet Wt.
2. Pallet Radius
1. Pin Distance.

Due to the direct relationship between pallet weight and pallet radius, so let's think about it as a one parameter. Hence now in second case the major parameter affecting design is pin radius.

Now main design parameters are

1. Pallet Wt.
2. Pin Radius
3. Pin Distance.

Now obtaining optimizes solution for these three design parameters, we will again do RSM with these parameters in Case IV.

Case 4 (Pallet weight, Pin radius, Pin distance)

General Linear Model: time versus Pallet wt, Pin radius, Pin distance

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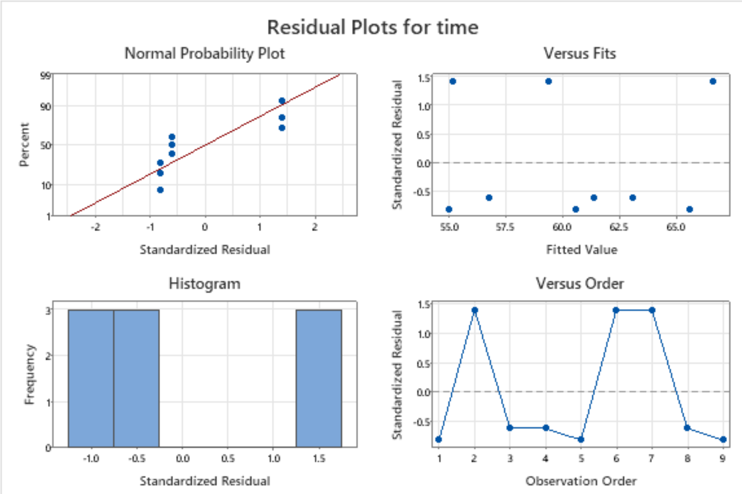
Regression Equation

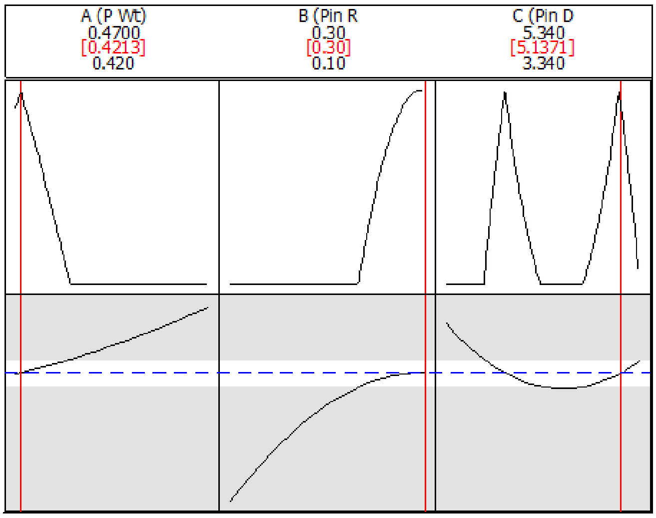
Time = 54.99+ 0.0 Pallet wt_0.42+ 3.40 Pallet wt_0.45+ 6.27 Pallet wt_0.47+ 0.0 Pin radius_0.1 + 1.84 Pin radius_0.2+ 1.00 Pin radius_0.3+ 0.0 Pin distance_3.34- 1.64 Pin distance_4.34 + 5.40 Pin distance_5.34



Optimization of model 4
Optimizing Response Variable.

Aim	Bottom	Aim	Higher	Mass	Import
T (time period)	59	60	61	1	1

<u>Global Solution.</u>
A (Pallet Size) = 0.421330 B (Pin Diameter) = 0.6 C (Pin Distance) = 5.13713
Predicted Responses
T (time period) = 60, utility transfer function = 1.000000, Composite utility transfer function = 1.0000
Optimization Plot
Utility transfer function = 1.000000 T (time period)
Aim- 60.0 y= 60.0 d = 1.0000



