DESIGN AND ANALYSIS OF AUTOMATIC LIQUID FILLING MACHINE

A Final Year Project Report

Presented to

SCHOOL OF MECHANICAL & MANUFACTURING ENGINEERING

Department of Mechanical Engineering

NUST

ISLAMABAD, PAKISTAN

In Partial Fulfillment
of the Requirements for the Degree of
Bachelors of Mechanical Engineering

by

Muhammad Munim Moazzam Dar

Muhammad Uzair Shakeel

Muhammad Hashim Bhatti

Fatima Khalid

June 2021

EXAMINATION COMMITTEE

We hereby recommend that the final year project report prepared under our supervision by:

Muhammad Munim Moazzam Dar	00000211803
Muhammad Uzair Shakeel	00000211073
Muhammad Hashim Bhatti	00000237679
Fatima Khalid	00000235420

Titled: "**DESIGN AND ANALYSIS OF AUTOMATIC LIQUID FILLING MACHINE**" be accepted in partial fulfillment of the requirements for the award of **BE MECHANICAL ENGINEERING** degree with grade ___

Supervisor: Dr. Sadaqat Ali, Asst. Professor School of Mechanical and Manufacturing Engineering (SMME)	____________________ Dated:
Committee Member: Dr. Muhammad Safdar, Asst. Professor School of Mechanical and Manufacturing Engineering (SMME)	____________________ Dated:
Committee Member: Dr. Mian Ashfaq Ali, Asst. Professor School of Mechanical and Manufacturing Engineering (SMME)	____________________ Dated:

______________________ ____________

(Head of Department) (Date)

COUNTERSIGNED

Dated: ________________ __________________________

(Dean / Principal)

ABSTRACT

Filling is a process in which liquids, such as water or beverages are filled in different bottles. Filling plants are extensively being used in beverages and pharmaceutical industries. Present times require a cheap and more accurate alternate to increase the productive capacity which can be achieved by implementing necessary modifications. The purpose of this project is to convert a human based filling machine into automatic filling machine by deploying Geneva mechanism supported by cam mechanism. This method uses a tray mechanism to fill multiple bottles at a time. A stepper motor is used to run that conveyer belt. As our system uses less sensors, hence its relatively cheaper. Here, system for bottle filling is developed which consists of compressor, Geneva & cam mechanisms. Compressor is used to control pressure difference, the driving force to fill the liquid. Our machine is easy to use, as it is automatic and very simpler steps are needed for its operation. The machine is portable and require less space which makes it environment friendly as well. As this machine is quite simpler than the previously used machines, hence it can be easily manufactured by the coordination of industrial and engineering sector.

ACKNOWLEDGMENTS

We are foremost grateful to Almighty Allah, who blessed us with the energy and strength to accomplish all the tasks successfully.

The conclusion of this major project was not feasible without the motivation and guidance of Dr. Sadaqat Ali at every stage and time.

Consistent prayers, sentimental encouragements and being the moral supporters, we will remain indebted to our parents.

We have placed our whole hard work out to make sure that the system is comprehended and explained easily.

ORIGINALITY REPORT

Whereby declare that no part of the work or report is plagiarized and the workings as well as the findings produced are wholly original. The project has been done under the generous supervision of Dr. Sadaqat Ali and has not been a subsidized part of any other similar project leading to similar degree's requirement from any institute. Any reference used has been clearly mentioned and we take the utter responsibility if found otherwise.

Automatic Liquid Filling Machine

ORIGINALITY REPORT

7%	6%	2%	3%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	smenec.org Internet Source	2%
2	Submitted to Engineers Australia Student Paper	1%
3	www.ijitee.org Internet Source	1%
4	ijc.ilearning.co Internet Source	<1%
5	Submitted to Asia Pacific International College Student Paper	<1%
6	Banoth Mohan, V Ashok Kumar. "CFD analysis for counter flow in concentric tube heat exchangers", International Journal of Engineering & Technology, 2018 Publication	<1%
7	aquila.usm.edu Internet Source	<1%
8	Submitted to British University in Egypt Student Paper	<1%

9	Submitted to Higher Education Commission Pakistan Student Paper	<1 %
10	pt.scribd.com Internet Source	<1 %
11	Kunal Chakraborty, Indranil Roy, Palash De, Soubhik Das. "Controlling the Filling and Capping Operation of a Bottling Plant using PLC and SCADA", Indonesian Journal of Electrical Engineering and Informatics (IJEEI), 2015 Publication	<1 %
12	docplayer.net Internet Source	<1 %
13	scholar.uwindsor.ca Internet Source	<1 %
14	core.ac.uk Internet Source	<1 %
15	Prasad Birmole, Madhushri Kamble, Sayali Naik, Anjali Sadamate, Heenali. V. Korgaonkar. "Designing and Implementation of Chemical Mixing and Filling Bottles Using PLC", 2018 Second International Conference on Inventive Communication and Computational Technologies (ICICCT), 2018 Publication	<1 %

16	www.freepatentsonline.com Internet Source	<1%

Exclude quotes	Off	Exclude matches	Off
Exclude bibliography	Off		

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABBREVIATIONS

CFM	Cubic feet per meter
GPU	Graphic processing unit
CPU	Central processing unit
PLC	Programmable logic control

NOMENCLATURE

P	Pressure	Pa
γ	Specific weight	N/m^3
v	Velocity	m/s
z	Vertical distance	m
f	Friction factor	-
G	Gravitational acceleration	m/s^2
d	Diameter	m
Re	Reynold's number	-
ρ	Density	kg/m^3
A	Area	m^2
V	Volume	m^3
$\dot{V}$	Volume flow rate	m^3/s
μ	Dynamic viscosity	kg/m.s
ε	Surface roughness	mm
l	Length of pipe	m
t	Time	s
T	Time for cam movement	s
N	Revolutions per minute	RPM
ω	Angular speed	rad/s
K_L	Loss Coefficient	-

Subscripts

r	Rise
fd	Fall dwell
f	Fall
rd	Rise dwell

CHAPTER 1: INTRODUCTION

Technology has evolved a lot since last few decades. Apart from being technologically advanced, initial (capital) cost involved and maintenance cost are also a great factor. Although sensor and other electronic devices can be more reliable in sense of accuracy, but they are very sensitive to environment and accuracy along with its operational life is severely affected if it is used outside those ranges. In contrast mechanical devices can operate over a greater range of environmental conditions. If properly designed and then analyzed with proper calculations, the mechanical components can be used in place of sensor to achieve same accuracy. Cost is one of the very main factors that effects the growth of industry in any region/country. Thus, developing a low-cost machine.

Currently, most of the available machines in market are based on sensor and are very expensive to procure or they use a mechanism that is not very reliable in the sense of maintenance cost and operational life hence if any small or medium scale industry wants to install a liquid filling machine for small scale, they have very limited options available hence they must compromise on efficiency and production cost. Meanwhile, the machine that we have developed has a very broad operational range in terms of filling capacity. It can vary from few hundred liters per day to millions of liters per day, depending upon the parts used thereby reducing the cost of production and capital required to set plant up. Along with this another benefit that can be derived from our project is that the manpower and skills required to maintain our machine will be very limited as it contains mostly mechanical parts and very few electrical parts.

Problem Definition

Current automatic liquid filling machines available in market are very limited in terms of operational range. Along with this, cost of procuring the filling machine is sometimes so high that either it is outsourced, or partnership is needed. Apart from this, the rare earth metals are very scarce in market therefore it is better to divert reliance from them as many international firms are doing such as Mercedes which has developed a motor that does not uses rare earth metals. As electronic sensors and devices heavily depend upon rare earth metals and need more technological advancement to operate them. Development and reliance upon electronic devices is therefore very dangerous for environment and economy hence we need to find alternatives to use of these until they are made from other materials. One such example is seen recently that due to high demand and low supply of these rare earth metals the Graphic processing units (GPUs) and CPUs have become more expensive.

