Automated Coil Spring Sorter

By: **Gaurav Shetty**

N15748148

Submitted in partial fulfilment of the degree of

Master of Science (MS) in Mechatronics and Robotics

New York University

Mechanical and Aerospace Engineering

May 2018

MEGY 9966

Acknowledgement

I would like to thank Professor Vikram Kapila for introducing me to a current scenario in the spring manufacturing industry and sharing his ideas on coming up with a mechatronic solution to simplify the existing process. I would also like to thank Dr Mizanoor Rahman for timely checks on the progress of my project and guiding me on a professional path. The Makerspace at NYU Tandon School of Engineering was a very useful resource for the construction and assembly of my project. My fellow colleagues in my class were a great source of information and brain-storming to tackle problems and move forward with my project.

Table of Contents

Motivation

Manufacturing automation has been common since the 1970s. Advances in technology, including robotics, big data, machine learning, artificial intelligence, and the Internet of Things have improved factory production since then. By improving age-old designs and robotics hardware, businesses can save money and free up valuable factory or warehouse space. Effective as well as efficient design of mechatronic systems are fundamental prerequisites for competitiveness in a harsh industrial environment.

Abstract

The aim of this project is to design a mechatronic solution to ease the transition between two consecutive steps of the coil spring production process. The springs are produced by a coil forming machine and then transferred to the grinding machine where the top and bottom surfaces of the springs are grinded down as a finishing step. The layout of the factory has the coil forming machine and the grinding machine at different parts of the factory, separated by a distance.

In the current scenario, the springs produced by the coil forming machine are collected and transferred in batches to another part of the factory where they are manually loaded into cartridges placed on the rotating grinding table. My solution is to design a unit which automatically loads the springs from the coil forming machine into a modified cartridge which holds the springs during its transfer which is then placed on the rotating grinding plate for the finishing process.

Spring Sorter Design

The structure consists of support bed which moves on a XY Cartesian plane controlled by two NEMA-17 stepper motors, similar to that of a 3D-printer. A PVC tube replicates the feeding shaft via which the springs will be released into the cartridge. The release of the springs is controlled by 2 mini push-pull solenoids, which is timed to release the springs accurately. A Logitech camera is used for image processing using OpenCV which will determine if the springs have been fed into each space in the cartridge.

Cartridge Design

The traditional design of the cartridge involved a wooden cuboid with rows of cylindrical holes going through which holds the springs such that the top and bottom surface of the springs protrude above the wooden cartridge which allows for them to be grinded down.

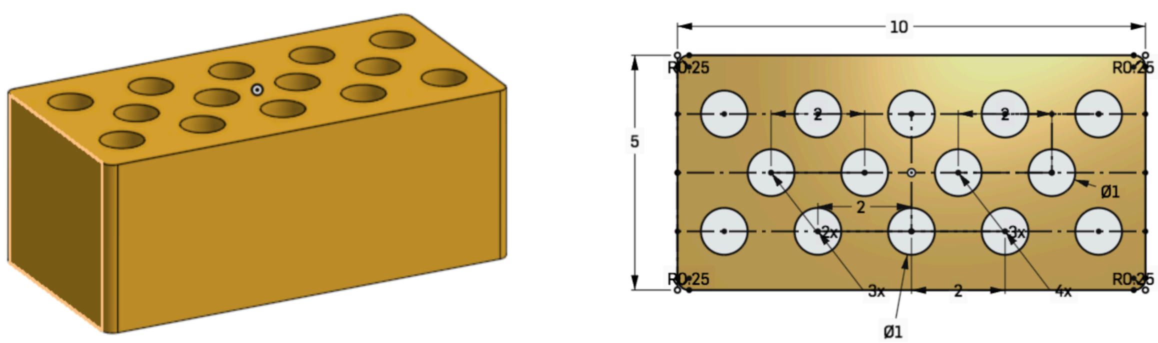

Figure 1: Traditional wooden cartridge

The modified design of the cartridge consists of two parts –

1. The top portion of the cartridge is the traditional structure of the cartridge with cylindrical holes running through and has grooves located close to the bottom running along its breadth
2. A movable support is supported on the grooves, to the bottom surface of the cartridge which replicates the positions of the holes of the top portion. It moves horizontally on the grooves, perpendicular to the axis of the cylindrical holes.

