AUTOMATED HIGH SPEED ASSEMBLY MACHINE DESIGN

Murat Demirci
Graduate Student
School of Engineering
University of Bridgeport

Zheng Jeremy Li, PhD
Associate Professor
School of Engineering
University of Bridgeport

Abstract

Recent years, automation is still important for industrial world and in the global economy. Because of the global competition, industries started to look for new technologies and designs in automation field. There is no more enough time, energy and material to catch people needs for industries in nowadays. Thus, automated systems are becoming more interesting and important. The potential benefits of automated systems are reducing the cost of product, labor and waste; increasing the production quality, repeatability, work safety. In this paper, I describe the design steps of an automated high speed machine which is assembling the parts of a pen, according to manufacturing and production specifications. In the design project, automated system perform different kinds of process in assembly line, such as cartridge loading, point fitting, ink filling, plug fitting, gas charging and cap installing and final sealing. Furthermore, as our goals in project, automated machine must be cheaper, easier to maintain and working at "high speed" repeatedly. Working on the design project, it was really good experience to solve major design problems and to understand of engineering technology limitations in today's world. I concluded my paper with a description designing of an automated high speed system and its distinguished advantages.

Introduction

In current world, the population of humanity is increasing day by day. Simultaneously, people needs are increasing, as well. In order to catch this trend and to meet the people needs; design engineers created automated machines to produce more products in short times. Especially, high speed machines are able to do many these jobs less than a second. The new machines are more accurate, faster, more powerful, and more durable. They don't need to think, not to sleep, not to get a rest or eat.

The designing an automated high speed machine is required to consider many different design principals which are different than regular automated machines designing procedures. High speed machining brings different problems in design area; such as high accelerations and high decelerations, unpredictable forces and moments while machine is working, more repeats than normal machines due to high volume production, requiring more accuracy, right positioning and design materials and special environmental units.

In this project our task as a group is to design an automated assembly machine to assembly the high volume pen production parts; which include a point, cartridge, ink, plug, gas charging and cap; with the required principals in high speed machining keeping one thing in mind that the automated machine should be cheaper, easy to maintain and work at high speed.
We have divided this project to 5 steps;

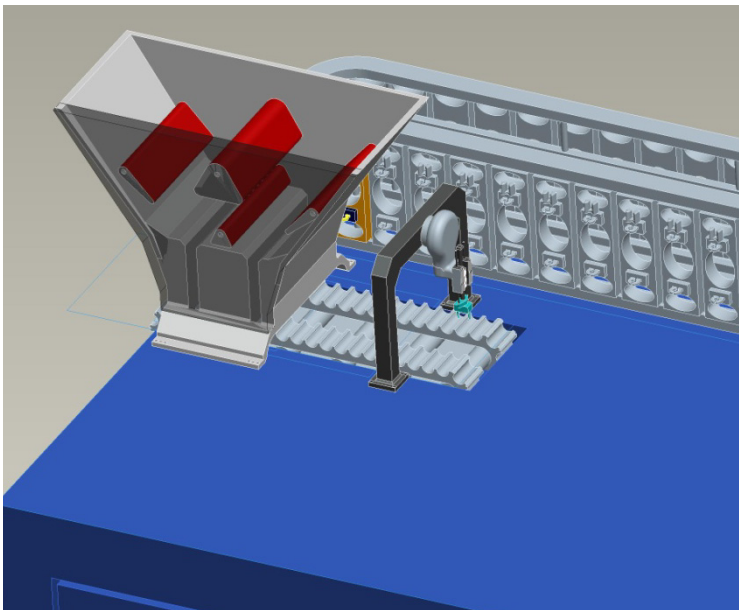
1. Loading the cartridge to the automated assembly machine. (Loading Station)
2. Fitting the point into the cartridge. (Point Fitting Station)
3. Filling the ink into to cartridge. (Ink Charging Station)
4. To obtain a pressure inside of the pen; charging air into the cartridge and closing tightly with a plug. (Gas Charging and Plug Fitting Station)
5. Using a cap to close the gap and sealing of cap. (Cap Inserting and Sealing Station)

