1.0 SUMMARY

There is no doubt that mechanical mechanisms have and still playing a vital role in the industrial advancement they are being used even before the industrial revolution started. Humans have used different types of mechanisms to obtain a certain controlled motion that helped in various aspects such as agriculture and lifting; now mechanisms are used in factories as machines. Engine for example uses different mechanisms such as piston-crank, Cams, Gears and belts to obtain the final output power that drives our cars or electric generators.

we have given a task to design, simulate and build a working automaton. This automaton should have three mechanisms to fulfil the desire task. So, we decided to make a toy we name it “dodo” this device has three different motions as per the given criteria, the internal function of this automata consisted of three different mechanisms cam, crank and friction wheel and all of them are attached with the single shaft which can drive by a hand. But the outlook of the automata was not really anticipated or looked-for which we really want to represent/make. So, we change it. Due to the changes we made in outlook we have to replace two mechanism completely and change the last one.

2.0 INTRODUCTTION

The outlook of Dodo was meant to be a wooden dog who is trying to eat a bone when he tries to eat the bone it goes away” back and forth” its head move up down and its tail move right left. But our group members didn’t like the idea and we replace it with the similar idea which affects the mechanisms and due to which we must change mechanisms.

After considering various ideas of the automata, and also bearing in mind of the manufacturing cost and easiness “the Hungry cat” automata was finally selected by the team, the idea is using three different mechanisms to obtain the continuous motion of a cat trying to catch a mouse as its food, the mouse would be rotating around a point and the cat is using its hand trying to catch it, also the cat`s tail is moving making it look more relaxing.

we have explained all the details in this report.

The complete report has base on three different steps, proposal, design and complete report with device. In this second report a discussion of a fully designed Automaton is introduced, starting from concept design and going through different designing steps such as part design, material selection, modelling, assembling, stress analysis, motion study and simulations till the final prototype is ready for manufacturing.

3.0 ADDITIONAL DISCUSSION ON MANUFACTURING, TESTING, AND ANY ALTERATIONS THAT WERE MADE.

- **Manufacturing**

  After finishing the second part of the project we put our focus on the manufacturing and we tried to make the automata with cardboard for prototyping and that was an unsuccessful try. after another heated debated among us, on the materials used we decided to make it with basil wood and end up making some of the components but due to lack of experience that attempt was another failure we unable to made the gears work together without being stuck after that we finally realized that we need an expert help and some proper tools to complete this project.

  finally, we when to the Joondalup Men's Shed and with the help of some retired bloke's we gave another try to build our project. As per their advice we used MDF to make all the mechanisms.

  Please see appendix 5

- **Joining Method**

  Joining of wooden items can be done using variety of techniques. It is done depending upon type of wood used and results that are required. For this project as material used is all wood. Housing, mechanisms, and top parts that include Cat, and rotating disk are all made of MDF. Wooden glue and small nails of 10mm have been used to join all parts. To keep the follower aligned it required to pass it through another part.

- **Cost**

  It is an important factor to consider before starting any project. After deciding this project some research was made to estimate the finish cost of the project. As this is just for university project we tried to keep the cost low this automata is made of scrap wooden parts and some of them were bought from market it did not cost us much. Total cost for our project is $80 approx.

- **Tools and Equipment used**

  Please see the appendix 9

- **Testing**

  After making of each part we test them individually by putting them together to check if they are working properly or not.

  Please see appendix 6

- **Alteration**

  1. We used medium density fibre board (MDF) instead of basil wood, because the reason of choosing is that, its very light weight and can be cut by paper cutter but actually its strengths are its weakness as when we apply any tool on this wood its losses the shape and if apply any pressure it deforms for example if we nailed the basil wood it wouldn't withstand it.

please see appendix 7

2. The gears we trying to make was wooden carved and it's very hard to make them right, so we made both gears on a same size and also, we made their teeth with nails. Although it wasn't very easy to make but still doable.

3. The follower which holds the moments were lingering and making trouble in running, to avoid all sorts of these problems we put guider sleeve on each follower, so everything can work smoothly.

4. we make the follower with solid aluminium rod in order to work smoothly and also have less friction.

4.0 LITERATURE SURVEY

Mechanisms Survey during the lecture our lecturer give us a brief description about the mechanical movements and told us about the weblink "507 mechanical movement" for review we found it very helpful as this weblink has a detail information of mechanical movement like its name its working pattern and animated picture of each movement. So, we selected more than six types of movements from there, to achieve different movements and it also required less work to build and to do calculation.

Outlook Of Automata during lecture session lecturer showed us many designs and the previous work done by students which was really helpful, knowing the fact that there is a lot of competition going on our group made some points prior to start search after long discussion we agreed on four common points that the design should be simple and attractive, I shouldn't be complex by all means, it should fulfil the desired criteria and most importantly it should compatible with the selected movements.

5.0 CHANGES OCCUR FROM FIRST PART

Due to time constrain and mismanagement we won't be able to work on indecisive decisions. Therefore, our group has decided to change few things after submission of the first proposal report.

Outlook amendment

1.The running dog is replaced with the steady cat who is moving only one arm which provides linear motion" up and down"

2. The moving bone has been swapped with circling mouse which is providing rotary motion

Mechanisms amendment

1. To get the required outcome we change crank with snail drop Cam which delivered motion to the cat's arm.

2. For the spinning mouse we exchange friction wheel to the gear for more efficiency. As friction wheel will not offer proper motion if in placed improperly and we can avoid slipping element of friction wheel by using gear.

Material amendment

1. Considering factors like cost, efficiency and stiffness we replaced the chosen basil wood to beech wood as it has all the required characteristic.

6.0 DESIGN

- **First concept description "The Alpha Design"**
    i. The device should have 3 mechanisms.
    ii. The device should be presentable.
    iii. The device should be low in cost.