Objective:

These above-mentioned problems of high cost, low supply of rare earth metals and others can be tackled to a certain extent by our machine. We have not compromised on accuracy and tolerance range along with reducing the reliance upon electronic devices and making a machine that uses mostly mechanical components and do not need high performing computer to operate. Our machine will be cheaper to install and operate apart from being versatile in terms of operational range. We assumed certain conditions in our machine but it can be upsized or downsized according the requirements of a particular company, all of the formulas will be given along with steps for calculations in manual of machine which can be used to calculate and find components according to different requirements.

In vacuum based liquid filling machine we vary the rate flow rate and final volume of the liquid filled via pressure difference and no sensor or computer is required to control the flow rate. Only sensors used are for quality control that no bottle filled outside the allowed range of volume passes to the packaging site.

We had objective to select the best suitable material for each component, considering that we have a financial constraint as well along with other constraints. Material selection plays a very important role in design of machine as its performance and feasibility is dependent on this. Along with this we had to select suitable mechanisms for our project that will provide us with the optimal solution and is long lasting and fulfils all of the objectives or requirements that we have set for our project. Selecting mechanisms to be used and in what ratio and mutual link they are to be used is one of the biggest requirement/objectives of this project. Once selected properly the mechanisms will help achieve our end goal easily.

CHAPTER 2: LITERATURE REVIEW

Many more bottle filling machines are already installed in industries but with the advancement in technology, these machines need modifications as well. Most of the machines make use of PLCs which make them extra expensive. Some of them have limitations such as one bottle capacity at a time, large space utilization etc. Moreover, some of them don't use any external driven force for liquid to fill within the bottle, rather they rely on gravitational push which makes the whole process slow and inaccurate. Below are some of the projects we came across working on different methodologies and different principles.

Design and filling using Geneva Mechanism:

Darji, V. P., & Parmar [1] proposed an automatic bottle filling plant using Geneva mechanism for tray movement and microcontrollers for operational purposes. This plant has four major operations, filling, capping, loading and unloading. PLCs are used for these operations while a motor runs the Geneva mechanism. This project uses index rotary motion. In rotary bottle filling plant the entire task from the bottle loading to the bottle unloading will be carried out on rotary table at various stations. Rotary bottle filling plant have advantages as no mechanism required to control motion of table, cost is comparatively low, and less space required but have one limitation that only six slot carried only six bottles to fill at a time.

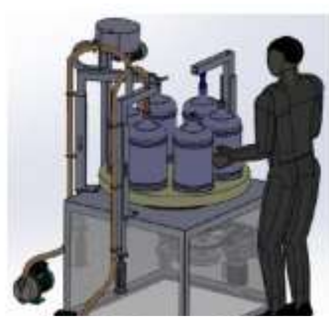

Figure 1: Rotary bottle filling point [1]

PLC based automatic liquid filling process:

Shaukat, N. [2] proposed PLC based automatic liquid filling process. Here, microcontrollers are used to fill same size of bottles using volumetric filling method as it is faster and more accurate than gravitational filling. In this project, AC motor is used to move the conveyer belt which is further fed into cam-shaft mechanism. This mechanism is further attached with the piston. One end of the piston is attached to moveable iron block, hence by rotating the block we can control the volume to be filled.

The principal followed is “If we control the upward and downward motion of the piston, we can control the liquid to be filled.” Degree of rotation of cam controls the liquid to be filled. Here, a turntable (disk-plate) is used to pick the bottle from conveyer belt, put it under the nozzle to get the liquid filled and after filling place it back on the conveyer belt. This model has some drawbacks. When this plant works at higher speed, resonance starts and it becomes difficult to control it. As it is a PLC based filling model, different sensors and microcontrollers are used to control the flow and make the filling much more accurate.

Figure 2: Gravitational filling of bottles [2]

Automatic Bottle Filling System:

Chawathe, A. et al [3] proposed a model based on bottle holder, chain conveyer, microcontrollers, relay, sensors, proximity sensor and solenoid valve. Here, user input is fed into microcontrollers which give signals to solenoid valve as well as servo meter. A proximity sensor usually emits electromagnetic radiations and can look for change in field or signal. A proximity sensor has a transmitter and a receiver. It controls the microcontrollers which further controls the solenoid valve. As the power is on, microcontrollers give signals to solenoid valves which gets open and tank release water into the pipes to the bottles. Servo motor accompanied with geared teeth sprockets are used to move the chain conveyer while solenoid valve allows the liquid to flow from reservoir tank towards the bottles on conveyer. Flowing of liquid is gravity driven which is slow and not accurate.

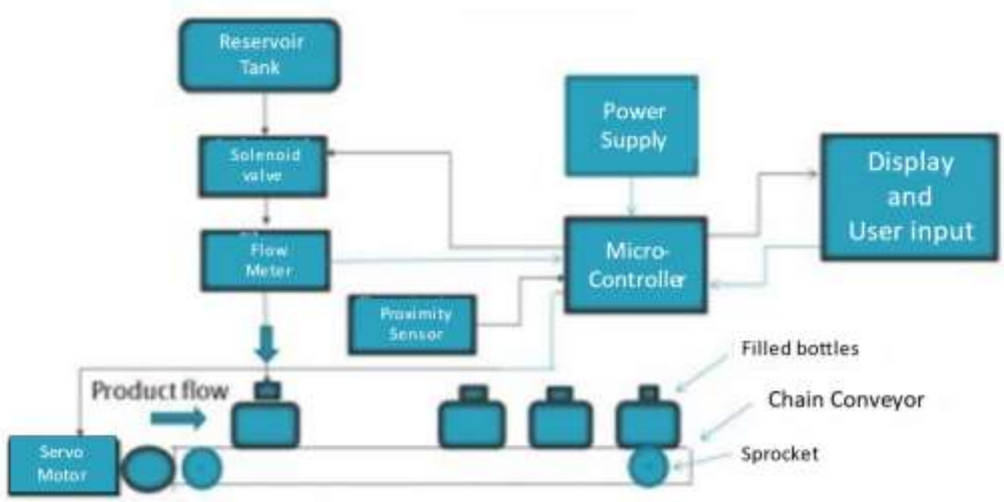

Figure 3: Flowchart of microcontroller bottle filling machine [3]

Development and Application of Geneva mechanism for bottle washing:

Ujay et al. [4] presented a model on development and application of Geneva mechanism for bottle washing. This study was developed for beverages plant where the bottle filling operation carried out manually. They developed a test rig for bottle washing by Geneva mechanism. as the speed of the Geneva mechanism increases, the cycle time, washing time and indexing time decreases. the washing efficiency of the test rig from 5rpm to 19 rpm increased from 81.57% to 96.89%. This study helps us in getting a better understanding of Geneva mechanism and how to use it regarding our project.

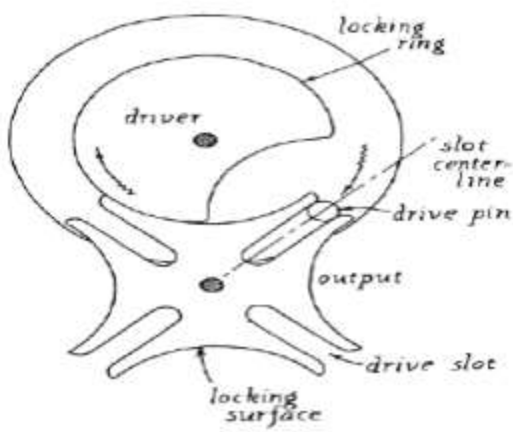

Figure 4: Geneva mechanism [4]

Design and Fabrication of Liquid Dispensing Machine Using Automatic Control for Engg. Industry:

Rajesh G. Khatod et al. [5] proposed this model of liquid dispensing machine with the aim to bring modifications in already available dispensing machine. They want the machine to dispense the liquid to the required amount and turn the system off immediately. This system will not require any person to take care of the plant. Basically, they are using the following mechanical components, i-e solenoid valve, gear motor, hydraulic pump and aquarium pump. This model helped us in understanding the liquid flow in our system.