Since it is a high speed environment care should be taken that all the design layouts and calibrations are accurate otherwise it would lead to a lot of damaged products.
To explain the entire process in brief;

- The first station takes care of picking up the cartridge coming from the vibration bowl and placing it in the fixture with correct orientation.
- The second station takes care of picking the points coming from the vibration bowl and fixing it on the cartridge. In order to hold cartridge, we use a special fixture. The fixture should be designed in such a way that it should be able to move to and fro along the assembly line at high speed and at the same time should be able to rotate the cartridge by 180 degrees for ink filling once the point is fixed to the cartridge.
- The third station is the ink filling station.
- The forth station takes care of the gas charging and plug fitting. Both these jobs have to be done at the same station.
- The fifth station takes care of the cap fitting and sealing and the seventh station is the final inspection of the finished product before it is packaged.

It should be noted that this is a high speed environment, so during all the assembly process, our stations must be working accurately and properly.

The First Station (Continuous Cartridge Loading)

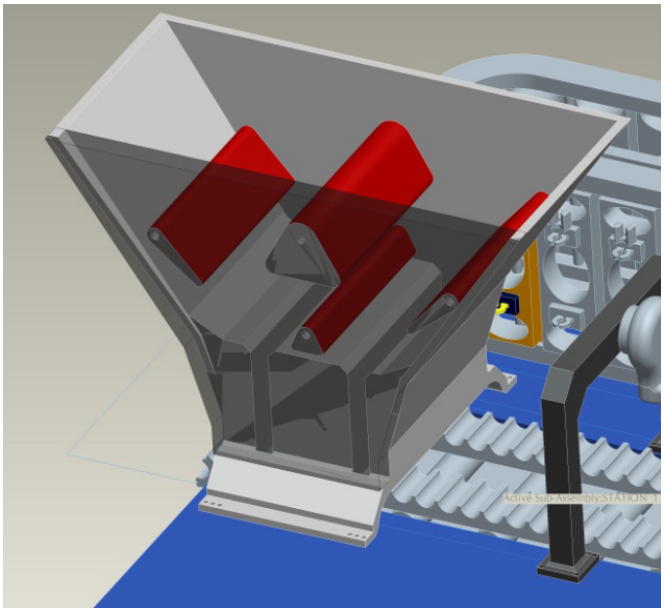


Station 1

Components for this station;

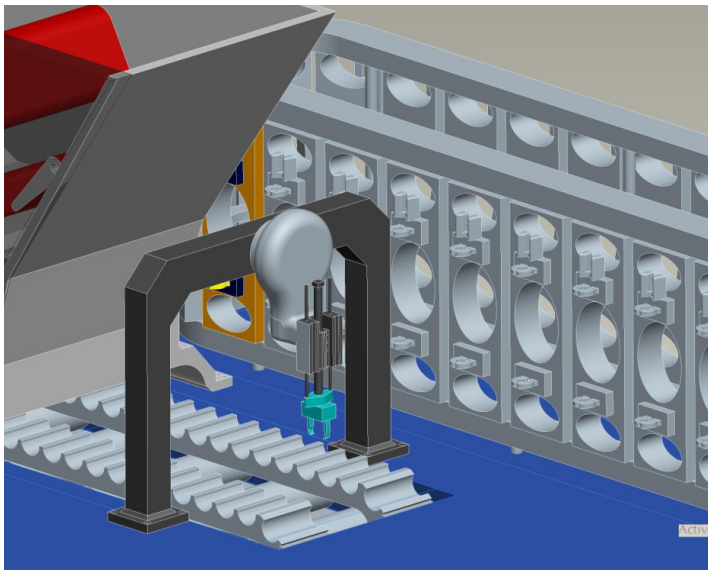
No	Name
1	Cartridge Hooper Machine
2	Metal Conveyor
3	Air Rotation Robotic Arm

