Propose & Design an Automated Mechanical System for Capping and Water Level Measurement of Water Bottle

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The purpose of this paper is to develop an automated production layout along with its design for capping and water level measurement of a water bottle. The research work includes designing a fixture for holding the bottle, while capping and three-finger self-centering gripper for placing and moving the bottle to and fro from guideways to the bottle bottom holder and vice versa. Suggesting an automated system and technology for checking the water level in the bottle and effectively removing insufficiently filled bottles from assembling line would also be one of the objectives of this paper. Tools like automated torque wrench, precision indexing conveyor belts, three-way self-centering grippers, three jaw chuck (bottle holding fixture), infrared level detection sensor have been used in this system. FEA analysis of three-finger gripper and three-jaw chuck is done to verify their design. The components of this system are designed using Creo Parametric 2.0. Designed components are analyzed using ANSYS Workbench 16.0.

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Introduction

Clean water is an essential basic human need. Packaged drinking water is a solution for getting pure and germ-free water when clean drinking water isn't available. Due to high demand for packaged drinking water there are a lot of companies providing it. Recycling and washing the bottles, proper orientation of bottles and caps, filling the bottle with required quantity of water, capping of bottles, labelling the capped bottles, inspecting them & packaging the inspecting bottles are the processes of bottling in any bottling plant. Expect a few, most of these companies are small-scale and local industries due to market availability. The companies with large turnover mostly have all their systems automated. Moreover, the cost of installation of a fully automated bottling system in the plant is quite high with respect to the total budget of the company. So most of the small scale industries have some systems automated but not all [8]. For example, capping of the water bottle would be done by the torque wrench, but there is a possibility that either water bottle is manually fed to torque wrench or torque wrench is manually operated. In countries where labor is cheap, this type of production system is generally adopted, slowing down the company's output [8]. In this paper, a production layout for automatically feeding, capping and inspecting capped bottle is discussed.

Automated Water Bottle Feeding, Capping and Inspecting System

The total assembly prototype of the automated system is shown in fig 1. For convenience, we can divide the whole system into different sections depending upon the components they use. The system is designed for a bottle length of 10.23 in and base diameter 2.75 in with neck radius of 0.8 in and bottle head of 1.1 in. The bottle is already filled with a measured quantity of water in the earlier stage and is ready for capping. The different components of assembling system are discussed below.

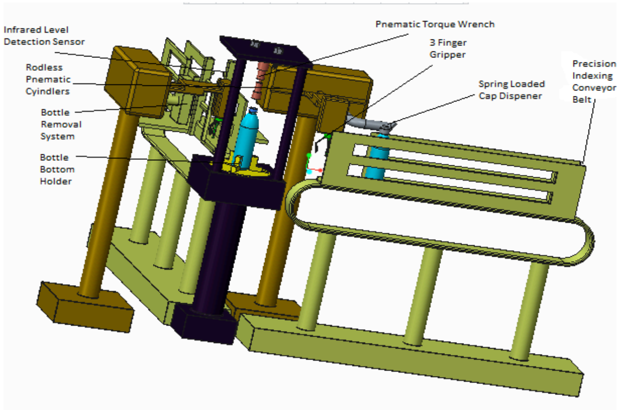

Fig 1- Pro-e model of assembly of Capping System

1. Precision Indexing Conveyor Belt

All the conveyor belts used in this layout are precision indexing conveyors [5]. These conveyors are used for moving the water filled bottles from filling station to capping station. They also carry capped bottles for their inspection and finally to the packaging section. These conveyors have long dwell time and short index period and can be integrated with pneumatic, cam-controlled or servomotor actuated operations. They have compact footprint; narrow frame width with different fixture sizes and index pitches.

