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DESIGN AND MODELING OF AUTOMATIC BOTTLE FILLING PLANT USING GENEVA MECHANISM

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ABSTRACT

Productivity improvement is the aim of today's manufacturing system. It may relate to manufacturing, services or plants working with any other aspects of production. Increasing productivity in recent time of global competition is great affected by automation concept and strategies in the industries and plants. All the industries worldwide are moving towards the automation. Out of these all type of production types, filling is a task in which any item liquid or solid are filled into the bottle or container. At this time filling is carried out by automatically in large scale industries and manually in small scale industries. Human operated filling industry can be converted into automatic filling plant by providing indexing motion to the container or bottle. Indexing motion may be rotary or linear. Geneva Mechanism is one of the best ways to provide rotary indexing motion from the continuous rotary motion. This Research Paper focused on the design and modeling of automated water bottle filling plant by using Programmable Logic Controller (PLC) and Geneva mechanism. This system is suitable for all kind of filling operations like water bottle filling, oil bottle filling, pharmaceutical bottle filling, syrup filling and many more with appropriate modifications. This work is mainly based on filling of bottle on rotary table which is rotated by six slot Geneva mechanism. Here, the system is developed for bottle filling which is based on automation consisting PLC and sensors. Design of different components is carried out in solid works 2017 for such mechanical for the filling of required quantity with high efficiency in less time by the use of Geneva wheel.

Keywords: *Filling Task, Six slot Geneva Mechanism, Beverages Plant, Modeling and simulation.*

1. Introduction

The current trend in all the industries is to adopt new technologies to proceed towards automation. The same vision is exercised in water bottle filling plants. To meet the customer demands and to accelerate the filling of bottles, and also to remove all the difficulties occurred by manually filling in all operations are nearly automated. In small industries, water bottle filling operation is done manually. The manual filling process has major shortcomings like (i) Spilling of water while filling it in bottle (ii) non uniform quantity of water being filled and (iii) delayed operating time.

In water beverages plant, they have different amount of water filled in the bottled water, like 0.5ltr, 1ltr, 10ltr, 20ltr etc. Packed water is drinkable available in plastic or glass bottle. It may be carbonated or may not carbonate. Now a day's requirement of bottled water increase continuously. Earlier, water was filled into bottle manually but with innovation in technology, large beverages plants use advanced machine to fill the water into bottle but it does not suit to small scale plant because of its costly machineries.

All the beverages plants have similar sequence of operations need to be finished in stipulated time to cope with the market satisfaction. It is also important to fill the bottle in required quantity of water. These are loading of bottle, filling of bottle, capping of bottle, unloading of bottle and labelling on bottles. The quantity of water must not waste during the series of operations.

In the present paper attempts are made to design a simple, logical and economical automatic mechanism for a beverage plant located in Surendranagar, Gujarat, India. The Meghdev beverages plant is located in out skirt of Surendranagar. Total bottle filling capacity is of approximately 1700 bottles

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of filled with 20ltr mineral drinking water for residential and commercial customers. Out of these almost 1100 bottles are filled with normal water and 600 bottles are filled with chilled water. In performing this task the plant needs to employ 8 to 10 workers. Because of some human nature issues, the filling capacity and time required in filling the bottles are sometimes out of control. The mechanism developed in the present work.will increase the plant efficiency by removing the ideal time and hence the output will be increased enormously.

1.1 Background

The first water bottling plant was begun in U.K. in 1621.The demand of bottled water was increased in Europeans and Americans countries during 17th and 18th century. As technology was innovated in 19th century, the cost of making bottle and water purification was reduced, bottled water was able to produce on large scale and the beverages plants were grown up speedily. The main reason of increasing demand of bottled water at this time is water supplied by the municipal corporation contaminated pathogens like typhoid. The people are now aware of the benefits of drinking clean and fresh mineral water.

2. Beverages Plant In India

The requirement of bottled water is rapidly increasing in India since 1990. Many renowned beverage plants like Bisleri launched packed drinking water in India. It is due to advertising by the beverages industry that "it was pure and healthy". The data available in literature shows that total market values was 60 billion INR in 2013, Which is only of top five companies (like Bisleri, PepsiCo, Coca-Cola, Dhariwal and Parle) of India and approximately it will be 160 billion INR in 2018.