We put the cartridges from the top of a pen cartridge hopper machine, and cartridges will drop from the top to the bottom. In the hopper, two side parts will hop up and down every two seconds to prevent any cartridges deadlock in the machine. At the same time, two vibration bars in the middle of the machine will vibrate themselves. Thus, pen cartridges will drop into the two tunnels in the bottom one by one. After the cartridge line in the tunnel, they will be release by every two second from the tunnel by a electro-mechanic stopper, and load into the metal conveyor.



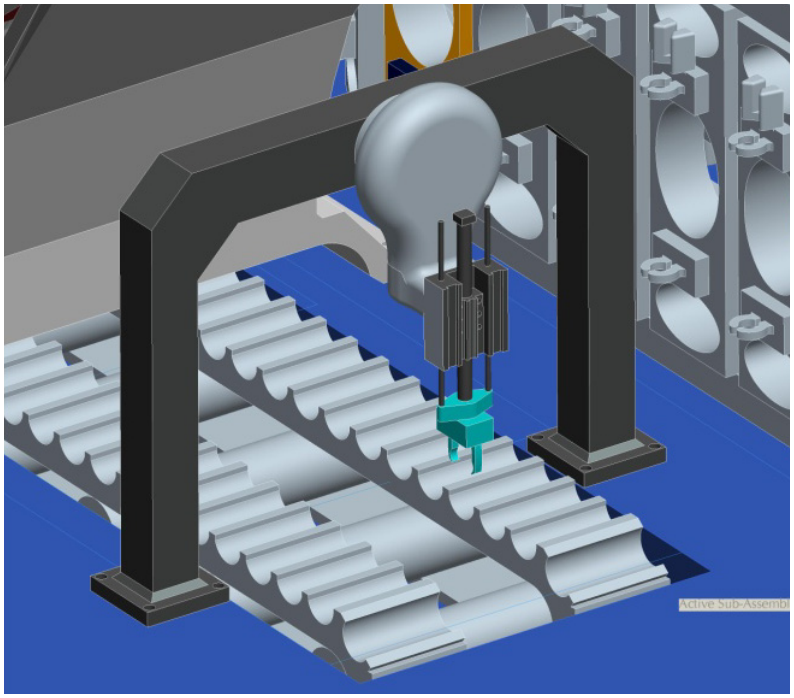
Cartridge Hooper Machine

When the pen cartridge was loaded into the metal conveyor by hopper machine, they will fall into the slots of the metal conveyor. The metal conveyor will carry the pen cartridge to the air rotation robotic arm, and the metal conveyor will stop for a moment to allow it pick-up. The robotic arm will pick up the pen cartridge and put them in the fixture. Simultaneously, two pen cartridges will also be release from the pen hopper machine.



Main Conveyor Line

Air rotation system will rotate the arm from the down to the front in 1 second. When the arm is down, the clamp arm will move down to the metal conveyor and it will clip a cartridge. Then the clamp arm will get back and the air rotation system will rotate the arm to the front next to the fixture. The clamp arm will move to the fixture direction and the fixture will clip the pen cartridge. Then, clamps release the pen cartridge in the fixture, and the arm will be pulled back.



Robotic Arm

The Second Station (Point Tight Fitting)

Components for this station;

No	Name
1	Vibrating Bowl
2	Metal Conveyor
3	Linear Actuator and Gripper
4	Pneumatic Pusher