CHAPTER 3: METHODOLOGY

Basic methodology followed in our project is basically the design and analysis of our machine. Starting from the 3-D model design and then moving onto the analysis part of our machine, we performed analysis on ANSYS. Along with this we also performed analysis on all of the mechanisms deployed in our project, i,e Cam mechanism and Geneva Mechanism.

Analysis of liquid flow:

Different parameters were assumed during our analysis. It was supposed that our machine would operate under room temperature and standard pressure and water is used as liquid hence all properties used for calculations were of water at standard conditions.

Conditions:

Temperature: 25 °C Pressure: 1 atm

Along with this it the diameter of pipe and time to fill one bottle was assumed and calculations were made accordingly. Using these values, flow rate of liquid and hence required pressure difference very calculated. Vacuum pump was then selected according to our calculated and assumed values and operating conditions given in manuals of certain vacuum pumps.

Material selection:

Several materials were considered for our machine but at last we finalized two materials, that proved to serve our purpose along with being cost effective.

Finally selected materials were stainless steel which will be used at points where direct contact with liquid is occurring or is expected to take place. Apart from stainless steel we have cast iron which will be used in places where no contact with liquid is expected. Both of these materials are best available options in terms of strength and cost.

We also considered other materials such as plastic, ceramics, bronze, brass etc. Many materials among these were potential materials and are also used in some industries for almost same purpose but different conditions. Therefore, we finally decided to use stainless steel and cast iron, given all the restraints that we had.

After thorough research we decided to use these above-mentioned materials which fulfil our requirements. The most common material used are stainless steel and cast iron.

Although stainless steel is expensive, the greatest advantage in our case was that it do not rust like other materials such as cast iron so we had to use stainless steel in places where there is direct contact with liquid or high humidity or vapors which can cause rusting in cast iron therefore the stainless steel is more favorite material in case of all these components. Another benefit of stainless steel is that it is more impact resistant therefore making it even suitable for certain parts. As we have to deal with fluid a lot in our project, we had to use stainless steel for several components and parts where the was no expected impact, we used cast iron or any other material.

Table 1: Material of different parts

Part	**Material**
Cam	Cast Iron
Cylinder	Stainless steel
Overflow bottle	Plastic
pipes	Plastic
Pipe fittings	Plastic
Nozzles	Stainless steel
shaft	Cast Iron
Table	Wood
Tray	Cast Iron
Reservoir	Plastic
Bevel Gear	Cast steel
Geneva	Mild Steel
Mover of geneva	Stainless steel
Base of geneva	Stainless steel

Cam:

For the cam mechanism we used cast iron as it is cheaper, and we didn’t have any possible contact with fluid or high vapor air here so we decided to use cast iron as this is more economical and fits our requirements therefore making it the perfect material for manufacturing of Cam.

Figure 5: Cam

Geneva mechanism:

For the Geneve mechanism we have used the cast iron as in this case as well, no direct contact with fluid or high moisture content air was expected and we wanted it to be more reliable along with being cheaper, therefore we have used cast iron to manufacture Geneva plate but we have also used stainless steel for mover as it is more reliable as compared to cast iron.

Figure 6: Geneva Mechanism

Nozzle:

Nozzle is a point where impact from the bottles and other materials is expected as it is the most exposed part of the machine and along with this, it has direct contact with fluid therefore making it prone to rusting and any rust or bacterial/viral presence isn't preferred at nozzle as our machine is also proposed for the pharmaceutical industry. Therefore considering all of the above reasons and possible issues that might come in forward, we have used stainless to manufacture nozzle as it is one of the most economical and reliable material in for this purpose.

Figure 7: Nozzles

Shaft:

Shaft is a part that gets most of the wear and is supposed to be one of the strongest component of the machine and no risk can be taken in this regard therefore we have selected stainless steel to manufacture it.

Figure 8: Shaft

Bevel gear:

Bevel gears are made from cast steel as it has high strength and are depict good behavior when continuously used and the teeth wear is one of the lowest along with being an economical material. Gears are supposed to be hard as they have to constantly slide against each other thus making them prone to the wear, for this purpose hardness to a certain extent is preferred. Therefore, it is the best possible material for bevel gears.

Figure 9: Bevel gear

Pipes and sanitary:

Pipes and sanitary items are the ones that are continuously in contact with fluid and therefore are most prone to the rusting. As we propose our project for pharmaceutical industry, pipes are supposed to be anti-bacterial in this field therefore we can use anti-bacterial pipes made from plastic as they are cheaper, more reliable and economical.

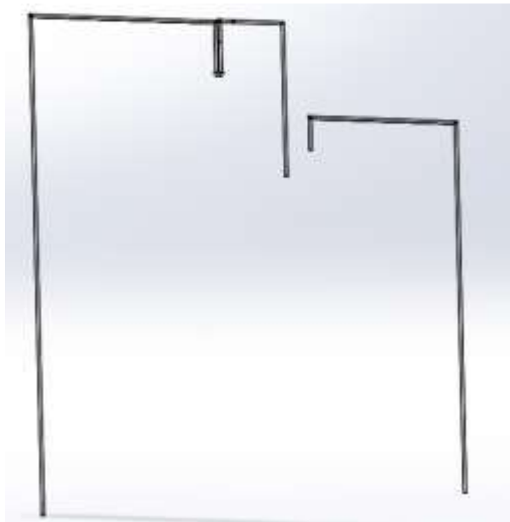

Figure 10: Pipe structure

Analysis for vacuum pump:

Vacuum pump is used to reduce the pressure inside bottle to be filled once seal is ensured at nozzle thus developing a flow of liquid from reservoir (which is at atmospheric pressure) towards the bottle. Several calculations were made in order to find the parameters required for our machine. Once we had all the required values, we consulted the data sheets of several vacuum pumps and chose the one that fits according to our assumptions. Vacuum pump will vary according to the flow rate requirements of machine in every case.

Assumed time to fill one bottle = 4s

Volume of bottle to be filled = 150 cm^3 = 0.00015 m^3

$\dot{V}$= Volume flow rate = $\frac{0.00015}{4} = 0.0000375$ m^3/s

$\dot{V}$ = 0.0000375*2118.88 = 0.08 CFM

Thus, we need a vacuum pump with pumping capacity of 0.08 CFM.

Mechanism Analysis:

Two main mechanism that we are using are Geneva mechanism and cam mechanism which we have used to move our bottles in circular motion and up and down motion, respectively. In our particular case we have 6 bottles on each tray which is circular hence we need 6 different slots in our Geneva mechanism so that all bottles are filled in each cycle meanwhile cam mechanism is used to move bottle up towards the nozzle once it is moved in place by Geneva mechanism to ensure the seal and ensure that no air enters the bottle from spaced between nozzle and bottle.

CAM Mechanism:

Cam mechanism is used to convert the circular motion into the linear motion by help of rotating/sliding mechanical linkage. Mostly it is used as part of shaft or rotating wheel and has contact with lever at one or more than one points in the circular motion.

The calculations for cam mechanism are as follow:

From cam design:

Rise-dwell angle =123.16^{o}

Rise angle = 73.4^{o}

Fall-dwell angle = 90.04^{o}

Fall angle = 73.4^{o}

GENEVA MECHANISM:

Geneva mechanism is used to produce a rotating motion of certain periods from a continuously rotating motion. A pin on continuously rotating wheel moves into the slot of

Geneva plate and produces motion. In our case we get 6 steps in one complete round of Geneva plate.

