Broadhead Assembly Optimization

Group: Xuan Thang Bui, Sawyer Greaves, Abdiqadir Ibrahim, Andrew Kennington
Advisor: Dr. Jiyoung Chang

Department of Mechanical Engineering
THE UNIVERSITY OF UTAH

Introduction

Our team was tasked with continuing the development of the automated broadhead manufacturing device for Grim Reaper Broadheads, a project initiated last year. The device is designed to take a variety of loose ferrules as input, then heat and coat their threaded ends with nylon powder, and output the finished, coated product.

Problem

In archery, broadhead performance and safety depend on the secure attachment of the ferrule to the arrow shaft. When released, the broadhead is subject to vibration which will loosen it, affecting the aerodynamics of the arrow. The solution to this problem is adding nylon coating powder to ensure better stability within the threaded arrow. Although the solution seems easy – the real challenge is heating the surface of the ferrule to the nylon's melting point and automating the whole process to reduce manual labor.

Heating Analysis

To ensure success, the broadhead manufacturing device must heat the broadheads to 300 degrees Celsius in a three second interval. Through research, we found that an induction heater will be able to accomplish this task. The desired temperature and frequency required for the induction heater were calculated using the following equations:

$$T_{corr} = T_{final} - 20℃$$

$$p_{corr} = p_{20℃} \ * (1 + w * \Delta T_{corr})$$

$$f = \frac{p_{corr}}{\pi \mu_r \mu_0 \tau^2 * 0.0625}$$

Pneumatic System

- Vacuum component to remove excess nylon
- storage containing nylon
- Sprayer mechanism – connected to the storage to spray nylon
- Pneumatic controller to control the sprayer and vacuum pressures

Final CAD Model Design

Figure 1. CAD model of the fully integrated broadhead assembly device, illustrating the complete configuration of the vibratory bowl, induction heater, and the pneumatic subsystem consisting of a nylon sprayer and a vacuum.

Electrical Design

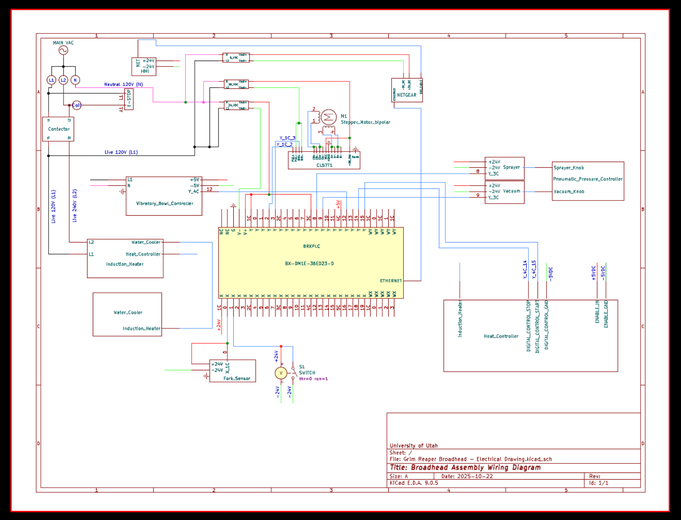

Figure 2. Electrical diagram of the broadhead assembly device.

Final Product

- Threads still intact
- Nylon coating over ferrule
- Desired cycle time achieved – will result in 7,200 coated broadheads in a single working day

Results

Heater: From the analysis, we found that the required frequency from the induction heater is 2 KHz. This frequency will be enough to heat the aluminum ferrules to 300 ºC in three seconds.

Broadhead Movement: The quantitative data gathered from testing demonstrates proper system performance, reliability, and efficiency. All the subsystem components operated as expected. The bowl vibrated enough to reduce the time it takes for a ferrule to exit the bowl. The stepper motor completed one rotation (from hole to hole) in one second (while accounting for the 3 second heating cycle). The fork sensor successfully alerted the PLC when a broadhead dropped into a slot on the rotary table. Finally, the switch successfully alerted the PLC once the stepper motor completed a full cycle.

Nyon Sprayer: After iterating valve opening time and air pressure, the pneumatic sprayer was able to consistently dispense the intended amount of nylon coating onto the threaded portion of the ferrules.

Table 1. Design metrics vs system performance values

Metric	Target Value	Average	Standard Deviation	Range
Rotation Speed (hole to hole)	1 second	1 second	0 seconds	0 seconds
Nylon Mass per Spray	0.25 grams	0.25 grams	0.0289 grams	0.05 grams
Vibratory Bowl (Ferrule Lead Time)	75.4 seconds	30 seconds	0.5774 seconds	1 second

Conclusion

After an extensive period of prototype testing and revision, our team has demonstrated the ability to meet the desired design metrics as agreed upon by our sponsor and ourselves. The rotary ring, vibratory bowl, and orientation system all work quickly enough to keep us within our desired cycle time of four seconds. We have assumed three seconds of that time to heat the ferrule, based on testing results from the supplier of our eventual induction heater. The project was a success.