- **Conceptual Design/Sketch an Automata**

  After the idea of the hungry cat automata was selected different schematic drawings were introduced trying to fulfil the concept design, the team finally agreed on the schematic drawing show in Fig. and as a starting point the design of each part was then taken care of as shown in the diagram, a crank supported on the housing runs three different mechanisms the subsequently move the cat and mouse.

  Please see appendix 1 Figure 1 Schematic Drawing Automata

- **Final Parts Design**

  In this section different parts are designed be drawing suitable geometries and selecting suitable materials.

- **Outlook of Automata:**

  Housing

  The housing which is the main frame of the automata is designed as a cuboid that supports the crank shaft using journal bearings as well as holding all the other parts and mechanisms allowing the followers to rotate or reciprocate in the most suited place so that different mechanisms are synchronized. Beech wood was selected as the housing material.

  Using Solid works, a 2D sketch was drawn and the housing was modelled

  Please see appendix 1 Figure 2 Housing Drawing Figure 3 Housing modelled.

  Cat

  The cat body is simply modelled to have the shape of a cat trying to catch a mouse by drawing a 2D sketch and extruding it.

  The cat legs were also modelled and fitted into the cat body three of them being fixed legs while on of them is movable as it`s the leg trying to catch the mouse and failing, the snail drop cam mechanism controls its movement. As there are no loads on the cat`s body a cheap wood is preferred so pine wood was selected as the suitable material.

  Please see appendix 1 Figure 4 The Cat model

  Mouse

The mouse is rotating around a point that is on the axis of the rotating follower of the gear mechanism, the movement is obtained by fixing the mouse on a rotating disk that has its centre locked with the rotating follower of the mechanism.

Please see appendix 1 Figure 5 The mouse model

- **Mechanisms of Automata:**

Mechanisms are what give the soul to any automata; they are running continuously behind the scenes to create the final expected motion. In this section, generating the expected motion of the tail, hand and mouse is discussed and achieved by all the three mechanisms.

Main Shaft

The crank is the most important part of the whole automata as it is the part that runs all the different mechanisms it holds the cams and wheel in a specific pattern also having specific angle that ensures tuned motion of the automata. The crank was mainly modelled using extruded boss by drawing different sketches on different planes. As it`s a very important part oak wood was selected as a material for the crank.

Please see appendix 1 Figure 6 Main shaft

Snail Drop Cam

One of the important parts modelled is the snail drop cam as it required some research to obtain the design equation that helped eventually achieving the desired movement of the cat`s hand trying to catch the mouse. Considering the material and manufacturing cost beech wood was selected as the suitable material

Please see appendix 1 Figure 7 Snail Drop cam

The rotating mouse

For the rotary movement of the mouse around the centre of the disk the motion would be transferred as discussed before from the crank to the follower using gear between the two wheels. The gear wheels are designed with diameter ratio that provides the appropriate rotating speed of the mouse while at the same time synchronizing it with the movement of the cat`s hand. After the mechanism is modelled as shown in the figure the gear wheels were mated together with a tangent mate that achieved the expected motion.

Please see appendix 1 Figure 8 The rotating mechanism

The Cat`s Hand

One of the biggest challenges that faced the team is obtaining the cat`s hand movement in the correct order the follower movement is having a small stroke of 2.5 cm that was finally obtained using the snail drop cam mechanism, the cam has some relations between its diameters that had to be taken care of in order to create a smooth circumference for the follower to slide on ,the cam was then fixed on the main shaft and aligned with the follower and the cat`s hand movement was finally obtained.

Please see appendix 1 Figure 9 The Cat's Hand

The cat`s tail movement

The third motion in the hungry cat automata is the motion of the cat`s tail as it`s supposed to move up and down this motion could be obtained by various mechanisms but the team found it much better to add an ease in and ease out motion using the eccentric cam mechanism, where a disk cam is fixed on the main shaft with an eccentricity that controls the rate of the reciprocating follower thus the tail.

Please see appendix 1 Figure 10 The Cat's Tail movement

7.0 CALCULATIONS

- **Friction losses**

The main losses in the automata are the friction losses and to make a sustained motion there has to be an applied moment to overcome the corresponding friction moment, as the crank shaft would be rotating in the rubber journal bearing the kinetic coefficient of friction is the one to be used and for wood and rubber it was found to be (the engineering toolbox, 2004) equal to μ = 0.6

(K.Gopinath, 2018)

But α = $tan^{-1}(\mu) = tan^{-1}(0.6) = 30.96°$

As the summation of the forces in the y direction should be equal to zero $\sum F_Y = 0$

Then the reaction force (R) on the bearing can be taken equal to the shaft weight (W) which is 0.2kg

R – W = 0 >> R = W = 0.2 x 9.81 = 2 N

But the friction force is equal to the reaction force multiplied by Sinα

$$F_{fr} = R \times Sin(\alpha) = 2 \times \mathrm{Sin}(30.96) = 1.02\ N$$

BUT there are two bearings so the total friction equals 2 x 1.02 = 2.04 N

And taking a factor of 2 that represents other sources of friction gives the final friction force equals F_{fr} = 4.08 N

The friction moment due to the bearing is F_{fr} multiplied by the bearing inner radius r = 10 mm

$M_{fr} = F_{fr} \times r = 4.08 \times 0.01 =$ 0.042 Nm

For a moment arm of L = 10 cm as the lever

- **Power & efficiency**

The required human force can be calculated as $F_h = \frac{M_{fr}}{L} = \frac{0.05}{0.1} = 0.5$ N which is under t maximum human force limit as indicated in the modeling and assembling section.

The friction power can also be calculated for a rotating speed of N=30 RPM

As the power = Torque x ω ; $\omega = \frac{2\pi N}{60} = \frac{2\pi 30}{60}$ = 3.14 rad/s

Thus; P = 0.05 * 3.14 ≅ 0.2 watt

This power loss due to friction will be added to the required motor power thus decreasing the total efficiency of the system. The energy dissipated can also be calculated by multiplying the power with the running time of the machine.