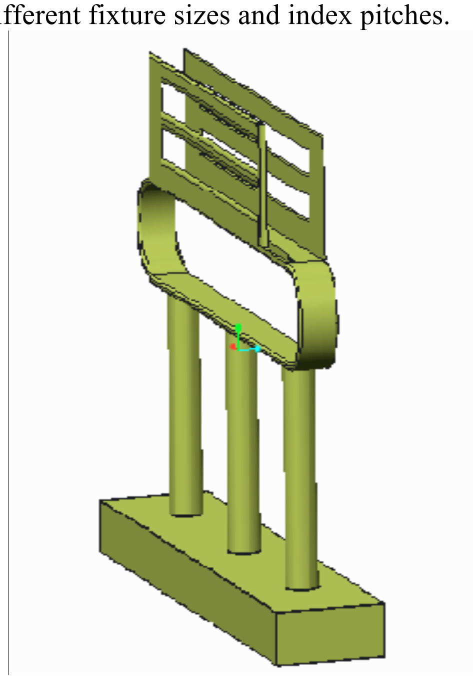

Fig 2- Pro-e Prototype of Precision Indexing Conveyor System

2. Spring Loaded Cap Dispenser

Oriented caps flow by gravity down a chute that has a cap dispenser mounted at its end. The dispenser is located directly over the path of the bottles traveling on the conveyor belt [6]. Bottles must be supported at their necks as they pick-off a cap from the dispenser. Two rollers, support the bottle head, just enough to let it pass while the cap is being dropped down. When the bottle hits the flap at the entrance of the dispenser, the flap moves in, actuating the stopper at the end chute to move down through a spring mechanism. As the stopper moves down cap drops on the bottle head, and the bottle moves ahead on the conveyor.

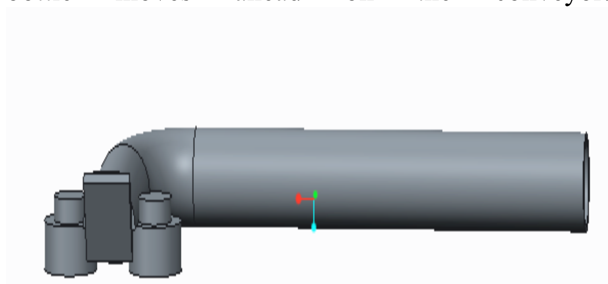

Fig 3- Pro-e Model of Spring Loaded Cap Dispenser

3. Three-Finger Self-Centering Gripper

This gripper is used to pick the bottle from the conveyor and place it in the three jaw chuck for capping, then another gripper places the capped bottle again on the conveyor for further inspection process [2, 3, 5]. These grippers are mounted on rod less pneumatic cylinders with three degrees of freedom. The fingers of the gripper are equally placed to support and grip the bottle. These three fingers work as pneumatic actuators having a converging and diverging motion.

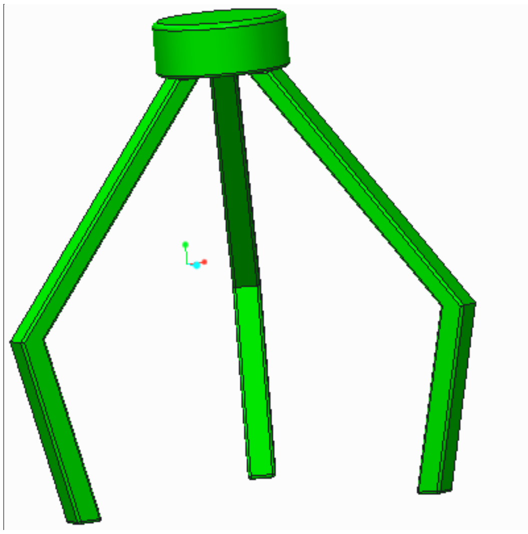

Fig 4- Pro-e model of three finger self-centering gripper

4. Bottle Bottom Holder

The bottle bottom holder is basically a three-jaw chuck which clamps the bottle during the capping process. The jaws have motion to move in and move out through the guideways. Therefore they can be used for bottles with different base diameters.