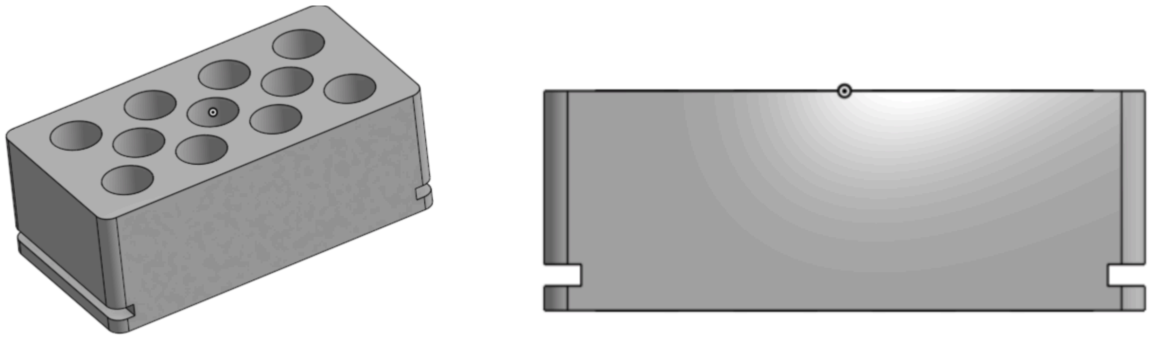

Figure 2: Top portion of modified cartridge

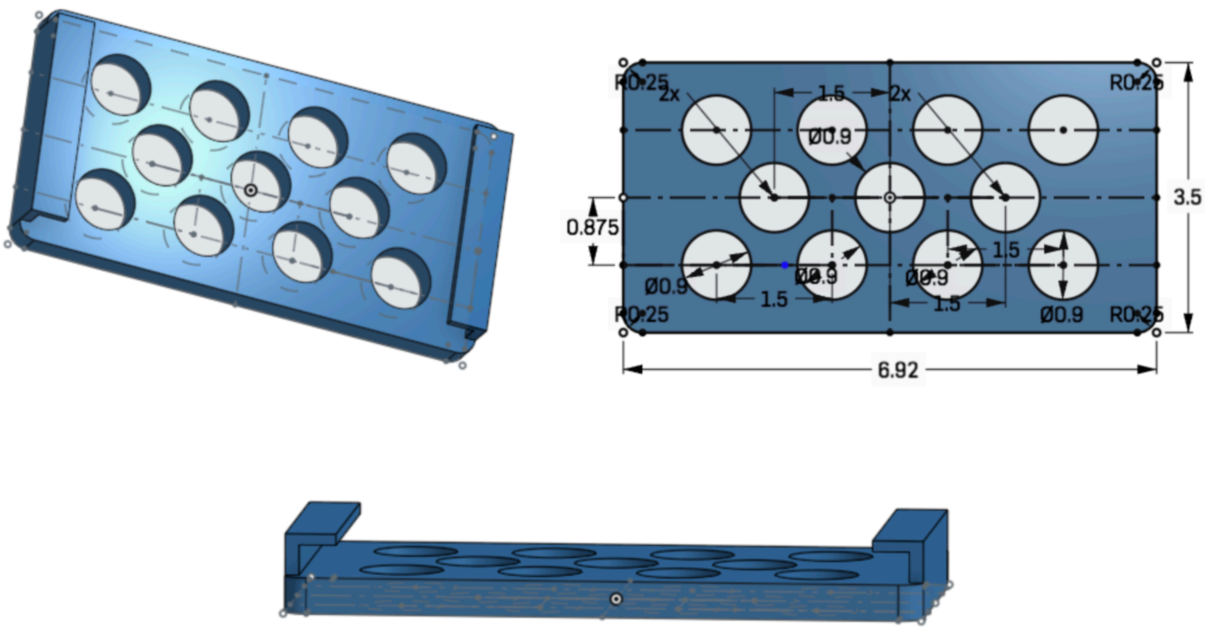

Figure 3: Movable bottom surface of modified surface

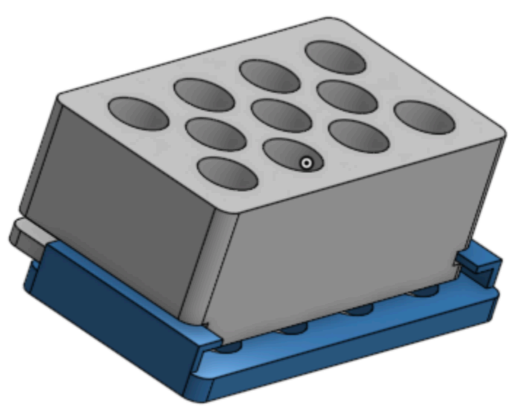

Figure 4: Modified Cartridge

Hardware

Structural Components –

The base of the test bed consists of two movable planes, X and Y axes respectively. The NEMA-17 stepper motor drive shaft is connected to an 8mm steel rod with a shaft coupler. This steel rod consists of 2 timing pulleys on its either ends and driving belts connects this driving rod to another steel cylindrical rod located 12 inches away. On each driving belt, a tensioner is placed with a connecting rod attached between them. As the stepper motor rotates the driving rod, the connecting rod fixed to the tensioners move back and forth to allow for translation on the X axis direction. This setup is replicated with another set of belts, pulleys, rotating cylinders and tensioners to generate motion on the Y axis.

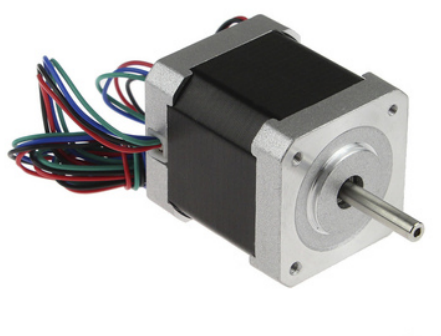

Figure 5: 12V NEMA-17 Bipolar Stepper Motor

Figure 6: Driving belt pulley with 8mm diameter shaft

Two linear motion ball bearing sliding bushes slide along each connecting rod, their motions perpendicular to each other, on the X and Y axis respectively. These two sliding bushes are fused together by cold-welding them. A 3D printed base plate which holds the cartridge is screwed into the top of the fused sliding bush arrangement. This fused arrangement allows the base plate to move as a whole along the two axes. The base plate has support struts which hold the cartridge in place while its being filled with springs.