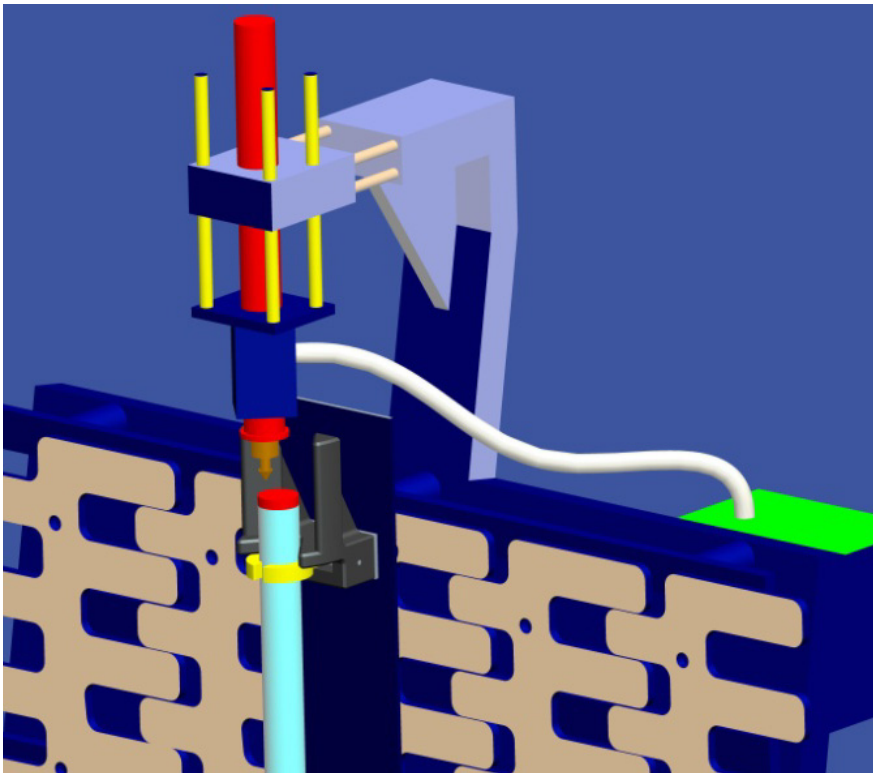
In this station; a vibration bowl; we are going to use is of a conical shape and it is used for supplying the plugs in correct orientation to the metal rail conveyor. The metal conveyor is used for transporting points from the vibration bowl to the place where point will be taken a gripper.

The process; a metallic point is fitting in top of a vertical cartridge. Every time, we need to be sure that point and cartridge both are the right position and orientation before the assembly process. Thus, we will design a special designed fixture on cartridge holder which has two support plates for proper alignment of gripper arm to fit the point on a cartridge and pneumatic pusher to push to point into the cartridge.

The Third Station (Ink Filling)

Components for this point;

No	Name
1	Micro Pump
2	Nozzle
3	Bush
4	Linear Actuator (Slider)

