Low Friction Feeder of Enhanced Specular Reflector Material for CMS Detector

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***Abstract* — With significant advancements in the field of particle physics, continuous upgrades to the sensors and machines used are necessary. One of those upgrades is the manufacturing of scintillator tiles for the CMS detector, which requires the punching and folding of 3M enhanced specular reflector (ESR) material. Feeding the material into the die punch manually for thousands of tiles can prove to be a daunting, time consuming task. Significant automation of the task can realize cost savings in both time value and reduction of waste material. A machine was designed to transport strips of the ESR material into the die punch, all the while taking into consideration issues with strips sticking together, strips being scratched during transportation, and strips being damaged by folding/bending/creasing.**

Keywords – Scintillator, pick and place, suction, conveyor

I. INTRODUCTION *(HEADING 1)*

Scintillator tiles are small plastic tiles that, when particles are passed through, produce light. The light produced can then be measured to investigate properties of the particle which passed through. These tiles are wrapped in a reflective material (ESR) that helps to contain all the produced light so that measurement of the light is both easier and more accurate [2].

These scintillator tiles are used in the Compact Muon Solenoid (CMS) calorimeter at CERN to measure the trajectory of high energy particles immediately following an extremely high velocity collision between two particles in the large hadron collider (LHC) [1].

The ESR material, produced by 3M, has a nominal reflectance of greater than 98.5 percent. To maintain this level of reflectance, great care needs to be taken in handling the ESR material, including the avoidance of abrasion, creasing, and dirt or oil getting onto the material.

The vendor of this ESR material, 3M, changed from manufacturing rolls of the material to manufacturing only sheets of the material. This meant that to feed the die punch, a mechanism for selecting single, thin layers of material and feeding those thin sheets into the die punch needed to be designed.

II. MATERIALS AND METHODS

A. *Design Requirements*

A comprehensive list of requirements for the design was crafted early in the process. First, the product must be able to feed ESR strips into the die punch without damage to the strips. This is a basic requirement that shaped much of the final mechanism design. Second, the product must be able to feed the product with little to no input by an operator, who would remain nearby for observation and reloading of the machine but would not be continually feeding the machine. This also shaped much of the mechanism design. Third, the machine must be able to feed at a sufficiently fast rate such that the die punch and folding portions would not be waiting on the feeder, which quantitatively means approximately 1 die punch per every 5 seconds. The last primary requirement for the machine was full integration into the existing die punch and folder both mechanically and electronically.

B. *Mechanism Design*

A review of existing products used for feeding materials into another machine, especially materials that are thin or delicate, was done. A patent was found for a suction-based pick-and-place machine used for processing and transferring a thin film material [3]. Other mechanisms that used the idea of a firearm magazine-like holding devices for feeding were considered, but ultimately inspiration was taken from the suction-based design due to the performance gains in reduction of damage, reduction of operator input requirements, and the ability to still feed at a sufficiently fast rate. In addition to the suction-based design, a conveyor was needed for fully feeding the material into the die punch. After cost considerations, a belt conveyor was chosen over a roller-based conveyor. A pinch roll mechanism was added at the end of the conveyor for tight control of the linear feeding of the ESR strips.

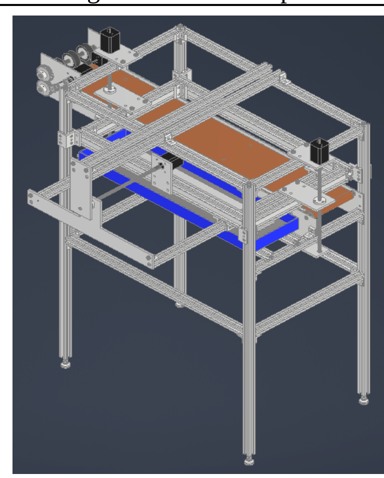

Figure 1: Suction-Based Feeder with Belt Conveyor

C. *Controls and Electrical Design*

Failure points and safety need to be taken into consideration for all designed mechanisms. The suction mechanism is prone to failing if a sheet fails to be picked up by the vacuum cups for a variety of reasons, such as significant dust being introduced, failure of vacuum system, etc. For this reason, an infrared proximity sensor is used for detecting if a strip has been picked up from the strip holder, so that the system may return to the sheet stack and attempt to pick up a sheet once more. The conveyance system is also prone to potential failure if a sheet is somehow jammed and is not being fed into the die punch. To avoid this problem, another infrared sensor is included to detect the feeding of the sheets into the die punch.