The calculations for Geneva mechanism are as follow:

$T_{dwell} = T_r + T_{rd} + T_f = 18.235s$

Angular velocity of both cam follower and Geneva drive is same as both are connected with same motor.

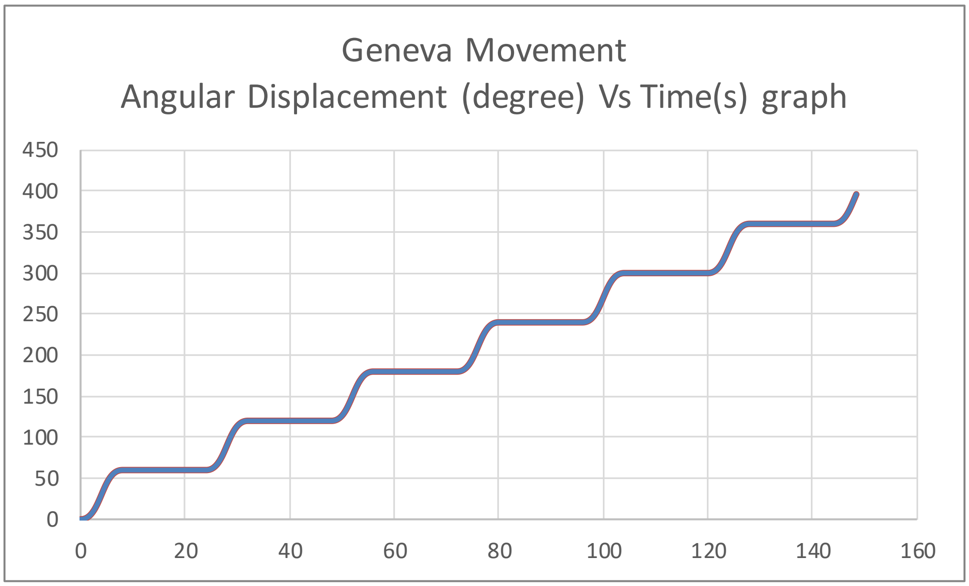

Figure 11: Angular displacement-time graph of geneva mechanism

We had to calculate the time and speed for both mechanisms, so that they are in synchronization. Time taken for each bottle to fill was initially assumed to be 8 second and mechanisms were designed accordingly.

Such as we know that we have 8 second to fill each bottle and then we have time to move bottle up and then down so our time to complete one round of tray (6 bottles) will be greater

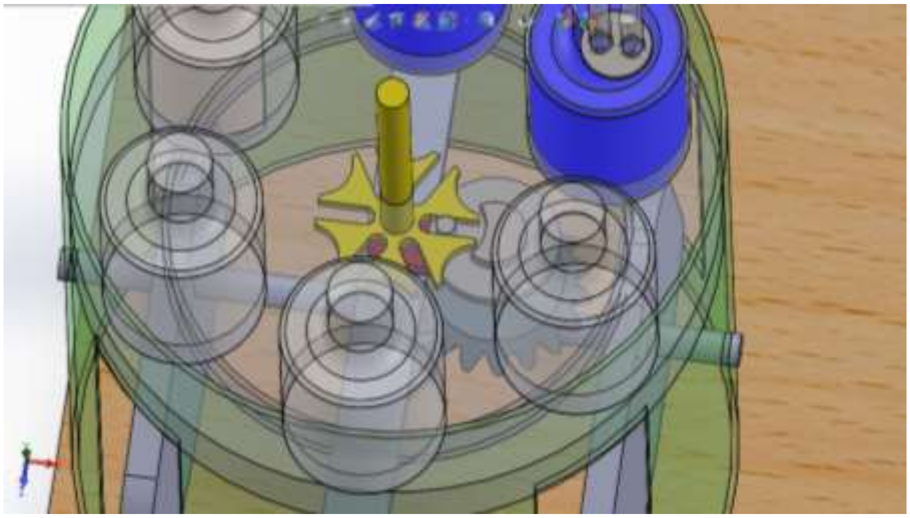

Figure 12: Geneva Mechanism

than 144 seconds and exact time will depend upon the speed of cam mechanism that how long does it take to move bottle up and then down.

Time calculation:

We know will calculate the time to create the pressure difference (as calculated above) before the flow of water.

Assume the velocity at point 1 as v_1':

$\dot{V} = A_1 v_1' = 3.167\times10^{-3}\ v_1'$

$v_2' = \dot{V}/A_2 = 411.58\ v_1'$

$Re = 399.5065\ v_1'$

Assuming laminar flow;

$f = \frac{64}{Re}$

Putting above values in equation (i) and solving:

$v_1' = 1.184025\,\frac{m}{s}$

This velocity satisfies the above assumption of laminar flow.

$\dot{V}_{1-2}$= $3.75\times10^{-5} m^3/s$

Volume of pipe from point 1 to 2 is:

V_{1-2} = $0.000047057 m^3$

$$t'_{1-2} = \frac{0.000047057}{0.0000375} = 1.2549s$$

Solving similarly;

t'_{2-3} = 0.453495s

t'_{4-5} = 2.610488s

t = 4+1.2549+0.453495+2.610488 = **8.319s**

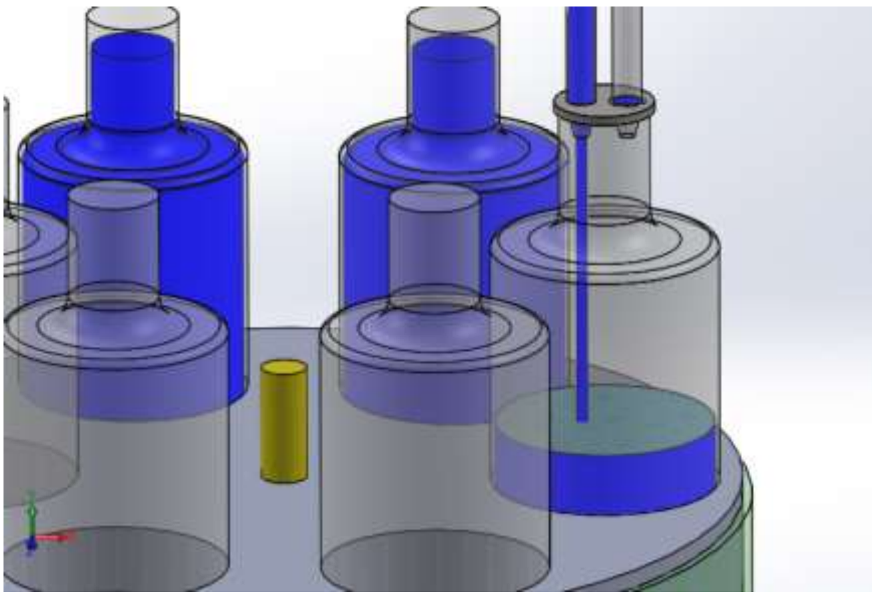

Figure 13: Filling of bottles

CHAPTER 4: RESULTS AND DISCUSSIONS

Pressure difference calculation:

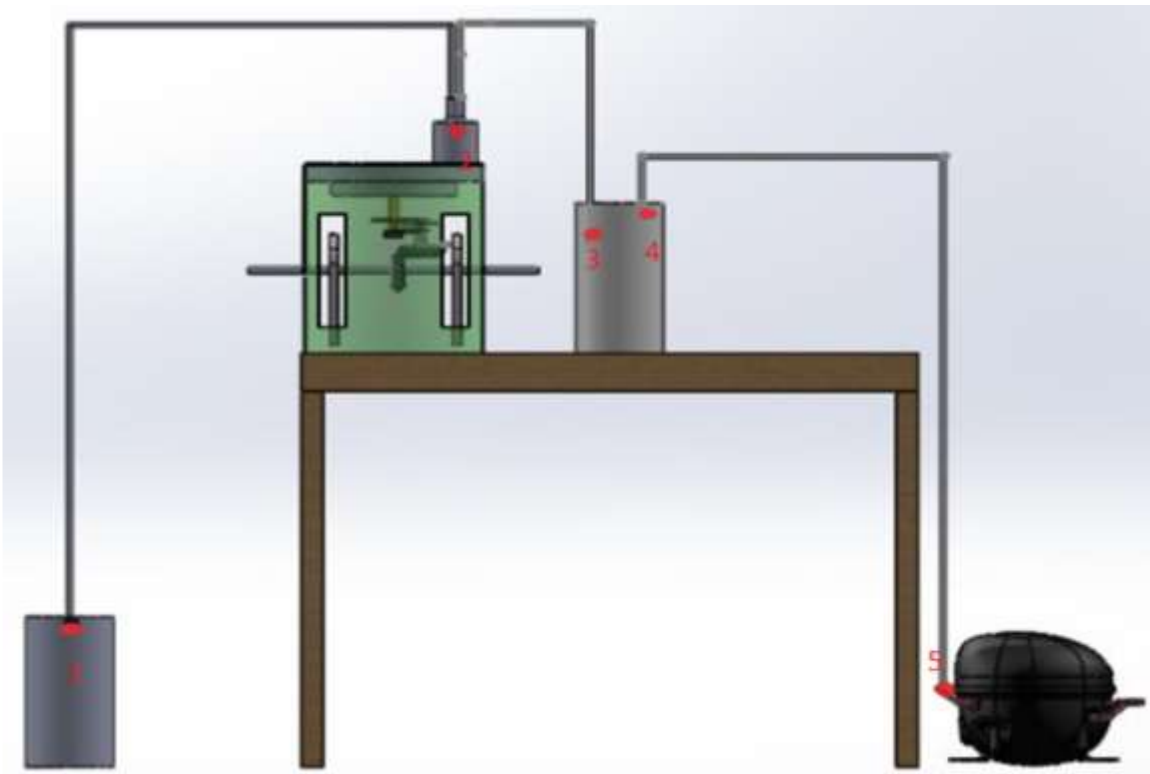

Figure 14: Different points for pressure calculations

In this section, pressure at different points will be calculated using Bernoulli's equation, which is given as:

$$P_1-P_2=\gamma(z_2-z_1)+\frac{\rho}{2}(v_2^2-v_1^2)+\text{Minor losses}$$

Minor losses in our case are due to:

- Length of pipe
- Elbows
- Nozzle

The equation now becomes;

$$P_1 - P_2 = \gamma(z_2 - z_1) + \frac{\rho}{2}(v_2^2 - v_1^2) + \frac{v_1^2}{2g}\left(f\frac{l}{d_1} + K_{L,elbows}\right) + K_{L,nozzle}\frac{v_2^2 - v_1^2}{2g} \quad \ldots\ldots\ldots(i)$$

For regular 90º threaded elbow

$$K_{L,\ elbow} = 1.5$$

We designed nozzle with angle α = 15º and at this angle

$$K_{L,\ nozzle} = 0.24$$

Assumed time to fill one bottle = 4s

Volume of bottle to be filled = 150 cm^3 = 0.00015 m^3

$\dot{V}$= Volume flow rate = $\frac{0.00015}{4}$ = 0.0000375 m^3/s

Diameter of pipe= d_1= 6.35 $\times 10^{-3}$ m

$\dot{V} = A_1 v_1 \quad \Rightarrow \quad v_1 = 4.656$ m/s

d_2 = 3.13mm

$\dot{V} = A_2 v_2 \quad \Rightarrow \quad v_2$=19.16m/s

$Re = \frac{\rho v d}{\mu}$

For water;

ρ = 998 kg/m^3

μ = 1.002 $\times 10^{-3}$ kg/m.s

Where v and d is velocity and diameter at point 1.

Re = 29447.57 > 2300 $\Rightarrow$ Turbulent flow

Reynold's number remain same throughout the whole calculation as diameter of pipe is constant.

Using Haaland equation we get friction factor as:

$$\frac{1}{\sqrt{f}} = -1.8 \log\{(\frac{\varepsilon/D}{3.7})^{1.11} + \frac{6.9}{Re}\}$$

f = 0.03349

z_1 = 0.9498m z_2 = 0.10178m

l_1= 1.4842m

Solving equation (i) we get;

P_1-P_2 = 2851.338 Pa

P_2 = 98473.66 Pa (P_1 = 101325 Pa)

$d_3 = d_1 = 6.35 \times 10^{-3}$ m; v_3 = 4.656 m/s

z_3 = 0.29108m l_2 = 0.54065m

Solving equation (i) for points 2 and 3;

P_3-P_2= 9300.1014 Pa

P_3 = 107773.8 Pa

$d_4 = d_5 = d_1$ $v_1 = v_4 = v_5$

z_4 = 0.06133m z_5 = 0.7039m

l_3 = 1.10703m

Solving equation (i) for points 4 and 5 where second and last term of right side got cancel due to same velocities;

P_4-P_5= 6291.636 Pa ($P_4 = P_3$)

P_5 = 3008.465 Pa

Cam-follower calculations:

From cam design:

Rise-dwell angle =123.16^o

Rise angle = 73.4^o

Fall-dwell angle = 90.04^o

Fall angle = 73.4^o

To check the design of cam we plotted displacement-time graph, velocity-time graph, acceleration-time graph and jerk-time graph.

Four graphs are given below:

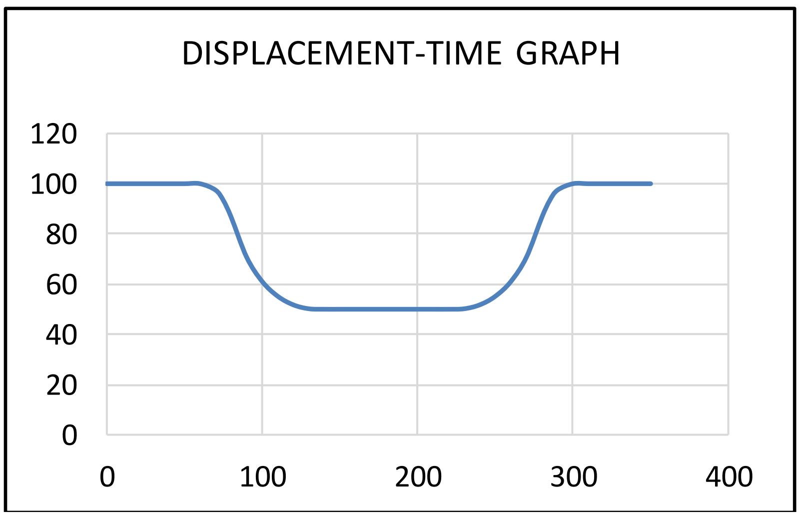

Figure 15: Distance-time graph of cam-follower mechanism

In this graph displacement is plotted against angular rotation of cam. It shows that maximum displacement of cam is 100 mm and minimum is 50 mm.

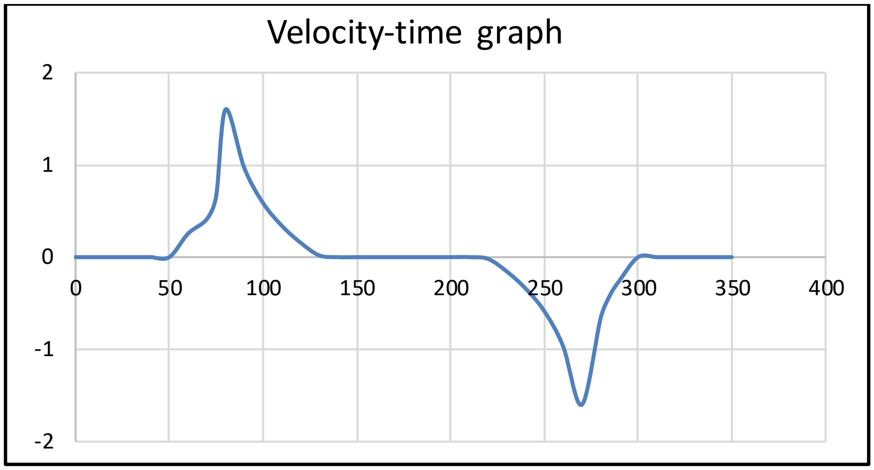

Figure 16: Velocity-time graph of cam follower mechanism

In this graph velocity is plotted against angular rotation of cam. It shows that maximum velocity of cam has a value of about 1.7 mm/s and minimum velocity is -1.7 mm/s.