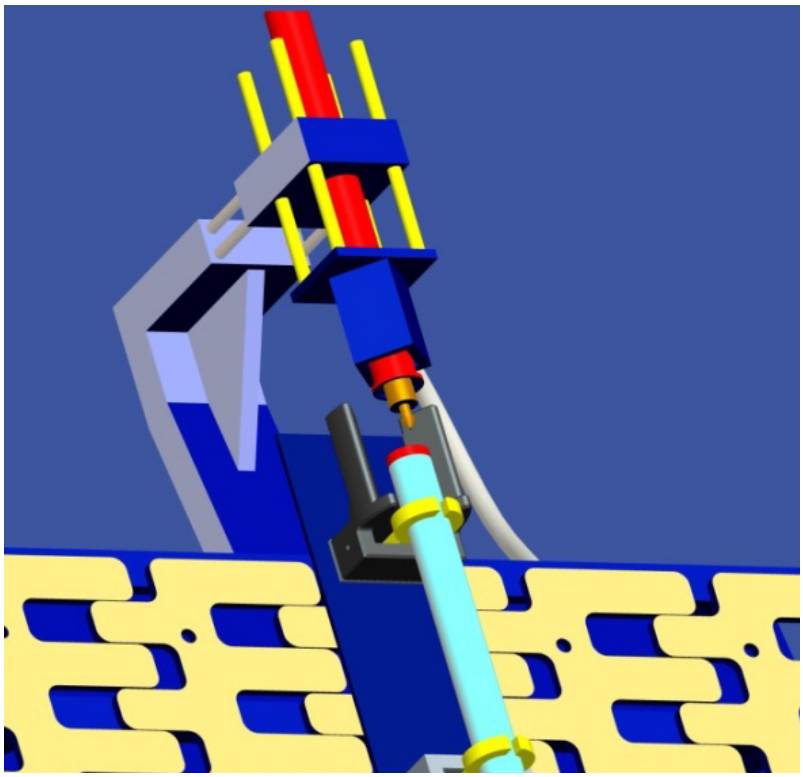


Nozzle Assembly Side View

The cartridge was initially brought to the ink filling station. Then we operate a horizontal slider so as to make the nozzle touch the two reference surfaces. This ensures that the nozzle axis is in alignment with the cartridge axis. The vertical slider is then operated to insert the nozzle into the cartridge. The ink is then filled into the cartridge. During the filling the ink is spread into the sides walls of the cartridge preventing the splashing of ink while filling process.

We use a timer based PLC circuit to control the flow of ink into the cartridge and retraction of the vertical slider. Since pump produces uniform and continuous flow, filling of cartridge takes certain amount of fixed time. The pump is only allowed to operate within this time interval by the PLC circuit. Then vertical slider returns back into its original position.

After the filling process is completed, in order to confirm the correct the level of ink we use two opposed mode sensor as shown in the figure below.



Nozzle Assembly Bottom View

Pump helps to deliver the sufficient amount of ink to the nozzle. The pump used in this case, however, has to withstand the high temperature of around 170°C. The flow from the pump is uniform and continuous.

The nozzle helps in filling the ink into the cartridge. For this purpose we use pressure overflow filling type of nozzle. A point to note is that we fill the ink by spreading the ink into the walls of the cartridge. In pressure overflow filling systems the product is pumped from a tank through a filling valve to the container. The filling valve contains an over flow tube to drain the excess product back to the supply tank and prevent overfill. The fill level of the container is determined by the depth of the overflow port within the neck of the container. When the product reaches the overflow port, the fill is completed, but the flow continues through the overflow tube until the seal on the container is broken and the valve sleeve covers the ports in the filling nozzle and stops the flow. The fill level will be the same regardless of bottle inconsistencies.

To ensure the leakage proof mechanism, we need to design a seal. The seal should not change its characteristics at high temperature of 170°C. Furthermore, since the material of the seal is plastic, we need to make sure that the outer surface of the cartridge is not damaged during the ink filling process. Thus the material of the seal should be such that it should be somewhat flexible to ensure the protection of the outer surface of the cartridge and it should also be rigid enough to ensure the leakage proof mechanism. Hence, we use powder metal for seal material which has all of the above mentioned characteristics.

The slider is used for linear vertical motion of the system. We use two slider in the system – one for horizontal motion and one for vertical motion. LC- series Slides are ideal for non-rotating light duty horizontal applications where some deflection can be tolerated.

The Fourth Station (Gas Charging and Plug Fitting)

Components for this step;

No	Name
1	Vibrating Bowl
2	Metal Conveyor
3	Retracting Pusher
4	Linear Numeric Actuator
5	Gripper
6	Compressor
7	Pressure Gauge

The goal on this step is to design a gas charging and plug fitting station. Should be paid more attention for both these operations are done at the same station otherwise the gas will escape in the atmosphere before plug fitting. We are going to use for this design are a branched nozzle for gas charging through one branch and inserting the plug through other branch. We also need to use a rubber seal to prevent the gas from escaping in the atmosphere once it is charged into the cartridge.

