Automated Edge Rounding of Steel Sheets

Senior Design Project for CST Industries

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***Abstract* — The purpose of this project is to propose a device for CST Industries that can round the edges of their steel sheets of various gauges and dimensions. Ultimately, the team's research and proposed designs have allowed CST to move this project forward more quickly. The team has proposed a CNC milling device that will consist of four major systems: The Milling system, Adjustment System, Tolerancing System, and the Support/Guide System. These systems will work together to allow the device to round the edges of all of CST's sheets in a more efficient and cost-effective manner. Based on the team's recommendations, CST contracted a custom machine designer to get the bulk of their CNC device fabricated. Using a contractor will allow CST to use the team's effort and research to guide a company whose main service is building these types of systems. CST plans to have the team's system fabricated and installed over the summer.**

I. Introduction

CST Industries is a worldwide company that produces industrial storage silos for bulk materials. CST uses a proprietary enamel to act as paint and defend the sheets from harsh weather conditions. However, the enamel cannot be effectively applied to surfaces with sharp geometry. In order to ensure that the steel plates that make up the silos will be capable of receiving the enamel, all the edges of the sheets must be rounded. CST currently does this rounding using a combination of sanding, rolling, and hand beveling depending on the gauge of the sheets. However, this is very costly due to the time and manpower required to use the rolling and beveling systems. Alternatively, CST's sanding operation is completely automated and far more efficient. The problem with the sanding system is that it is only able to round the edges of CST's thinnest gauge sheets. The end goal of this project is to incorporate a bulk material removal process into the sanding line in order to round the edges of all gauges of material.

II. Material Specifications

Table 1. shows the required radius for each sheet gauge manufactured by CST [1]. These are the radius requirements that CST has determined will allow the enamel to effectively adhere to the sheets. The final system must create these radii on the sheet corners in order to be acceptable to CST.

Gauge size (in)	.228	.262	.293	.322	.354	.375	.438	.500
Req. Radii (in)	.125	.125	.1875	.1875	.1875	.1875	.1875	.250

Table 1: Gauge Size versus. Required Radius (in)

III. Sanding Line

CST Industries currently uses a conveyor belt system utilizing sanding machines to remove the sharp edges on the thinnest gauge steel panels. These belt sanders are mounted at a 45-degree angle with the backing plate removed so that the belt conforms to the edge of the sheet, creating the desired rounded profiles. There are two sanding machines on each side of the conveyor system to round the top and bottom of the sheets at the same time.

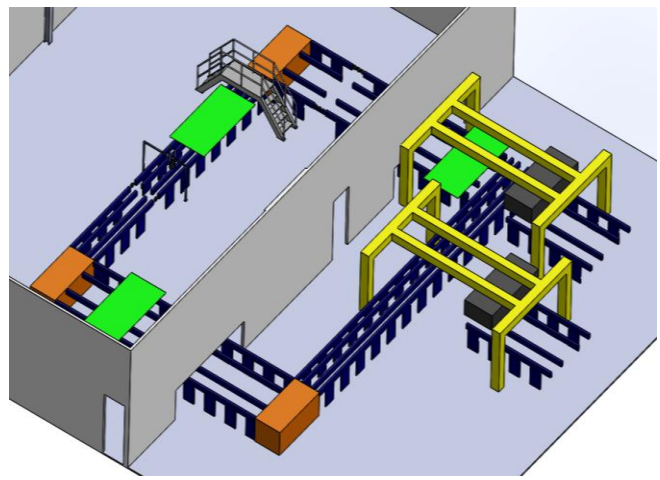

Figure 1 - Sanding Line Layout

The system does not rotate the sheets throughout the rounding process, instead it uses a combination of conveyors and moving wheels to translate the device around the system. The system can complete the sanding process within the first half of the conveyor line. The second half of the line is where the team's optimal design will be implemented to accommodate for the larger gauge sizes.

IV. Proposed Solution

A. *Milling System*

This system will include a high-powered spindle on both sides of the sanding line to round the edges of the sheets. As per our calculations, it was found that three horsepower is the power requirement to achieve the desired material removal rate [2]. These spindles are implemented to accommodate for the larger gauge sizes that cannot be handled by the sanding belts alone. Four spindles are necessary to achieve the desired profile on each side of the rectangular sheets. These spindles will be fitted with internal radius cutters to remove material from the panels. This will create a profile that will be desirable for the enameling process.

B. *Cutting Tool*

Each different panel gauge requires a different sized milling bit in order to accurately remove the corners. After numerous meetings with professional machinists and representatives from tooling companies, the conclusion that was drawn was that an indexable carbide milling bit would be best for this application. This is because the milling head and cutting indexes are separate. When the indexes wear down, they can be easily replaced. This is much more cost effective than replacing the entire cutting head, which is the case with solid carbide bits.