3. Literature Review

Bipin Mashilkar et al. [1] proposed an automated bottle filling System in which they give detail about design, fabrication and control system for automated bottle filling system. They use microcontroller to control various operations in plant. In this bottle fills up linearly by using conveyor with the help of sensors and electromagnetic valves. In this system entire sequence of operation is controlled by Arduino microcontroller with the help of c programming.

Sagar T. Payghan and Rani H. Deshmukh, [2] present automation of bottle filling plant with industry 4.0. The term Industry 4.0 is used for next industrial revolution. In this research paper they discussed about industry 4.0 concept into the automatic bottle filling plant, in which all the operation Like Blow Moulding, Rinsing, Filling, Capping, Packaging and unloading operation are carried out automatically. This study gives the information about issues of automation control system in operation development, improving management level and high process efficiency in bottle filling plant.

Ujam et al. [3] present their study 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%.

Deepak Sahu and Ghanshyam Kumar [4] carried research work on design and analysis of paper cutting machine works on Geneva Mechanism. They proposed detail about study of a mechanism which contains a Geneva wheel and gear Train to achieve intermediate motion. The Motion of gear pair was determined by reducing high jerk of Geneva wheel. The cutter will be back to its original position by spring effect. Aim of this study was, compact size, reduce cost, less skilled labour required, and no electrical inputs required, and reduced the cutting time.

Pratheep Kumar and E.Sanjay [5] presented the design and fabrication of Geneva conveyor for material inspection & noise reduction. This study was based on Geneva conveyor for noise reduction and material handling in various industries this study was very useful in various industries like, sorting; pick up, automotive, agriculture, bottling, food processing, aerospace etc.

Chandrasekhar S.G. and Dr. K V Mahendraprashanth [6] studied and the design and implementation of automated tablet filler prototype for pharmaceutical application using PLC. In this study they developed prototype of commercial tablet counting and filling machine for pharmaceutical application.

Pallavi Vivek shete et al. [7] proposed automatic vessel filling system using Raspberry-pi. They show automatic filling system in which user manually entered the filling volume and bottle fill up automatically. For this work they used Raspberry-pi microcontroller because it was very flexible, cost saving, time saving and space efficient.

4. Details About Bottle Filling Plant

Bottle filling plant broadly classified as linear bottle filling plant and rotary bottle filling plant. In linear bottle filling plant all the operation of bottle filling from loading to unloading are carried out in one line with using conveyor mechanism. 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 to easy to control because 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 process.

4.1 Details about processes of bottle filling plant

Bottle filling plant mainly consist various process Filling, Capping, Loading and Unloading.

Loading: - Loading is first task at which loading activity of empty water bottle carried out. It will carry out manually by labour

Filling: - Filling is second task which was carried out process of filling of water into bottle. Various filling systems are gravity filler, positive displacement filler, volumetric filler and vacuum filler etc. In this task water transfer from storage tank to bottle by using pump.

Capping: - Capping process carried out the task of fit the plastic cap on bottle to close the neck of bottle. In this Study two capping stations are used to fit the cap. Working of this two capping stations are, [a] One used to put the cap on the bottle when sensor give the signal about bottle is present. It will used to vibratory fader for feeding of cap to the station. [b] Second station used for pressing the cap to tightly fit cap on the bottle. This station working by the hydraulic cylinder which was controlled by the PLC Controller.

Unloading: - Unloading is the last task which is carried out unloading of filled water bottle manually at the last station.

4.2 Block diagram of bottle filling plant

Below block diagram shows complete working cycle of bottle filling plant from loading to unloading.

As shown in block diagram first of all switch on the motor so it will rotate continuously at certain required speed, then Geneva mechanism convert this continuous rotation into intermediately rotation. Now loading the bottle onto the table then sensor detect the bottle at filling station and fill the bottle then sensor detect the bottle again at capping station and cap put on to the bottle and cap press at the next station, and last bottle will unloading from the table. This is the working cycle of all the rotary bottle filling plant which are controlled by PLC controller.