8.0 DRAWINGS

Drawings of all parts are prepared on CAD using scale 1:5 and all dimensions are in mm.

We have attached all the drawings in the end of the report.

9.0 ANIMATION

Please check the YouTube link to watch animation.

https://youtu.be/RVh6C7y-wPs

10.0 MOTION GRAPHS OF THE DEVICE

Please see the graphs of motion attached in the appendix 4

Please see the mechanisms graphs in the appendix 8

11.0 MATERIALS

there are some important factors we considered while selecting the material for Dodo

Cost: The major factor of consideration for all of us is to get finished product with all the major functionalities and highest possible quality at the lowest possible cost

ii. Efficiency: To make the device efficient we chose not to used heavy materials because they consume lots of power, so we follow the industrial trend of full functional machines which consume low power and give high outputs

iii. Stiffness/ Rigidity: Was another factor, the machine should withstand of applied forces for which it is designed there shouldn't be any deformation of the automata or with its element beyond the specified limits because if there is any excessive deformation happen the chances of failure will be increased.

iv. Operational safety: from the safely prospect we decided to temper all the sharp edges to prevent cuts and cover the outside body with sticky paper

after a long discussion on the above factors our combine selection was wood. as we will be using offcut wood pieces of "beech wood "which is easily available at Bunning because it has all required characteristic i.e. strength, light weight and very low in cost.

Workability	Easy to machine and glue. Has a good workability.
Strength	Strong, durable with good scratch resistant.
Availability/Cost	Easily available, low Cost

- **Manufacturing Method**

Manufacturing of device depends on simplicity/complexity of device and materials used. Different factors need consideration for manufacturing process:

i. Cost: It is an important factor in manufacturing of machine for this project. Manufacturing of this automata must be cost effective. It is not required to be very expensive but still need to consider quality of device. As selected material can affect the manufacturing quality, efficiency and life time of device. After material selection and joining method bill of material is prepared to estimate the cost of device.

   Please see appendix 2 for Bill of Materials

ii. Integrity of device: Device reliability and life relies on the materials used and manufacturing process used to build the device. For this simulation are done to calculate stress analysis and total deformation to ensure selection of correct material with required properties.

   Please see appendix 3 for stress analysis

iii. Ease of production: It is based on the design of device and components used. If components are not available in market, it should be easy to manufacture the components. Materials selected to construct are easily available and manufacturing process involves simple tasks needed to cut/machine and construct using simple tools.

iv. Assembly: After every part has been designed and after checking the reliability of the designed mechanisms the next step is assembling the different parts and mechanisms, adding the mates that satisfies the required movements and then start the motion study.

- **Assembly Steps:**

The housing was fixed by making its plans coincident to the assembly plans, then the main shaft was fitted into the housing by a concentric mate and for the shaft to rotate freely two rubber bearings was also mated concentric with the shaft in order to minimize friction and wear. The lever was then attached to the shaft to enable manual running of the automata. The cat`s body was then placed on top of the housing and the legs were attached to it. The movable leg was then mated with the snail drop cam mechanism to generate its movement. The tail was placed in the back being mated to the eccentric cam mechanism. The mouse being fixed on the disk was also fitted and locked into the friction wheel mechanism. The assembly was finally ready for the first motion study, many trials were made till finally every this was synchronized and running perfectly.

Considering above given factors material selected which is wood, manufacturing will we done using simple tools like hand saw, cutter, drill to make the components. Joining of the components will require adhesive glue, nailing and screwing.

Drilling parts: Holes will be drilled according to the dimensions given in drawing drawings. It will be made sure that there are no deviations which could affect working of automata.

Cutting parts: A scroll saw will be used to cut which is best for cutting out the parts. To ensure that all parts fit well together, it will be cut carefully as per the dimensions.

Gluing/screwing wooden parts: After cutting the parts and making sure all the parts are cut perfectly with correct dimensions, they will be joined wooden glue and screws.

Hinge pins will be used for Cats leg and tail as they are moving parts.

Rubber bearings will be used at each end of shaft and housing connection.

Please see appendix 1 Figure 10 The Automata Assembly

12.0 SAFETY FACTORS

Safety is the most important factor to consider while working in any industry. It is very important to assure our safety and people working around us. This project requires to work with many different tools. While working on the construction of this automata it will be made sure to use appropriate PPe and to be familiarised with tools before using them to avoid any potential hazard.

13.0 WEEKLY PROGRESS TOWARDS THE PROJECT

Week3:

Research was done on different automata designs, constructing an automata. Each group member researched on different mechanisms, learnt how mechanisms work. Different ideas were searched to have an understanding about constructing a device using different mechanisms, and how to achieve desired motions using these mechanisms.

Week 4:

After some research about the project, we had a group meeting and all our ideas were discussed. Three mechanisms were selected, and design was discussed among members to get the preferred output motion of device. Manufacturing method and material was discussed as well considering some important factors like size of automata, cost, and ease of construction. All group member agreed on design. Each member started working on proposal report that included initial design, drawings, mechanism used, motions, and intended manufacturing method.

Week 5:

Report about conceptual design was done and submitted to the lecturer. We had a group meeting to discuss about part b of report which consists of final drawings, simulations, and animation.

Week 6:

We received the feedback about our project concept and its desired motion. The score we received for our conceptual design was disappointing so after having some discussion and it was decided to make some changes in our design. All members shared ideas about what changes we could make to our design to improve it.

Week 7:

Work was started on new chosen design. We had a discussion about final selection of material selection and manufacturing method to keep it low cost and easy to build. Work was stared on detailed design and final drawings.

Week 8: We keep continued full details of calculations and simulations of the motion of the device to complete the requirement about this part B.