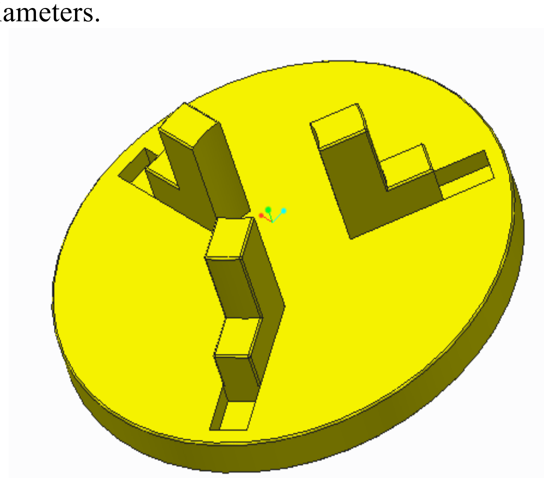

Fig 5- Pro-e model of Bottle bottom holder

5. Pneumatic Torque Wrench

Depending upon the cap diameter and material, a pneumatic bottle capper with the ability of providing necessary torque and air pressure, can be selected from the market [1]. As the cap has diameter 1.22 in and material is PET plastic, the standard capping torque required is 16-20 lb.in and removal torque is 10-14 lb.in [1]. The apt working pressure for this operation is 25-30 psi [1]. A torque wrench is fixed to an upper plate by bolts and has motion in the upward and downward direction.

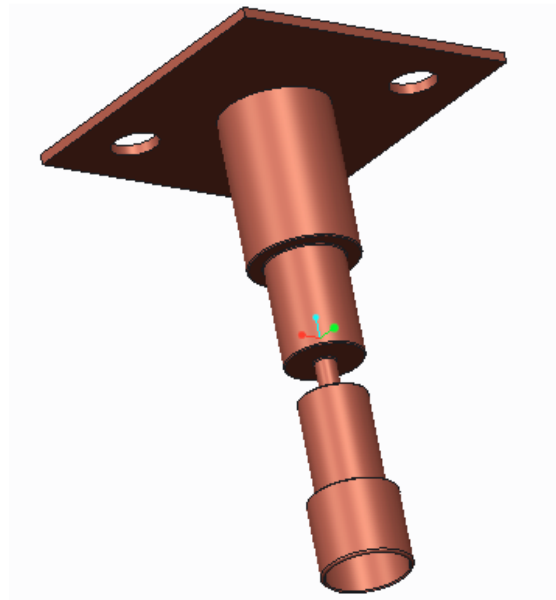

Fig 6- Pro-e model of Pneumatic Torque Wrench

6. Infrared Level Detection Sensor

This sensor uses a beam of infrared light of 13 mm in diameter and a wavelength of 1450 nm [4]. It has a transmitter to emit light and a receiver which detects the emitted light. At 1450 nm, water absorbs 1,000 times the energy of alternative wavelengths, allowing emitted beam to deliver accurate results in two ways. When the bottle is clear, the energy absorption of the water creates high contrast between the water and the bottle. The clear PET plastic bottle attenuates about 5% of the light emitted, while the water attenuates about 95% of the light, allowing for precise liquid detection. This light-blocking technique delivers both accurate sensing and a cost-effective price, with emitter/receiver pairs having a cost around $ 300, which is less than 3 percent of the cost of alternative solutions.

7. Bottle Removal System

This system is located on the conveyor for removing insufficiently filled bottles. When an incompletely filled bottle is detected by the sensors, it actuates the actuator to move forward. The actuator has a fixture to hold and carry bottle forward out from the conveyor.

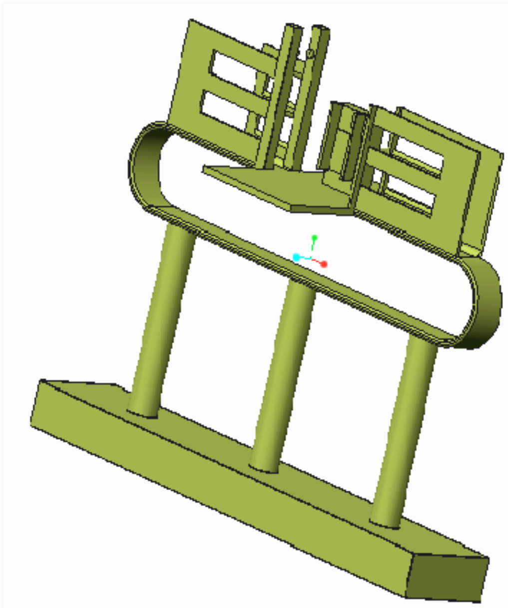

Fig 7- Pro-e model of Bottle Removal System.