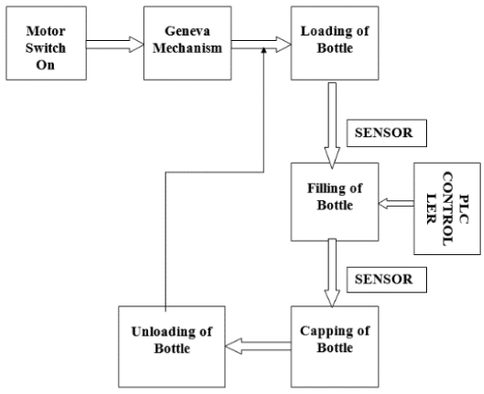

Fig. 1 Block diagram for working cycle of bottle filling plant

A Programmable Logic Controller is digital computer used for automation of system. It is an interface between program and the inputs. It is a programmable software.PLC works depending by the inputs given, turning on/off its outputs. And Proximity sensors are device useful to detect the presence of object without physical contact. They are used in automatic bottle filling plant for the purpose of detection of bottle at each stations. Sensors are give information as input to the PLC controller.

5. Design of Bottle Filling Plant

This paper study on 20ltr. Water bottle filling plant in which automatic bottle filling achieved using Geneva Mechanism. Geneva Mechanism use for convert continuous input rotary motion to indexing motion, which was useful to index the bottle at various stations. Bottle filling process required different operation in which filling of bottle is main. Mathematical design [8] of bottle filling plant and its parameter is given here.

5.1 Selection of filling pump

Pump is used in filling stations to provide water from tank to the filling nozzle with required amount of pressure. Pump will be controlled by PLC controller which gives the signal about when to start and stop. Here we choose one standard pump of “Tornado Multi Pump Company” which is manufacture different types of pump for various operation and from this based on requirement of Pressure head, Flow rate range and other. Pressure head: 3 m, Flow Rate: 4500lph (75lpm), Fluid: Water, Pump power: 65watt, Outlet Diameter:

25mm (1"). Model name of this specification pump is "PF1375".

5.2 Bottle filling cycle time calculation

Some important calculations are carried out here to design the automatic mechanism for bottle filling plant under considerations. These are [8]

(a) Time required to fill 10ltr.

Water into bottle (Processing Time)

Flow rate of selected pump is 1.25ltr/sec so time required to fill 10ltr water into bottle is,

$$FlowRate = \frac{Capacity(L)}{Time\ (S)} = \frac{10}{1.25}$$

$$Time = 8Second$$

In this machine we have 2 filling stations to calculate time required to fill 10Ltr only. Time required for processing operation is sum of filling time and ideal time (for nozzle up/down movement) is:

8 second + 2 second=10 second.

(b) Speed of Geneva wheel

In this work we use 6 slotted Geneva mechanism. The angle of rotation of Geneva driven is 60 degree for 360 degree rotation of Geneva driver.

$$Processing\ time(Tp) = \frac{(180+\theta)}{360\ N}$$

$$N = \frac{(180+60)}{360*10} = 0.06667 = 4RPM$$

So, it is required to continuously rotate Geneva driver at 4 RPM speed.

(c) Indexing time in Geneva mechanism

Indexing time in 6 slotted Geneva mechanism is half of the processing time, means indexing time is 5second.

Total cycle time in Geneva mechanism is sum of processing time and indexing time. Total cycle time=10second+5secoond=15Second

(d) Bottle filling rate per hour

Bottle filling rate per hour R_h is,

$$R_h = \frac{3600}{15second} = 240\ Bottle\ per\ hour$$

5.3 Design of Geneva Mechanism Parts

Geneva mechanism has two main parts which are (i) Geneva driver and (ii) Geneva drive. General parameter of Geneva mechanism is written below [8] and it can also be shown in fig 2. Drive Crank Radius (a), Drive pin diameter (p), Geneva wheel radius (b), Clearance (t), Centre distance (c), Slot centre length (s), Slot quantity (n) and Slot width (w).