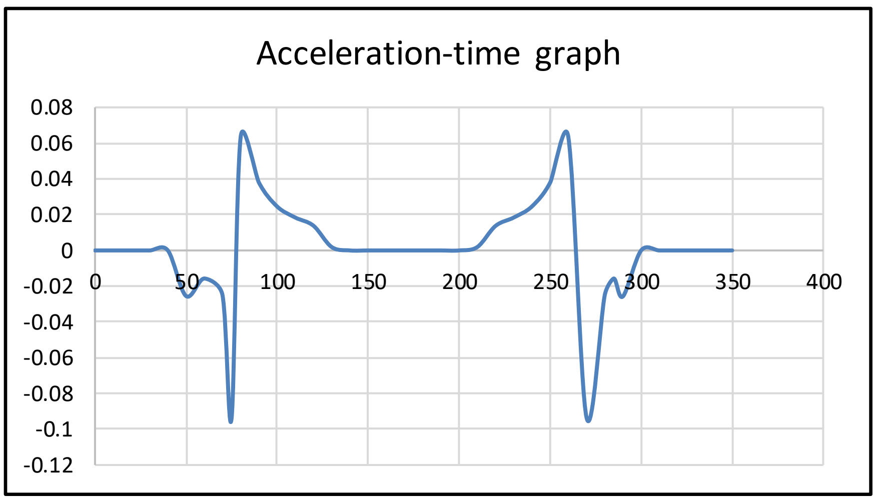

Figure 17: Acceleration-time graph of cam follower mechanism

In this graph acceleration is plotted against angular rotation of cam. It shows that acceleration is continuous over the entire interval of time which is required condition.

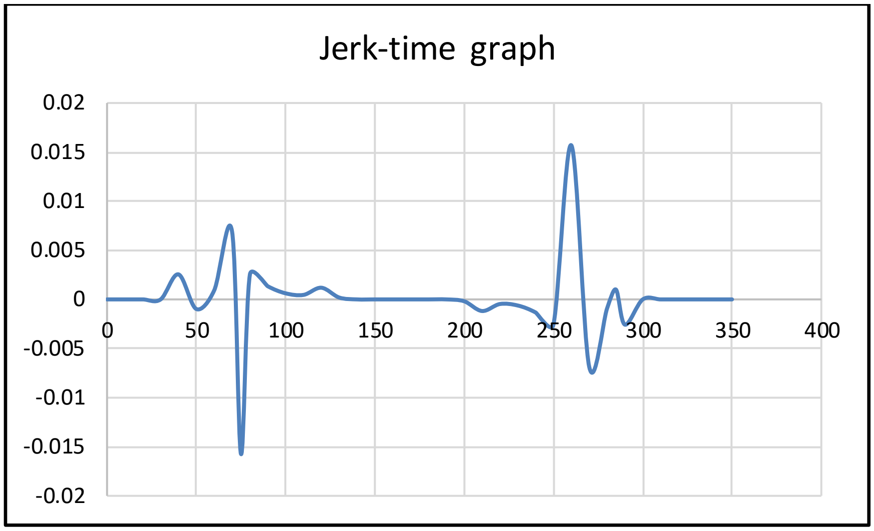

Figure 18: Jerk-time graph of cam follower mechanism

In this graph jerk is plotted against angular rotation of cam. It shows that jerk is finite over the entire interval of time which is required condition for an acceptable cam design.

For an acceptable design of cam, the velocity and acceleration always remain continuous throughout the whole interval while jerk remains finite. If the velocity, acceleration, or both become discontinuous at any time along the interval, the design of cam becomes inacceptable. In addition, if jerk has infinite curve on jerk-time graph then the design of cam is not applicable. As we can see in above graphs that both the velocity and acceleration have continuous functions throughout the whole interval of 360 degrees and jerk is finite so we can conclude that our design is applicable.

Calculation of time for rise, rise-dwell, fall and fall-dwell:

We know that rise-dwell time is the total time for one bottle to fill as calculated above;

T_{rd}=8.319s

$\frac{123.16^0}{360^0} T_{total} = 8.319s$ $\qquad T_{total} = 24.3167s$

$\frac{73.4^0}{360^0} \times 24.3167 = Tr$ $\qquad Tr = 4.958$ s

$\frac{90.04^0}{360^0} \times 24.3167 = T_{fd}$ $T_{fd} = 6.082s$

$\frac{73.4^0}{360^0} \times 24.3167 = T_f$ $T_f = 4.958$ s

To find the angular speed with which motor will rotate:

$\omega = \frac{1}{24.3167} = 0.04112$ rad/s N=2.467 rpm

Geneva Mechanism calculations:

$T_{dwell} = T_r + T_{rd} + T_f = 18.235s$

Angular velocity of both cam follower and Geneva drive is same as both are connected with same motor.

CHAPTER 5: CONCLUSION AND RECOMMENDATION

Conclusion:

Liquid Filling Machine thus designed takes 24.3167s to complete the processes to fill one bottle when pumping rate is 0.1 CFM. These processes include raising of tray up to nozzle, filling of one bottle, descending of tray and its rotation.

Number of bottles filled in 1s = $\frac{1}{24.3167}$ = 0.041124 bottles

Number of bottles filled in 1hour = 0.041124 * 3600 = 148 bottles

Thus, we can fill 148 bottles of 150 cm^3 in one hour using the above-mentioned flow rate with this machine.

Vacuum pump we are using has the capacity to pump liquid at the flowrate of 0.1CFM and this volume flow rate creates enough pressure difference to pull liquid from reservoir up to height of 1 meter against gravitational force.

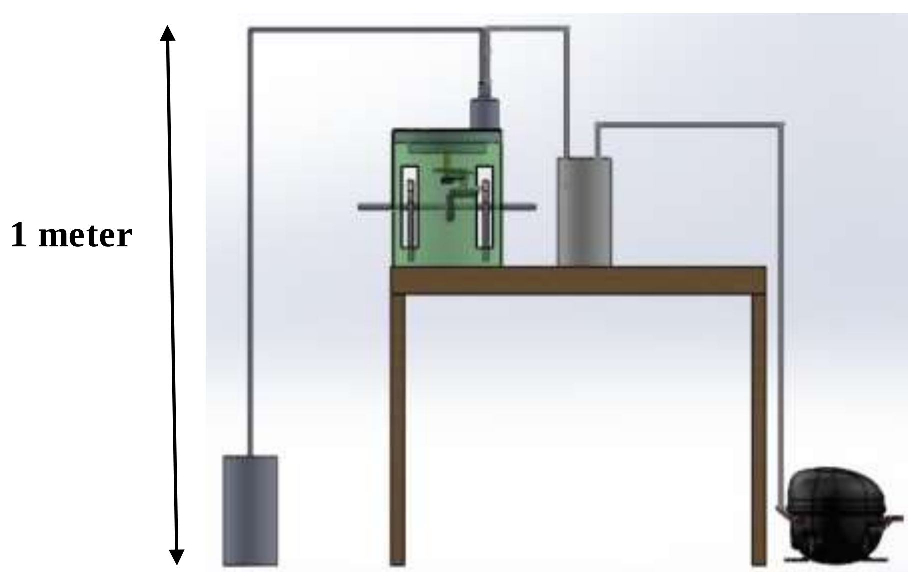

Figure 19: Head required for the vacuum pump

This design of liquid filling machine is quite flexible as it can be adjusted for different sized and different designed bottles. If the bottle is designed differently and its diameter is different compared to the diameter of bottles for which we have designed the machine, we can adjust the system just by changing position of nozzle and using seal of size comparable to the diameter of bottle. Further, for different sized bottles we need to first change the position of nozzle and then adjust the volume flow rate. We have an overflow bottle which gives us a huge margin of error, if we undergo minute to small differences in timing, pressure difference or volume flow rate it can easily be adjusted by flow of extra water to overflow bottle giving us a margin to adjust the error. It is a small unit and don’t need large space for installation.