The various commercial parts that we use includes the vibration bowl for the plugs, conveyor for transporting plugs from the vibration bowl to the assembly station, retracting pusher to push the plugs from the conveyor into the nozzle, numeric actuator to push the plugs to correct height, gripper for holding the nozzle in position above the cartridge, compressor for gas charging and pressure gauge to check accurate gas pressure in the cartridge.

The cartridge comes to the gas charging station after ink filling. We have to take care of gas charging and inserting the plugs. Both these operations have to be taken care of at the same station otherwise the gas will immediately escape in the atmosphere as it is at high pressure. At this station the cartridge will be placed below the branched nozzle which we are using for gas charging and inserting the plugs. The branched nozzle is held in position by a gripper.

First the gas is charged from the compressor through one of the branched nozzle. The pressure gauge connected at the mouth of the cartridge checks for correct pressure in the cartridge and sends a signal to the actuator which in turn stops the compressor by a compressor cut-off valve. A rubber seal is placed around the nozzle to prevent the gas from escaping in the atmosphere once it is charged in the cartridge.

As soon as the gas is charged the next step is inserting the plugs in correct orientation. The plugs are brought in by a vibration bowl and through a metal conveyor to the station. The plug feeding is vertical as they have to be inserted in the same orientation. When a single plug reaches the end of the rail it is pushed in the nozzle by a retracting pusher. But this plug is still not in its correct location, as it is just resting at the edge of the cartridge. This plug has to be pushed from the top to its correct location with the help of a numeric actuator. This numeric actuator will guarantee right height for the plug.Thus the gas charging and inserting the plug is a very crucial step in this assembly design.

The retracting pusher is used to push the plugs coming on the conveyor into the nozzle. This pusher will be controlled by a timer PLC circuit which will retract to allow one plug to move at one time and push one plug at a time into the nozzle. The pusher should be controlled accurately for proper functioning of the station.

The numeric actuator will be placed vertically above the nozzle used for inserting the plugs. This numeric actuator will push the plugs to correct height once they are resting on the edge of the cartridge. The

numeric actuator will be controlled by a PLC controlled circuit and it will guarantee the right height for the plugs.

External gripper was used to hold the nozzle in position above the cartridge. This gripper will remain stationary throughout the assembly process. The fingers are strong enough to hold the nozzle in correct orientation during gas charging as well as during inserting the plugs.

Compressor is used to provide compressed air continuously to the cartridge to maintain the required air pressure in the cartridge. We have used a regular air compressor for this job.

The pressure gauge is used to check the correct amount of pressure in the cartridge. This pressure gauge will send the signal to the compressor about the amount of pressure and the compressor will cut-off through a cut-off valve. The correct amount of pressure is very important for the efficient working of the pen.

The Fifth Station (Plug Fitting)

Components for this station;

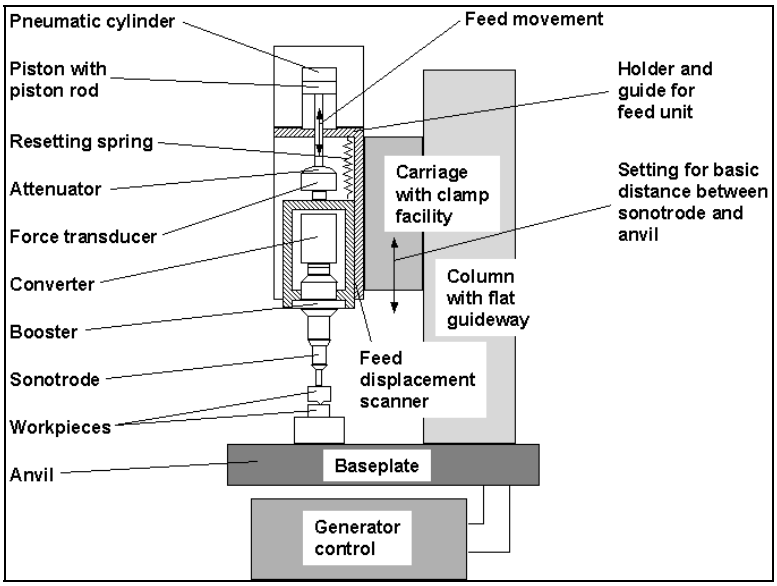
No	Name
1	Vibrating Bowl
2	Metal Conveyor
3	Retracting Pusher
4	Linear Actuator & Gripper
5	Ultrasonic welding unit