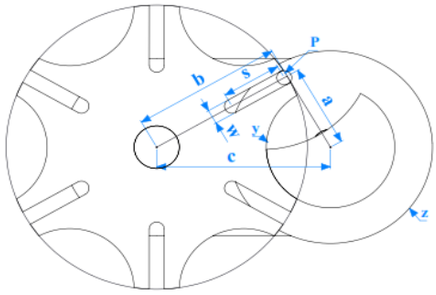

Fig. 2. Geometry of Geneva Mechanism

All the above parameter are mathematically calculated [9] based on our requirement which is shown below, By taking Geneva wheel radius (b) =400mm, Number of slots = 6, Pin diameter = 20mm, Allowed Clearance= 0.10mm, other parameter are

Centre distance between Geneva Drive & Driven (c)

$$c = \frac{b}{\cos(\frac{180}{n})} = \frac{200}{cos30}$$

$$c = 230.9401\text{mm}$$

Drive Crank Radius (a)

$$a = \sqrt{C^2 - b^2}$$

$$a = \sqrt{230.9401^2 - 200^2}$$

$$a = 115.4701mm$$

Slot Centre Length (S)

$$S = (a+b) - c$$

$$S = (115.4701 + 200) - 230.9401$$

$$S = 84.5299mm$$

Slot Width (W)

$$W = p + t$$

$$W = 20 + 0.10$$

$$W = 20.10mm$$

Arc Radius (y)

$$y = \frac{a}{p*1.5}$$

$$y = \frac{115.4701}{20*1.5}$$

$$y = 85.4701mm$$

Stop Disc Radius (Z)

$$Z = y - t$$

$$Z = 85.4701 - 0.10$$

$$Z = 85.3701mm$$

5.4 Mechanism for continuous input rotary motion

Required continuous input rotary speed of Geneva wheel is 4RPM.

Use of motor for continuous rotary motion

Servo Motor is a device which is used to get continuous rotary motion from electric power supply. Generally motor available in the market with output speed of 1000RPM to 1400RPM. For this work motor with 1400 RPM is selected

Speed Reduction through gearbox

Output speed of motor is 1400 rpm. Now it is required to reduce the speed. It can be possible by using gear box. Gearbox is a device which is useful to reduce the rotary speed by using different types of gear mechanism. For this study use Radicon Power Build company gear box which have power of 0.5KW and torque is 180Nm and 1.4 service factor.

Speed Reduction Using Chain Socket Mechanism

It is not possible to directly reduced speed from 1400RPM to 4 RPM by only providing gearbox or chain and socket mechanism. So first use gear box to reduced speed from 1400RPM to 12 RPM, and then from 12RPM to 4RPM by using chain and socket mechanism whose have speed reduction ration of 1/3. So diameter of driven shaft is 3times bigger than diameter of driven shaft.

6. Modeling of Automatic Bottle Filling Plant In Solid Works 2017 Software

SOLIDWORKS 2017 is solid modeling computer aided design software. This software is convenient and simple to use, making it time saving and efficiency improving software.

All the parts of automatic bottle filling are model in software and after it they all are assemble for complete model of machine. Here shows the 3D view of all the stations of filling plant individually with their detail and then shows the full plant (Machine) assembly.

6.1 Filling station

Filling Station is used to fill the water into bottle. Filling station is assembly of different parts like, Filling Pump, Flexible Nozzle, Fixed Nozzle, Pneumatic cylinder, Mounting Structure and Sensors.

At filling station first of all proximity sensor detect the bottle, and it gives input to the PLC Controller, if Bottle is Present then PLC Controller Switch on filling pump so the water transfer from water tank to water bottle through flexible and fixed nozzle in predetermine (10Ltr.) quantity. This study has 2 filling stations for reducing the bottle filling time. Assembly of filling station is shown in fig. 3.

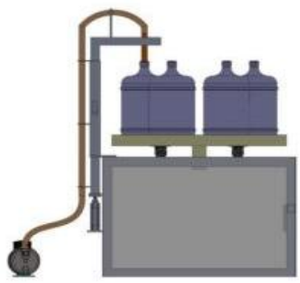

Fig. 3 Filling Station Assembly

6.2 Capping (Put Cap on Bottle) station

Capping station is divided into 2stations to reduce complexity, in which 1st is put cap on bottle. At this station plastic cap is put on bottle automatically with using vibratory feeder.