Cost analysis

The cost for different material is attached according to our survey. The survey was done in Lahore and Rawalpindi market. To make the price less we entered many shops so that least amount of money could be consumed in the process. The price of vacuum pump was determined by the electronics market. Whereas, the cam, cylinder, overflow bottle, shaft, tray, reservoir, bevel gear and Geneva was asked from the manufacturers of parts that have heavy machinery and can produce the parts on demand. However, if the amount of quantity is large than the price of the material will decreased accordingly. The table will be manufactured from the wood shop. The pipes, and the pipes fitting will be purchased from the market as they are readily available because we have selected the standard size of the pipe so that the price could be reduced it could be purchased on demand.

The bevel gear and cam will be manufactured with the help on CNC machine this is the reason why they are expensive as it have to be manufactured separately.

Table 2: Initial Cost of Components

Part	Qty	Price (Rs)
Vacuum Pump	1	2200
Cam	2	1000
Cylinder	1	500
Overflow bottle	1	500
pipes	10 ft	1300
Pipe fittings	6	700
Nozzles	2	200
shaft	1	500
Table	1	1000
Tray	1	500
Reservoir	1	500
Bevel Gear	2	1000
Geneva	1	500
Mover of geneva	1	500
Base of geneva	1	300
Total	**32**	**11200**

Recommendations

Some of the recommendations and limitations of the proposed prototype are discussed in this section and are as following;

- In the future, the shape of the prototype can be altered to make it look more aesthetically pleasing. To make it a successful product on a commercial level, it needs to be made more appealing and aesthetically pleasing for the public.
- In present design, one nozzle is used which fills one bottle at a time. For fast filling, we can use more than one nozzle thus numbers of bottles being filled at a certain time will increase. In this way multiple bottles can be filled at a time thus saving time and increasing productiveness of the system.
- Large pump can be used to increase the filling speed. Larger pumps have higher volume flow rates which means more volume flow per unit time meaning that bottles will be filled in less time.
- As a future recommendation we can make the nozzle adjustable so it can be adjusted when we are working with bottles of different height.
- In the existing design we have to use man force to take bottles from the tray when filled and replace them with empty bottles. But we can introduce a robotic arm which will replace the filled bottles with empty bottle once filled thus making system automated.
- Current set up is designed to fill glass bottles which are mostly used in pharmaceutical industries but if we want to fill plastic bottles for future use we have to check minimum pressure bottle can bear without squeezing. Then we need to decrease the pressure head of reservoir such that the pressure difference developed in bottles should always be less than the squeezing pressure. In this current system can be modified to make it applicable for industries using plastic bottles.
- Tray we designed can hold 6 bottles at a time and lot of time and man force is required to remove the filled bottles and replace them with empty bottles. For future use we can design the tray in such a way that it can hold more bottles, doing this we can reduce the human effort required to replace bottles as well as time consumed. Further we can design bottle holdings in tray such that it can hold

different sized bottles easily using some spring mechanism. In this we don’t have to use different trays when we are using bottles that differ in diameter.

REFRENCES

[1] Darji, V. P., & Parmar, B. G. (2018). DESIGN AND MODELING OF AUTOMATIC BOTTLE FILLING PLANT USING GENEVA MECHANISM. *Journal of Manufacturing Engineering*, *13*(2), 075-081.

[2] Shaukat, N. (2002, December). PLC based automatic liquid filling process. In *IEEE Multi Topic Conference* (pp. 2277-1700).

[3] Chawathe, A., Dabhade, V., Kamath, V., & Patil, G. (2016). AUTOMATED BOTTLE FILLING SYSTEM.

[4] Baladhandabany, D., Gowtham, S., Kowsikkumar, T., Gomathi, P., & Vijayasalini, P. (2015). PLC based automatic liquid filling system. *International Journal of Computer Science and Mobile Computing*, *4*(3), 684-692.

[5] Ujam, A., Ejeogo, G., & Onyeneho, K. (2015). Development and Application of Geneva Mechanism for Bottle washing. *American Journal of Engineering Research*, *4*(11), 63-73.

[6] Khatod, R. G., & Sakhale, C. N. (2012). Design and Fabrication of Liquid Dispensing Machine Using Automatic Control for Engg. Industry. *International journal of innovative technology and exploring engineering (IJITEE)*, *1*(5), 3.

[7] Pallavi VivekShete, Minal V Raundale, Bhosale D S (2016), "Automatic Vessel Filling System Using Raspberry-pi", International Engineering Research Journal, Vol.2 (3), 1449-1451

[8] Chandrasekhar S G, Mahendraprashanth K V (2015), "Design and Implementation of automated tablet filler prototype for Pharmaceutical application using PLC", International Journal for Scientific Research & Development, Vol. 3 (3), 3082-3085.

[9] Win, Z. K., & New, T. T. (2019). PLC Based Automatic Bottle Filling and Capping System. *International Journal of Trend in Scientific Research and Development (IJTSRD)*, *3*(6).

[10] Mallaradhya, H. M., & Prakash, K. R. (2013). Automatic Liquid filling to bottles of different height using Programmable Logic controller. *International Journal of Mechanical and Production Engineering*, *1*(4).

[11] Al-Hawari, T., Aqlan, F., & Al-Faqeer, Z. (2010, January). Simulation-based analysis and productivity improvement of a fully automatic bottle-filling production system: a practical case study. In *2010 Second International Conference on Computer Modeling and Simulation* (Vol. 4, pp. 195-199). IEEE.

[12] Deepak Sahu, Ghanshyam Kumar (1940), "Design and Analysis of Paper Cutting Machine works on Geneva Mechanism", IJARIIE Vol.2 (2), 1194-1197.

[13] Khurmi R S and Gupta J K (2004), "A Textbook of Machine Design", S.Chand & Compnay LTD., Delhi.

[14] Saeed, A. U. A., Al-Mamun, M., & Karim, A. Z. (2012). Industrial application of PLCs in Bangladesh. *International Journal of Scientific & Engineering Research*, *3*(6).