Figure 7: Driving belt tensioner

Figure 8: Linear motion ball bearing sliding contact

A set of ball bearings are attached to the bottom end of the fused sliding bush arrangement such that it is in contact with and moves around on an aluminum plate on the surface of the spring sorter base. This prevents the base plate from sinking when weight is applied on it, and hence reduces the friction which could be generated by the above effect.

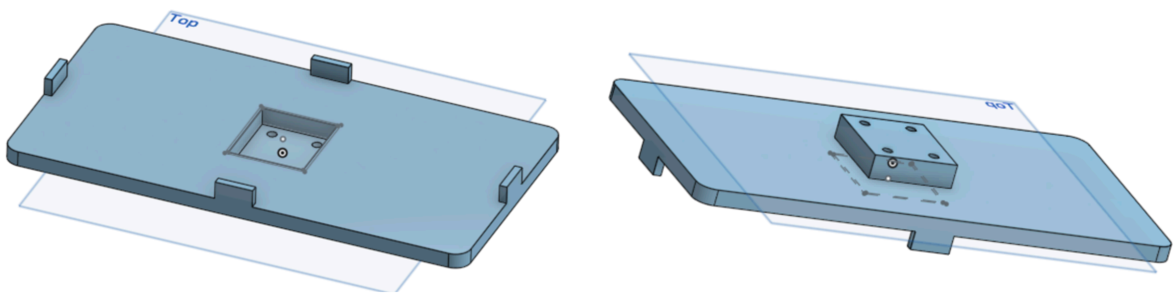

Figure 9: 3D Printed Base plate

Spring Feeding System -

The springs are loaded into the corresponding holes of the cartridge using a feeding tube with a pair of mini solenoid valves controlling the timely release of the springs. The springs produced by the coil forming machine move down a wire guide and into the feeding tube. The pair of mini push-pull solenoids behave as valves by extending and compressing alternatively and hence release consecutive springs uniformly. A PVC tube is used in this test to replicate the feeding tube. The mini solenoids are housed in a 3D printed casing in which the solenoids are spaced apart such that they are separated by little more than the length of the spring.

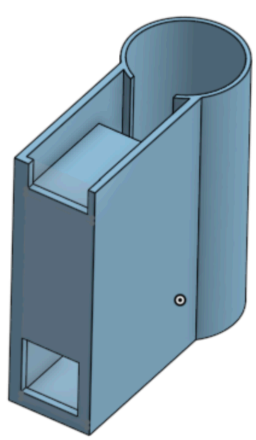

Figure 6: Mini solenoid housing

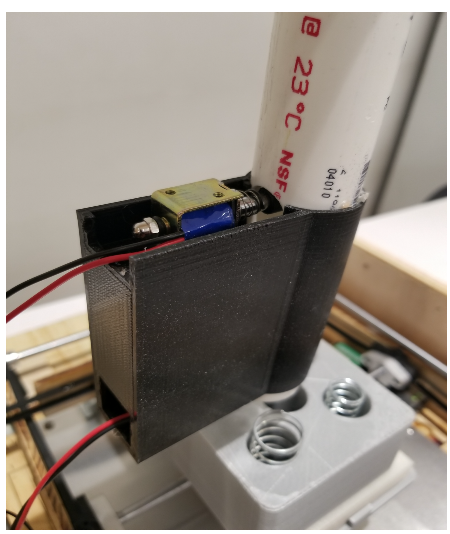

Figure 7: Spring Feeding System

Controller -

An Arduino Mega 2560 board along with a Stepper motor shield is used to control the stepping of the two stepper motors. An external 12V power supply is directly fed into the motor shield power terminals.

The bipolar stepper motor used has a motion of 1.8 degrees per step or 200 steps for one revolution with a holding torque of 40N*cm. It is possible to vary the stepping action in different ways simply by changing the sequence through which stator windings are energized. The following are the most common operating or driving modes of stepper motors.

1. Wave step
2. Full step
3. Half step
4. Microstepping

The main advantage of microstepping is to reduce the roughness of the motion. The only fully accurate positions are the full-step positions. The motor will not be able to hold a stationary position at one of the intermediate positions with the same position accuracy or with the same holding torque as at the full step positions.

Camera –

A Logitech 2 MP autofocus camera is used for image processing using opencv. The objective is to use the camera to detect the empty holes of the cartridge and ensure all the holes are filled with springs. The trend of using vision systems is ever increasing in the industry because of the advantages such as real-time tracking, interoperability and a large array of image processing techniques which can be implemented based on your desired operation.

Software

Motor control logic -

Image processing with OpenCV -

Tests and Results

Conclusion