Week 9:

We submitted our Part B as per required details.

14.0 CONCLUSION

As technology is advancing and we see so many inventions that make our life easier. We see a lot of mechanical devices around us, but many people don't know how they work. As this project involves design, simulation and construction of wooden automata that is made up of three mechanisms which helped us to have a better understanding of working of the mechanical devices and how different mechanisms can be used us meet required results. It gave us insight of different mechanisms and their applications. Before constructing, prototype was made after some failed attempts which gave us experience about problems that can occur working with machines and building any mechanical device. Construction of the project was done later using planned design and materials. It was learnt that not using correct material can effect working of automata and can decrease life of any device and in some situations device would not work just due to wrong material chosen for a certain application for example our first design included friction wheel and material selected was basal wood and it was learnt that it is a wrong material for using in this application as it is very light weight. Some market research was made to estimate cost of automata using different manufacturing method and after that selected method was chosen to keep it low cost. It involved working on different equipment's like band saw, bench drill etc. which provided us opportunity to get hands on experience. Project management was another part of learning of this project, as everything was divided in to small tasks and there were many obstacles that came along the way while working on it which delayed some tasks. When we work in a group each group member could have different skills that's what we applied in our group and divided the tasks so to keep all the work in a good flow and problems were discussed among group members in weekly meeting to analyse and find solution. We were not able to work on exact planned design because of not having the right equipment to work with for example it was bit difficult to make gears exactly on the drawings but after some failed attempts and we still managed to successfully make a working wooden automata.

15.0 REFERENCES

https://www.youtube.com/watch?v=vtG1mfI9nYs

https://www.explainthatstuff.com/cranks-and-cams.html

https://support.troybilt.com/s/article/337-1?language=en_US

https://www.brighthubengineering.com

Figure 1 taken from: http://wiki.dtonline.org/index.php/Displacement_Diagram

Figure 2 taken from: http://wiki.dtonline.org/index.php/Displacement_Diagram

Figure 3 taken from: https://physics.tutorvista.com/motion/uniform-motion.html

16.0 APPENDIX

Appendix 1

Figure 1 Schematic Drawing Automata

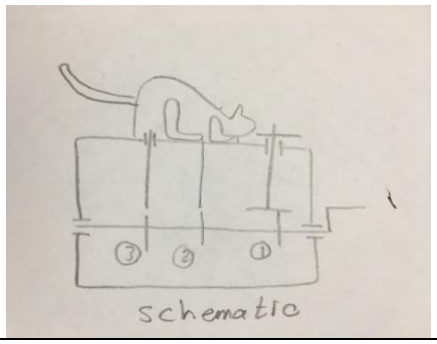


Figure 2 Housing Drawing

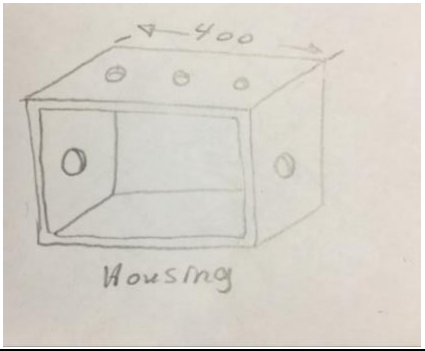


Figure 3 Housing modeled

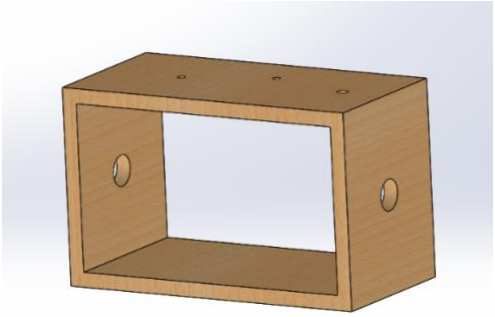


Figure 4 The Cat model

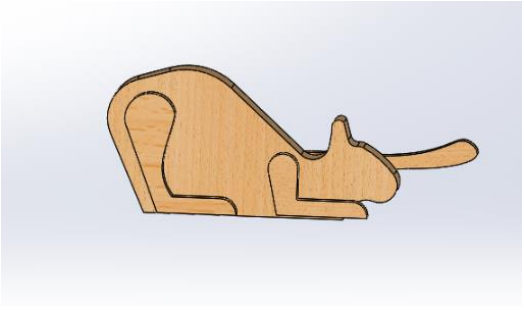
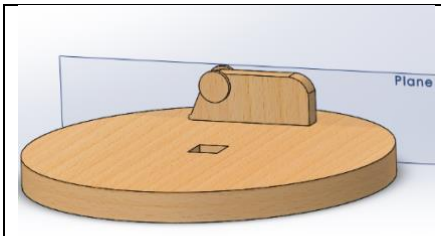