APPENDIX I: ANSYS FLOW ANALYSIS

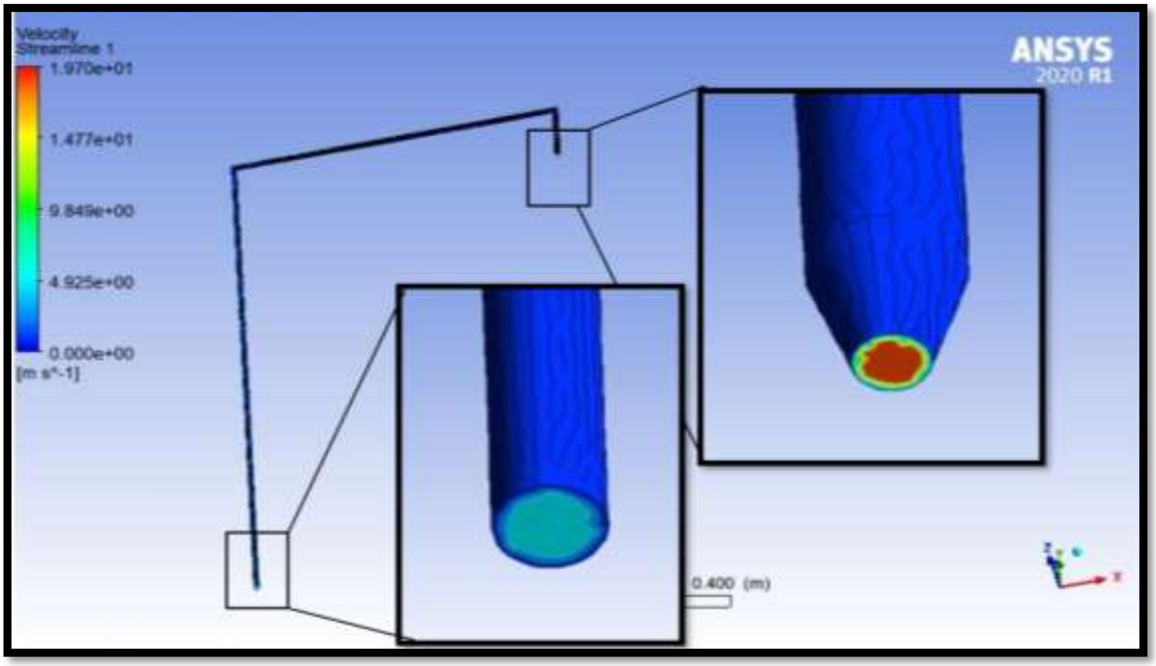

Figure 20: Velocity contour in pipe

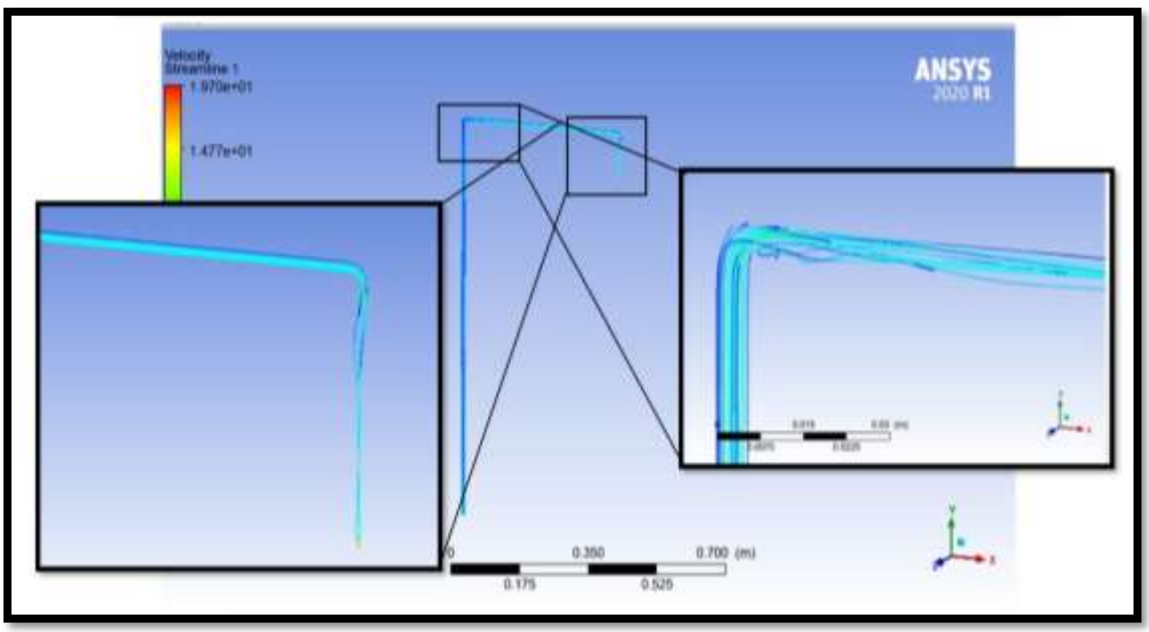

Figure 21: Velocity streamline in pipes

APPENDIX II: DIMENSIONS OF DESIGN

Table 3: Dimensions of Design

Component	Dimension
Height of base table	500 mm
Length of base table	700 mm
Width of base table	400 mm
Diameter of overflow bottle	96 mm
Height of overflow bottle	196 mm
Reservoir tank height	200 mm
Reservoir tank diameter	100 mm
Diameter of bottle to be filled	50 mm
Diameter of mouth of bottle to be filled	20 mm
Length of pipe from point 1 to 2	14842 mm
Length of pipe from point 2 to 3	540 mm
Length of pipe from point 4 to 5	1107 mm
Diameter of pipe	6.35 mm
Diameter of nozzle exit	3.13 mm

Shaft diameter	10 mm

APPENDIX III: ANALYSIS OF GENEVA

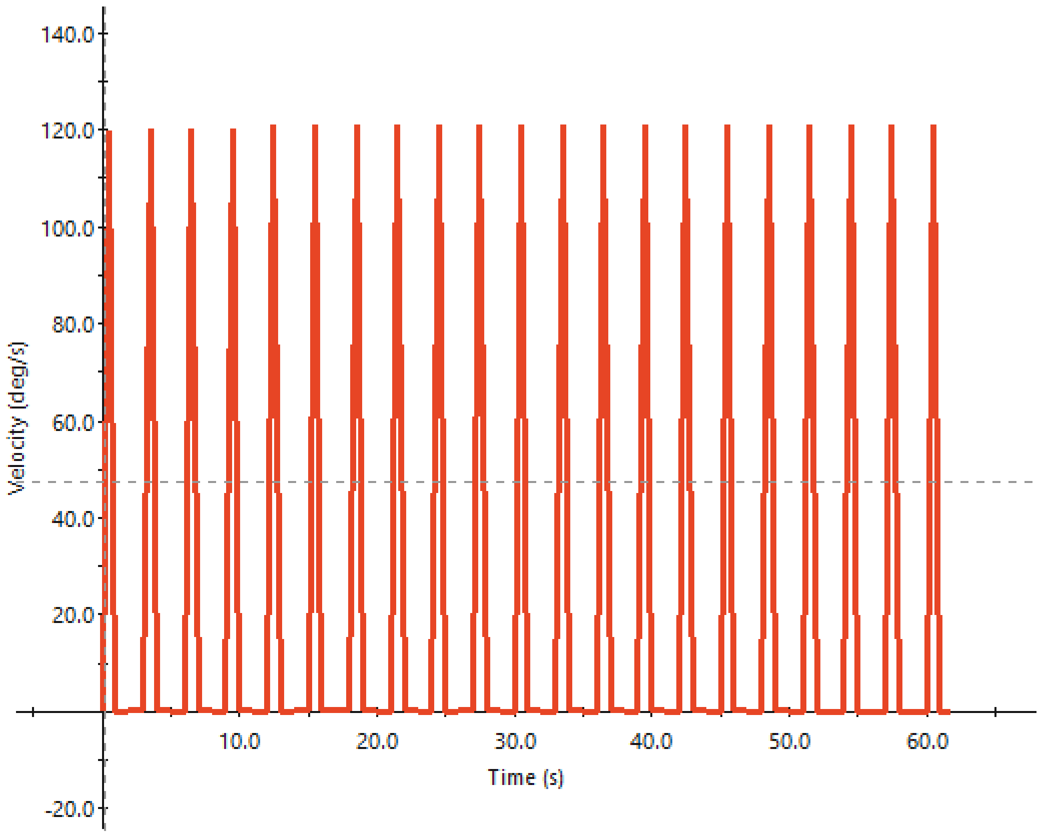

Figure 22: Velocity-time graph of geneva mechanism