Working of System

Initially water is filled in the bottles at filling station and bottles move towards capping station through the precision indexing conveyor. A cap is dropped on bottle head through cap dispenser mechanism, when moving towards capping station. A three-finger self-centering gripper moves the bottle from conveyor belt to the bottle bottom holder. The bottle is capped with the help of pneumatic torque wrench. Then another three-finger gripper moves the bottle from bottle bottom holder to the conveyor belt. The infrared level detection sensor senses the level of water in the bottle. If the bottle is insufficiently filled, it actuates the bottle removal actuator to move forward and take the bottle away from the conveyor belt.

Analysis

For checking the feasibility of proposed system it is necessary that the designed components should be analyzed for their functionality. Of the designed components, two critically important components are; three-finger gripper and bottle bottom holder. The fingers of the gripper should be strong enough to grip as well as to sustain the weight of the bottle. The jaws of the bottom holder should sustain the torque of the torque wrench and hold the bottle in its place during operation. Analysis of both the components are discussed below. Both these components are deigned in Creo Parametric 2.0 and validated using ANSYS Workbench 16.0.

1. Analysis of Three Finger Gripper

Structural analysis of a single finger of the gripper is done. The material selected for gripper is Al 7075. The approximate volume of water that the bottle can be filled is 1.30 liters .So, the weight of water in bottle is 2.87 lb and weight of water filled bottle comes to be 3 lb. The three fingers of the gripper should sustain the weight of the 3 lb filled bottle. So, the force acting of single finger of the gripper comes to be 1 lb. In this analysis, force of 1 lb is applied on the inner face of the gripper. The results for total equivalent stress and total deformation are shown in fig 8 and 9 respectively. The maximum stress acting is 5202.3 psi. The yield strength of Al 7075 is 21000 psi [7]. So the factor of safety is calculated.

F.O.S = Yield Stress/Maximum Stress [7].

F.O.S = 21000/5202.3 = 4.03

Thus, factor of safety is 4.03 which verifies that designed component is safe.

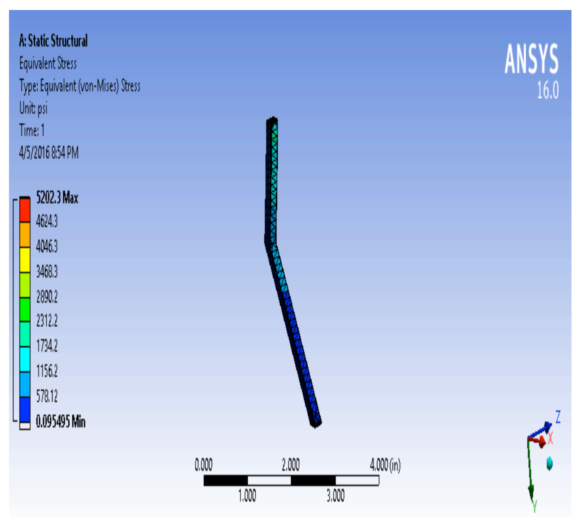

Fig 8- Result of equivalent stress analysis of finger of self-centering gripper using ANSYS

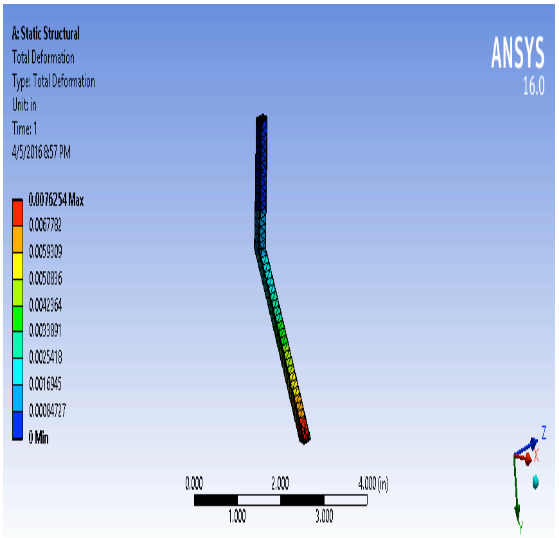

Fig 9- Result of total deformation analysis finger of self-centering gripper using ANSYS.