Graph VI: Optimization plot for case IV

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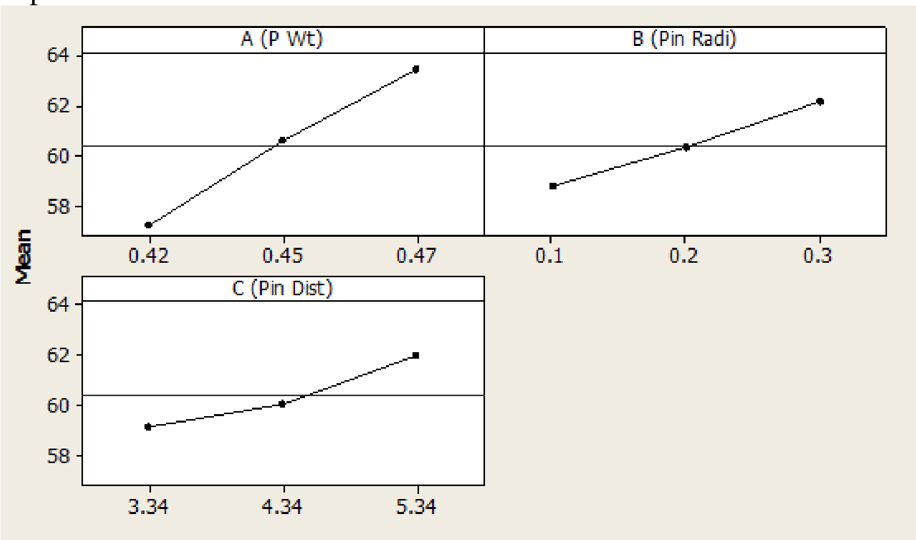
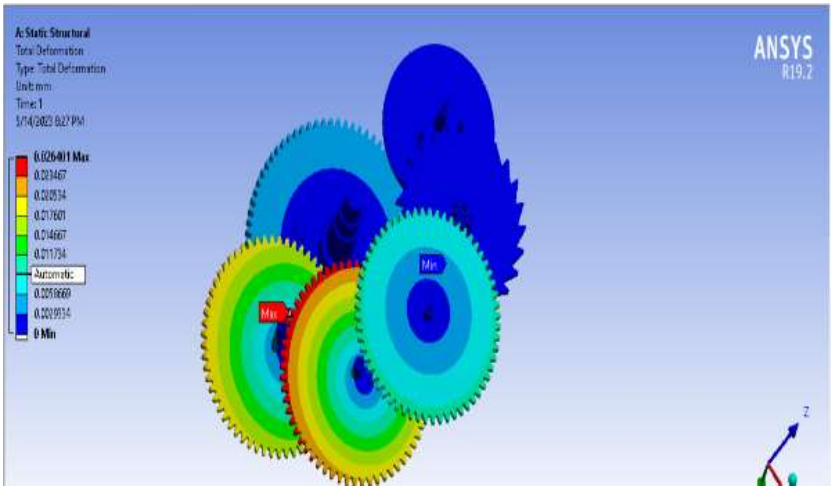
Main Impact Graph:



Graph VII- Main impact graph for Case IV

III. CONCLUSION

Total Deformation



Based on the analysis results it can be seen that the design is safe and there is no failure. Analysis has pointed some critical region which is at the After the successful selection of the mechanism and designing of the gear train we have performed a Static Structural Analysis on the gear train of the Mechanical chronometers .So, in this way we have successfully designed and developed the gear train used in Mechanical chronometers. Main Application of this object is in safety and arming device. In defence region there are some particular area or some particular ammunition where certain amount time delay is required. Those ammunition shouldn't function quickly after activation, because that can be harmful for person who is activating particular area. Creation of a mechanical chronometer for generating the necessary time amount of delay and after analyses using the response surface technique have been examined. RSM is a tool that may be used to approximate experimental and numerical answers. The creation of an experiment plan and the formulation of an approximation function are both required processes. Using a variety of parameters, including Dimensional parameters include angle, gear ratio, pallet weight, pallet radius, pin radius, escarpment wheel radius, pallet to pin distance, and pallet to escapement wheel distance, and escapement wheel tooth angle, we were able to derive

the overall value of time (60 min) from the experiment. The primary impacts charts for all nine factors versus Time reveal the one that has the biggest impact (T).
The following are the primary influencing parameters:
Pallet weight, Pallet radius, and Pin Pin Dist. Additionally, by employing simulation with a pin pallet configuration, the escape wheel's speed decreases and stabilizes, as seen in Graph II. The rpm in steady condition is around 62. The first gear's 330 degree revolution in the Mechanical chronometer takes 60 minutes.

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