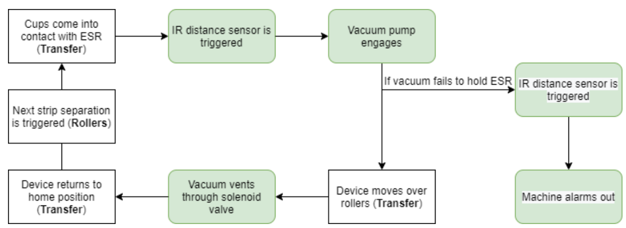

Figure 2: Block Diagram of Suction Subunit

During controls design, both a CNC and an Arduino-controlled system were considered. The Arduino was chosen for a few reasons. First, it is cheap, simple, and has existing libraries for driving steppers, reading sensors, and other various functions. Second, Arduino has been proven to be robust in not only fabrication of prototypes, but also basic, fully functional machines. Lastly, it was chosen due to its compact size and easy of mounting.

D. *Materials*

To accomplish a sufficiently high rate of feed speed while simultaneously focusing on reduction of cost, aluminum was used in much of the machine. This choice was combined with NEMA 17 stepper motors with a holding torque of 65 N.cm. It was used for the entirety of the lifting and translation systems, as well as all portions of the suction system where possible. The frame and support structures for all systems were built out of 1” square extruded aluminum profiles. This material was chosen primarily for its ease of use and significant strength. Aluminum plates were used for the lead screw translation system, along with steel lead screws and bronze bushings for all rotating components.

The suction system requires a delicate touch. To achieve this, silicone vacuum cups with bellows that allow easier compression of the cup were chosen. These vacuum cups are often used in the food industry for picking up items with variable height. This is beneficial for this machine, considering the strip holding device will be slowly depleted of strips, meaning there will be variable height product to be moved.

For the conveyance system, a neoprene belt was chosen to avoid scratching, and soft neoprene-coated rollers were chosen for the pinch rolls, to reduce scratching and increase grip on the strips. To avoid significant wear on the rotating shafts, bronze oilite bushings were chosen due to the low rotational velocity and low load required. The pinch roll drive was managed using a set of steel gears, chosen primarily for longevity with low wear.

E. *Manufacturing Methods*

Fabrication processes for this machine were straightforward. The production of the entire frame was done with the use of a simple bandsaw, due to the choice of extruded aluminum bars as the frame. Production for all aluminum plates was done using a waterjet cutter as well as drills and reams for any holes with tighter tolerances, such as those that held bronze bushings for rotating shafts. The production of all other parts that required any significant amount of machining were done using CNC mills as well as CNC lathes. Lathes were used to manufacture the rolls for the conveyor, for example, and mills were used for production of take-up bushings for the conveyor. Some fused deposition modeling additive manufacturing was used to fabricate small mounts for sensors, controllers, and other electronic equipment as well.

III. Conclusion

In summary, creating a machine which aids in the automatic die punching of thin, delicate sheets requires careful systems design and proper integration of a variety of devices from multiple manufacturers into a cohesive machine. The full system consisted of devices such as stepper motors, infrared sensors, vacuum solenoids, vacuum cups, conveyor belts, and multiple other mechanical as well as electrical components requiring careful selection and integration into the machine.

With this design in use, all design requirements can be met, including a sufficiently fast feed rate that will not allow backing up of the machines downstream of the feeder, minimal input by an operator, and delicate handling of the strips to avoid damage to them.

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