Figure 5 The Mouse

Figure 6 Main Shaft



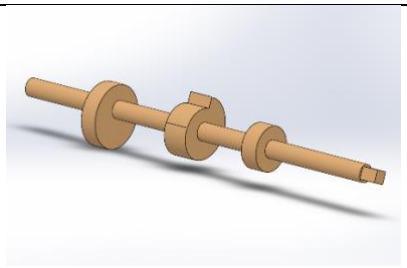


Figure 7 Snail Drop cam

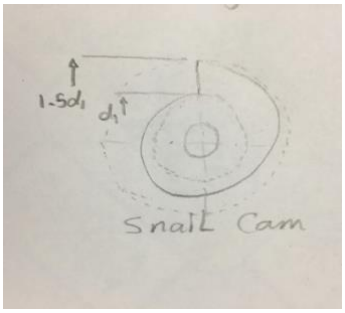


Figure 8 the rotating mouse mechanism

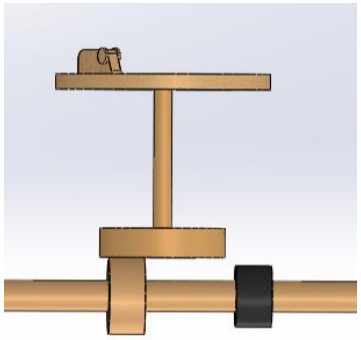


Figure 9 The Cat`s Hand motion mechanism

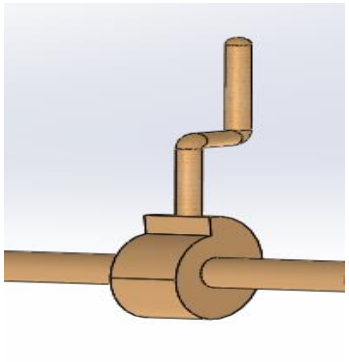


Figure 10 the Cat`s Tail movement

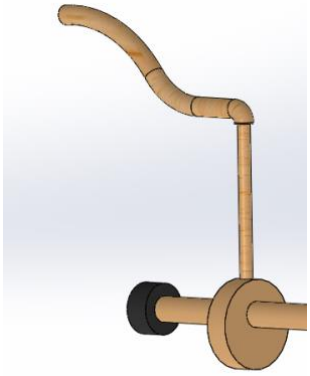
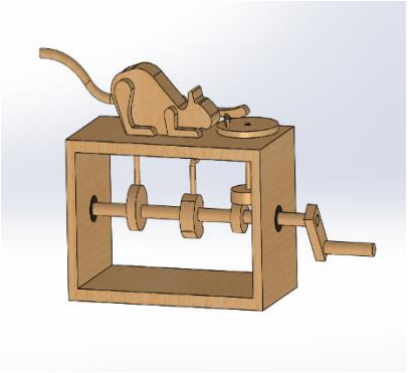


Figure 11 The Automata Assembly

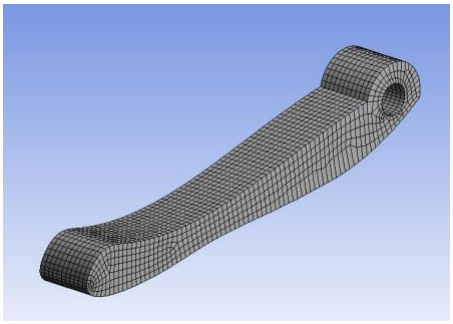
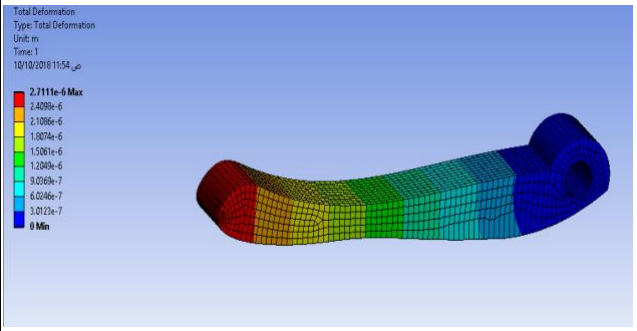
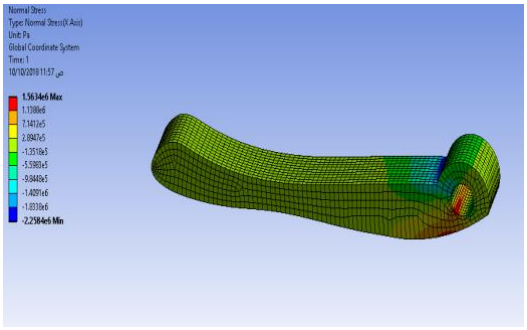


Appendix 2:

Serial number #	Name	Quantity	Dimension
1	Beech wood Plywood 	1	Offcut pieces of thickness 4mm
2	Wooden Dowell 	1	150mm ×⌀4mm
3	Rubber bearings 	2	8mm
4	Chip board Screws 	10	Ø1, 4mm
5	Hinge pins 	2	
6	Adhesive glue 	1	Wood Glue

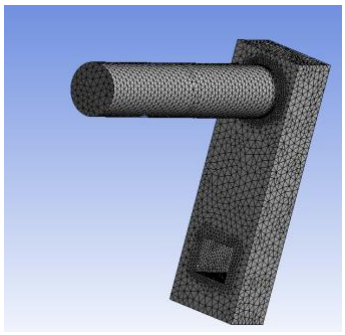
Appendix 3:

- **The movable leg**

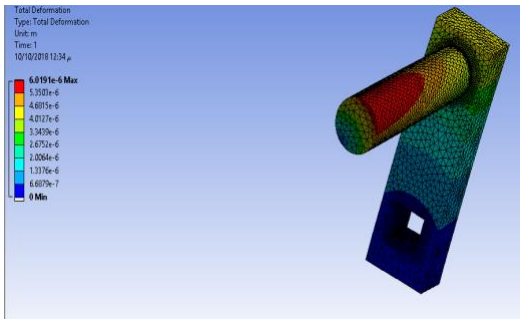
a. Meshing 	b. Results i. Total deformation 
	i. Normal Stress 