C. *Actuation System*

To allow for treatment of the full variety of different panel sizes and gauges, the milling spindles must be adjustable to align with each corner. To accomplish this, the milling spindles are mounted onto linear actuators, similar to a CNC system. This system will need to move the milling system, tolerancing system, driven wheel, and guide rollers to accommodate for the full range of sheet sizes.

D. *Tolerancing System*

The raw steel sheets that CST receives are not perfectly sized or squared due to manufacturing tolerances. In order to accurately remove the sheets' corners, the actual profile of the sheets must be known. A spring-loaded roller follows the profile of the sheets as they pass by on the conveyor. The distance that the roller deflects is recorded and passed on to the actuation system. This allows for the surface profile to be perfect regardless of the original geometry of the sheets.

E. *Support/Guide System*

After the main systems of this device, there are still two major hurdles that need to be addressed. The first is reducing chatter within the system. Milling bits used for bulk material processing need to be incredibly rigid. Chatter within the system will cause the bit to collide with the sheet in undesirable ways, drastically reducing tool life. To combat this, rigid support rollers will be aligned with the spindle in order to hold the sheet in place as it moves through the mill. A second structure will also be built to add rigidity. This will be a large motor-driven guiding wheel that serves two purposes. The first being support and the second is to help pull the steel sheet through the system against the added friction of the milling and guide systems.

V. THE FUTURE

There is still work to be done on this device going forward. The construction of this device is being outsourced to a custom automation/robotics company called Vention. They are using their expertise in the creation of custom CNC equipment to fabricate the proposed structure and actuation system. Although the optimal tooling for this project has been established, finding the right tooling distributor is key due to the need for custom bits with complex geometry. The effects of this tooling dilemma ripple into the rest of the device. The major effect of this problem is that tooling will define the final milling spindle used in the device. This leads to a problem where it is unknown how the milling spindle will be mounted. Therefore, the design of the adjustment system is difficult. However, work has been done with Vention to allow for custom fixtures to be mounted to the device after tooling has been finalized. This will allow Vention to continue the production of the device while CST determines a tooling contractor without either party being hindered by the other.

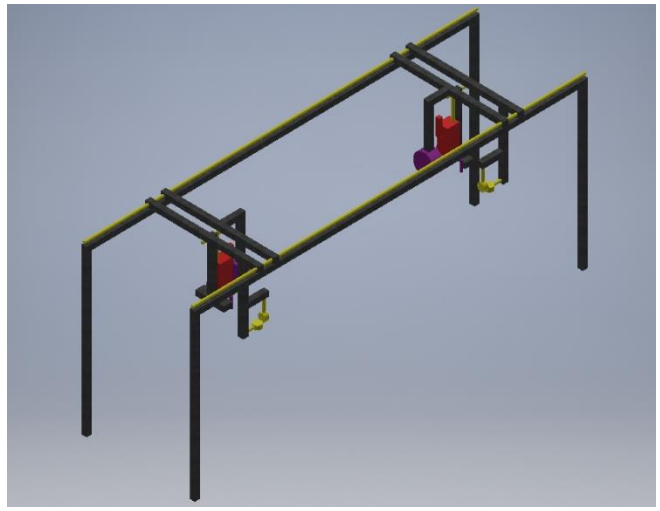

FIGURE 2 - PROPOSED DESIGN FOR FINAL DEVICE ASSEMBLY

VI. CONCLUSION

Ultimately, once constructed, the proposed device should be able to accomplish the task set out by CST industries. The proposal submitted by the team has moved CST forward in their ability to streamline their edge rounding process. CST is in a position where they will be able to have the CNC device itself constructed by an experienced company who is more than capable of satisfying their needs. The only work left in the hands of CST is to find the proper tooling contractor to produce the optimal cutting tools.

VII. ACKNOWLEDGMENTS

The CST team helped in any way they could when the team was discussing the current system. The team would like to thank the CST team for making it to our weekly progress meetings promptly and with an eagerness to achieve success.

Team #40 would like to also thank Dr. Gau and our teaching assistant, Ian Gilmore, for guiding the team throughout the project. They helped point the team in the right direction when things were difficult. Dr. Gau was able to connect the team with a contact at the machine shop who gave the team very useful information. They were both very knowledgeable and supportive throughout the year.

VIII. REFERENCES

[1] "Sheet Steel Edge Coat Radii Requirements", CST, Columbian Steel Tank Industries, 2020.

[2] Kalpakjian, Serope, and Steven R. Schmid. *Manufacturing Engineering and Technology*. 6th ed., Pearson, 2009.