2. Analysis of Chuck of Bottom Holder

Structural analysis of jaw of bottle bottom holder is done. The chuck has to withstand the torque of the torque wrench. The value of torque taken for calculation is 20 lb.in. This torque is also transferred through to the chuck along the perpendicular length, which is equal to the height of bottle (10.23 in). This torque produces a force which would act tangentially outwards on the vertical faces of all three jaws [7]. The value of this force is 20* 10.23= 204.6 lb. So the force acting on a single jaw is 68.3 lb, rounded up and taken as 70 lb for this analysis. Analysis of the single chuck is done for this force. The results for equivalent stress and total deformation analysis are shown in fig 10 and 11 respectively. The maximum stress acting is 9840.2 psi. The yield strength of structural steel is 36259 psi [7]. So the factor of safety is calculated.

F.O.S = Yield Stress/Maximum Stress [7]

F.O.S = 36259/9840.2 = 3.684

Thus, factor of safety is 3.684 which verifies that designed component is safe.

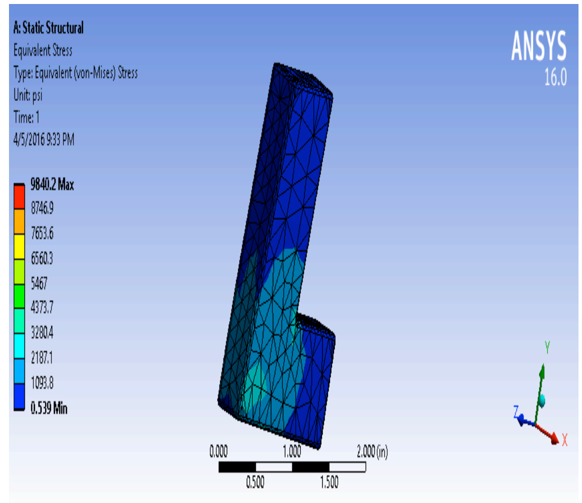

Fig 10- Result of equivalent stress analysis of chuck of bottle bottom holder using ANSYS.

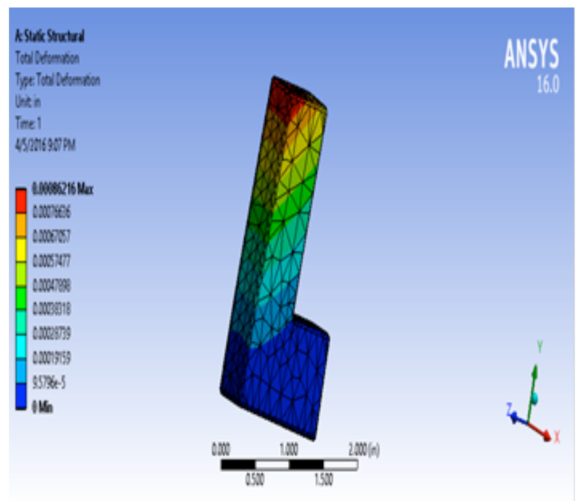

Fig 11- Result of total deformation analysis of chuck of bottle bottom holder using ANSYS.

Conclusion

The paper proposes a cost effective and automated model for capping the bottles, as well as detecting and removing insufficiently filled bottles. The various components discussed in the model are cheap and aptly suitable for the function which they are intended to perform. Stress analysis and deformation analysis of fingers of three-finger gripper and chuck of bottle bottom holder were done by ANSYS workbench 16.0. The factor of safety for both the components was found to be above two. Thus, this system would be very beneficial to small scale bottling plants with a low cost of installation and setup.

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