- **The Lever**

a. Meshing	b. Results

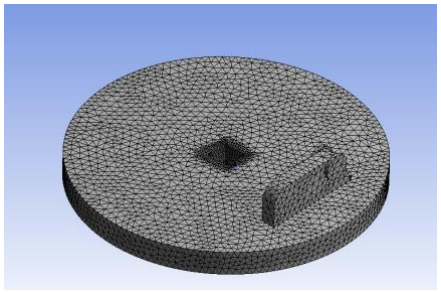


i. Total deformation



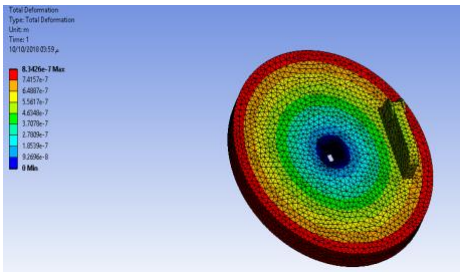
- **<u>The mouse and disk</u>**

a. <u>Meshing</u>



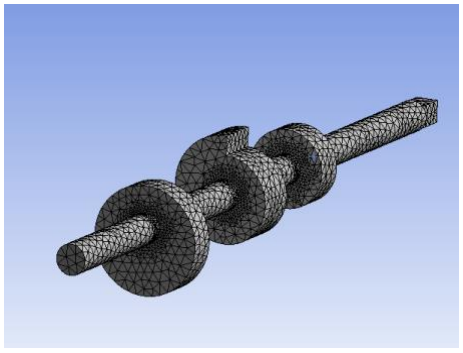
b. <u>Results</u>

i. Total deformation



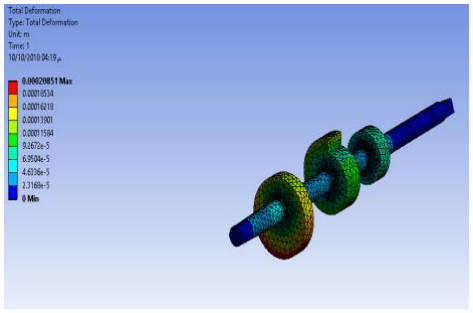
- **<u>Main shaft</u>**

a. <u>Meshing</u>



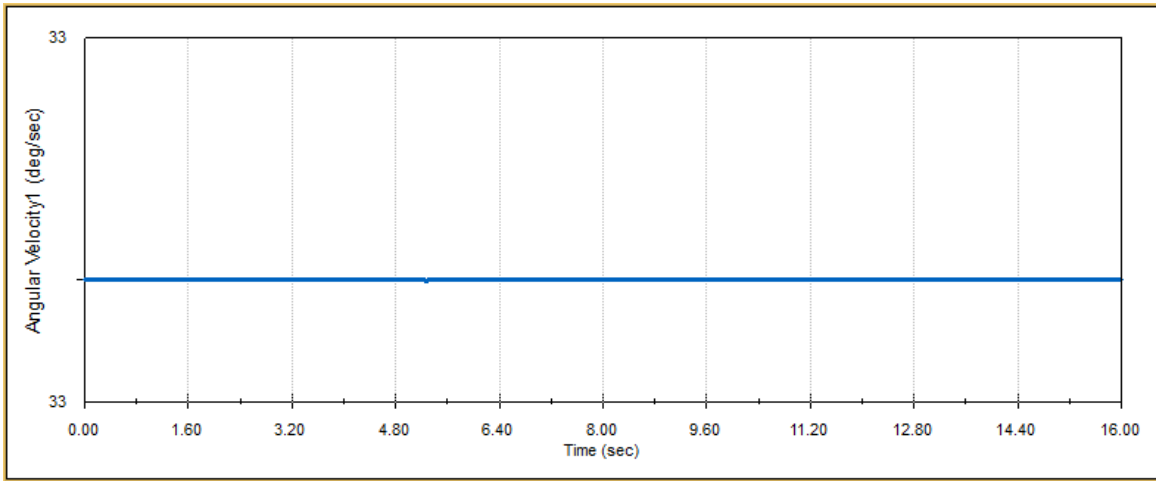
b. <u>Results</u>

i. Total deformation

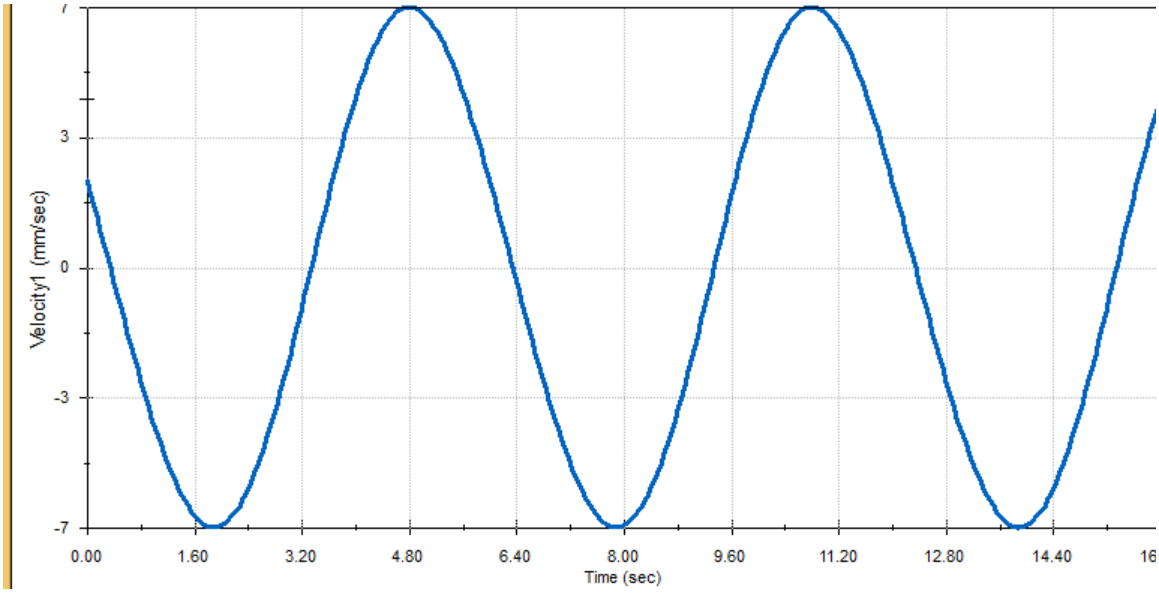


Appendix 4

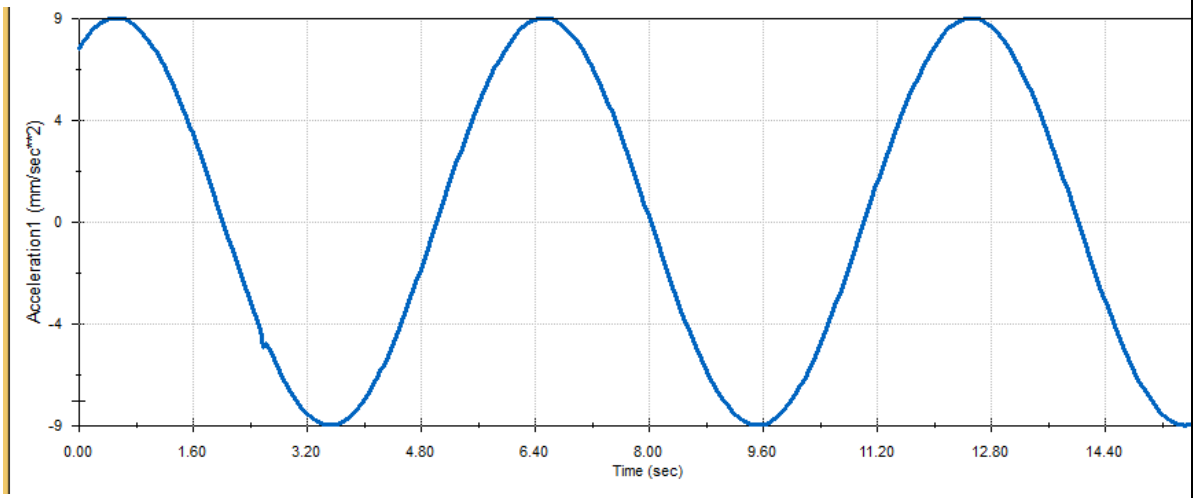
Angular velocity of mouse



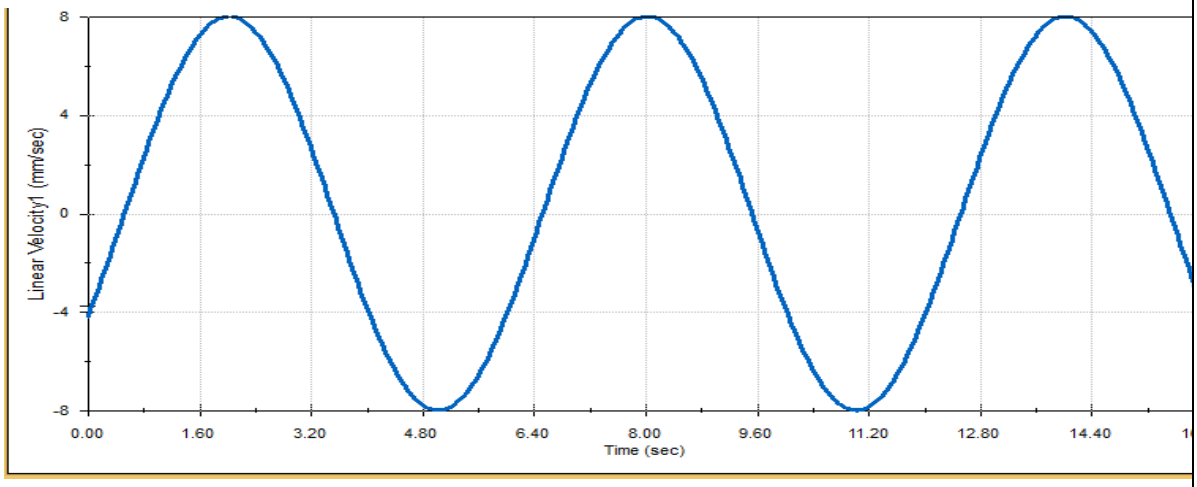
Moveable leg



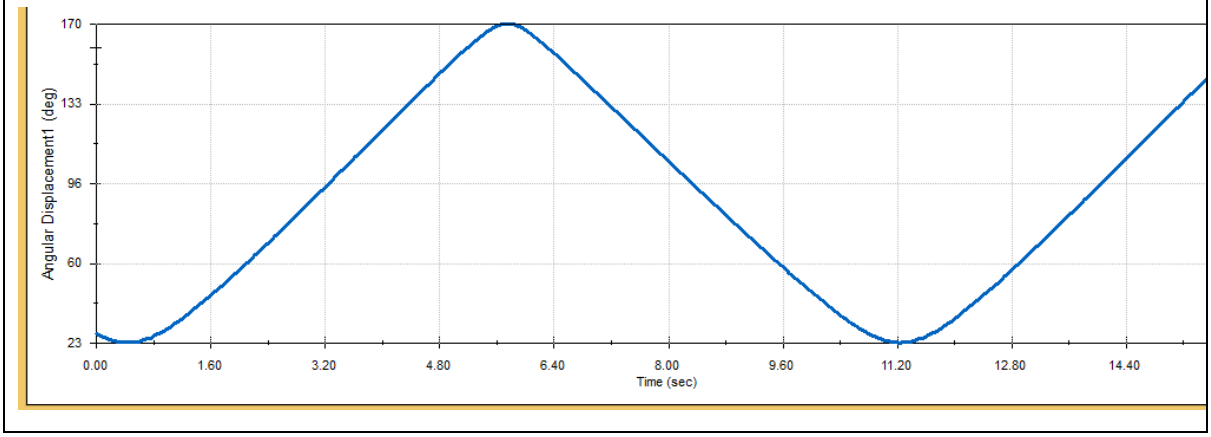
Tail Acceleration



Tail velocity

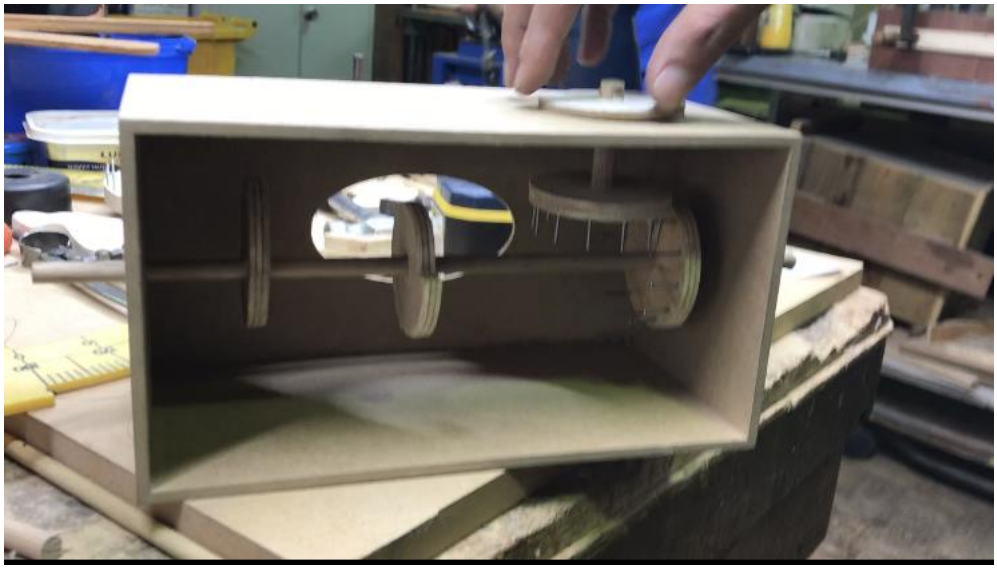


Mouse Angular Displacement



Appendix 5