The various commercial parts that we use includes the vibration bowl, conveyor for transporting caps from the vibration bowl to the assembly station, stopper to allow a single cap at a time, gripper arm, pneumatic linear actuator or slider for a linear motion of a gripper arm and Ultrasonic welding unit for sealing of cap.

Vibrating conveyor moves block from vibrating bowl to the wire feeding mechanism. There is a one vibrating motor is used in this conveyor. There is a sensor eject to conveyor which maintain the position of the block. In order to stop the conveyor we use a mechanical stopper on a rail next to the Vibrating bowl. Caps are coming in proper orientation from the vibrating bowl and move on a rail which carries them near to the assembly line. On this rail we have fixed a mechanical stopper to stop and supply only one cap at a time and it is connected with PLC timer. So once the cap touch the stopper, after the time set on timer, a gripper arm will come and pick up the cap to the assembly line.

This sensor sense the availability of the block if the is a no block then it send the signal to processor and is give the signal to pusher so pusher will push one block ahead.

Gripper arm is used to pick up the cap from a rail and place it on a cartridge and hold until the ultrasonic welding will done. This gripper has two fingers with a same profile like cap and is operated with linear actuator or a slider. This arm is moves in horizontal as well as vertical direction. By moving in horizontal direction it will pick up a cap from rail and after that moving in vertical direction it will carries that cap to the assembly line and then again moving horizontally it will place the cap on a cartridge and hold it up to the next process. After placing a cap on a cartridge we have to fit the cap and seal it. And for that we have used an Ultrasonic welding unit.



Ultrasonic Welding

The ultrasonic welding of thermoplastic parts involves plasticizing the join partners by deliberately converting ultrasonic energy into heat under pressure in the join zone. The geometry of the join zone plays a crucial part in the conversion of ultra-sonic energy.

- Strengths of the Ultrasonic welding are as follow:
- Cost effective process
- Large batch-sizes are possible
- Very short cycle time

Conclusion

By this project, we got a chance about understanding of main criteria and principals of automated machine design and manufacturing. Moreover, approaching a problem by using engineering and design knowledge is extremely important experience for us. It will be really helpful in the future engineering problems.

We are also expecting to implement new units and techniques on our design by learning more new technologies.

Bibliography

1. PHD, Inc. (2000). Retrieved April 10, 2007, from http://www.phdinc.com
2. National Instrument, LLC. (2000). *Liquid Filling Equipment & Systems*. Retrieved April 10, 2007, from http://www.filamatic.com
3. Festo AG & Co. KG. (2007, September 11). *Festo* . Retrieved April 10, 2007, from http://www.festo.com
4. Vissers Sales Corp. (2000). *Micropump - Gear, Centrifugal, Piston, Vane Pumps*. Retrieved April 10, 2007, from http://www.micropump.ca
5. Lanco Inc. (2002). *Lanco Assembly Systems*. Retrieved January 3, 2008, from http://www.lanco.net/Grippers/LG2002.htm

6. Parametric Technology Corporation. (2000). *Product Lifecycle Management (PLM) Software Solutions*. Retrieved January 3, 2008, from http://www.ptc.com
7. Koshal, D. (1993). *Manufacturing Engineer's Reference Book*. London: Butteworth-Heinemann Ltd.
8. Lee, J. (1999). Modern Manufacturing. F. Kreith, Ed.*Mechanical Engineering Handbook* (Vol. 13). Boca Raton, Florida: CRC Press LLC.