This station contain parts like, Gearbox, Bearing, Feeder, Hopper, Guide track, Sensor etc. after it all the parts are assemble to complete this station which is shown in fig. 4. At this Station sensor detect the bottle and gives signal to PLC Controller, if bottle is present at this station then switch on the gear box so feeder feed one cap on bottle.

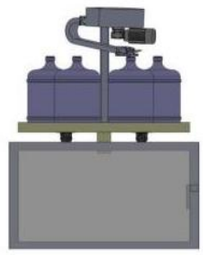

Fig. 4 Capping (Put Cap on Bottle) Station Assembly

6.3 Capping (Press) Station

2nd capping station is press station, at this station cap on bottle which are placed at earlier station is press with using Pneumatic cylinder.

This station contain parts like Pneumatic Cylinder Assembly, Mounting Structure, and tool for press. Sensor is not required at this station. At this station when cylinder close cap is press and fit into bottle neck. Assembly of this system is shown in below fig. 5.

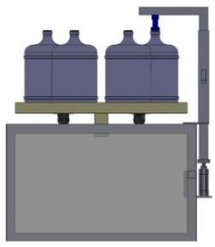

Fig. 5 Capping (Press) Station Assembly

6.4 Loading & Unloading Stations

In this study loading & unloading stations is manual. It means human worker manually put empty bottle on machine and remove filled bottle from table. Human model with table assembly is shown in below fig. 6.

Fig. 6 Loading & Unloading Stations assembly

6.5 Rotary Indexing Mechanism

In this study indexing motion for bottle movement is achieved with using Geneva mechanism. Complete indexing motion mechanism is achieved by using combination of different method.

First of all when Start machine from the Controller unit, Motor start to rotating at 1400RPM and it is connected to gearbox so speed reduced to 12RPM, after it Gearbox is connected with Geneva Driver shaft with using chain and sprocket mechanism, so speed reduce to 4RPM, which is speed of Geneva driver, by this input speed we get 10Second ideal time (Processing Tine) and 5Second Indexing Time. Assembly of this all parts is shown below in Fig. 7.

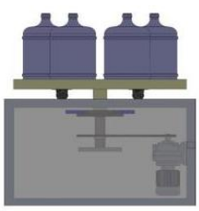

Fig. 7 Rotary Indexing Motion Assembly

6.6 Complete Bottle Filling Plant (Machine) Assembly

All the above model subassembly is assemble for complete bottle filling plant. Servo motor is used for input rotary motion. Six Slot Geneva Mechanism consist of 6 working stations which are Loading, Filling 1, Filling 2, Capping 1, Capping 2, And Unloading station. Full assembly of bottle filling plant is shown below in Fig.8,

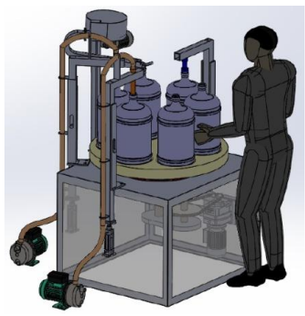

Fig. 8 Full Plant assembly

7. Conclusions

It is concluded from the study that, Small scale water beverages plant can move towards automatic bottle filling plant using this innovated mechanism. Following conclusions are drawn through this work:

- Through automatic bottle filling system, bottle filling rate can be increased from 150 bottles per hour to 240 bottles per hour which is almost 60% higher.
- The requirement of man power is reduced from 10 to 2 in automatic bottling system compared to manual bottling plant system as developed in this work.
- Machine required only 1.5 X 1.5 meter space; hence increased utilization of working space is achieved for processing by optimum arrangement of all the components.
- Due to reduce labor cost and higher bottle filling rate this system is found to be cost efficient.
- The design of entire system is made acceptable with appropriate changes to other applications like oil filling and pharmaceutical product filling.

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Nomenclature

Symbol	Meaning	Unit
Q	Flow Rate	Litre/s
N	Speed of Geneva Driver	RPM
θ	Angle of Rotation of Geneva Table	Rad/s