Appendix 6



Appendix 7

Appendix 8

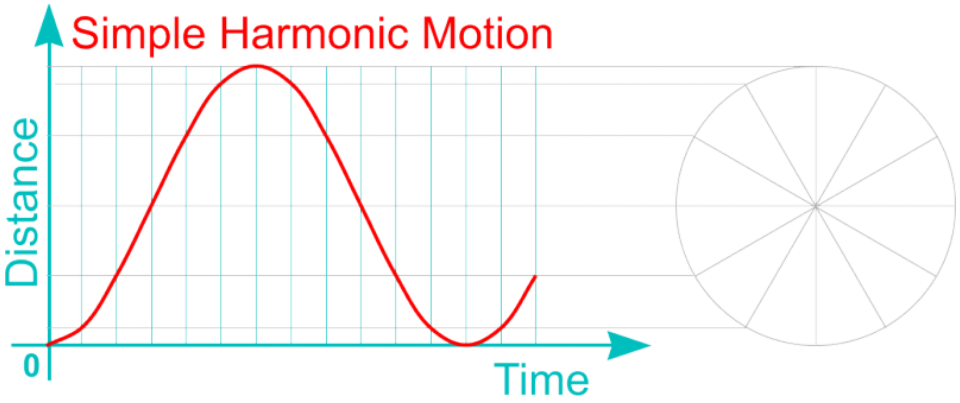


Figure 1

Above is the motion graph for Eccentric cam. To move the tail of the cat on Automata we wanted simple harmonic motion which we achieved my using Eccentric cam.

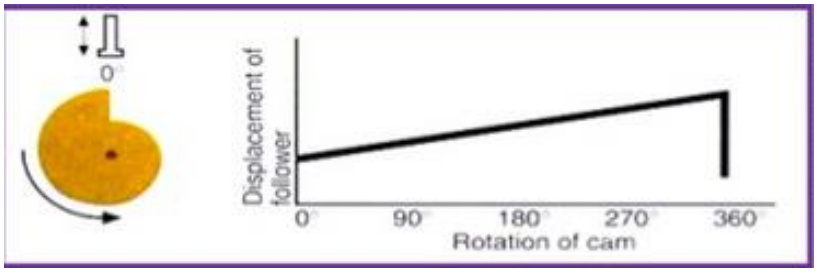


Figure 2

For the hand of cat slow ride and sudden drop was required as it catches the food. It was achieved using snail drop cam. Graph above shows motion of drop cam for 360 degree rotation.

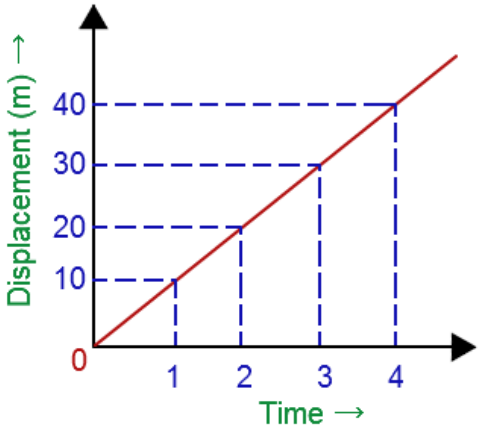


Figure 3

Small mouse has been mounted on rotating disk in front of mouse which is moving with uniform circular motion that is achieved using bevel gears.

Appendix 9

Hand drill	For making holes in gears, cams and housing hand drill has been used which is the easiest method to drill holes precisely.
Bench drill	For some parts it was not easy to drill using hand drill so bench drill was used to get work done.
Drum sander	Band saw was used to shape the parts and get the smooth surface where it was required.
Band saw	Band saw has been used to cut most of the wooden parts in to smaller required sizes.
Protector	To make the gear work which is made up of circular wood and nails which needed to be on correct angles in order to work perfectly.
Hole saw	To get the right size for cam and gears we used whole saw which made it easier to cut wood for mechanisms.
Hammer	To put nails for gears and in joining process nail were hammered.
Centre square	It's a very useful tool to get the centre of circular parts. It was used to get centre of parts while making gears and cams.