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Optimizing the Utilization of Remnant Sheet Material Through Inventory Tracking

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Abstract: Amphenol is regarded as one of the top global providers of high-performance interconnected solutions in various industries and applications such as lighting, transportation, telecommunications, and more. With an emphasis on busbar production, Amphenol's Enidcott location is seeking to improve their system by optimizing the utilization of remnant copper sheets and aiming to reduce waste, increase efficiency and save costs. Following an analysis of their manufacturing process, there is a need for an integrated system that tracks the usage of their remnant sheets and makes use of existing programming software in their facility. The system aims to shift from an estimated system of material usage to a proposed programming and tracking GUI for systematic batching and sorting. Application of the system will result in a maximized use of their material consumption, leading to a more cost-effective manufacturing process and improved organization.

Keywords: Nesting, GUI, Inventory Management, Waste Reduction

1. Background

1.1. Introduction

Amphenol IPC's current process has been in production for approximately three years; this new site specializes in low volume manufacturing and the customization of parts. As a result, every job is intrinsically different and standardization of production is difficult. The production of busbars, conductive metal strips that carry high currents, hold setbacks in the management of copper sheets used in production. Currently, the start of the process flow allocates copper inventory to the water jetting process for initial shape cuts. The process involves assigning weight measures to the inventory and manually nesting parts onto a copper sheet. This process has proven consistent but not efficient; it is not accounting for an optimized nesting of parts, leading to remnant sheets with little to no use for other jobs. Consequences of this include inventory inaccuracies of the stock present as well as the production of copper waste that could have been used if processed efficiently. There is a gap between the shop floor and their software system, indicating the need to streamline copper usage and enhance the utilization of current software. This involves minimizing waste, boosting efficiency, and cutting down on potential expenses for the company.

1.2. Copper Estimates

Currently, Amphenol IPC uses a software known as NestingWorks, an extension of SolidWorks, to provide a layout of busbars on a copper sheet. NestingWorks receives a drawing of the busbar geometry, and the dimensions of the copper sheet. From there, the program provides a theoretically ideal layout of busbars on a single sheet to maximize sheet utilization for a given set of parameters. The maximum yield of this ideal nest produced is used to estimate the amount of material consumed when a given part is produced. For example, under ideal conditions, 24 units of a given part can be nested on a single sheet. When a manufacturing order calls for 12 units to be produced, 50% of a copper sheet will be removed from the ERP inventory. However, due to the inability to nest the irregular geometry remnant sheets, this estimate may vary from actual consumption. This variation has been the source of error throughout Amphenol including purchasing and production control. Accurate reporting of material usage is critical for efficient operation of the manufacturing process.

2. Literature Review

Effective and efficient functionality is key to a successful manufacturing system. This involves various elements, including planning, scheduling, inventory control, quality, and production monitoring (Johnson, 2014). After thorough analysis of the Amphenol manufacturing floor, shortcomings can be seen in areas such as inventory control and planning. To structure the direction of the project there is a need to describe the software utilized by the company and the need for process improvement.

2.1. FlowNEST

The company's cutting process operates with the use of Flow Waterjet, a manufactured waterjet system containing both the waterjet machine and paired software. The Mach 500 series offers easy-to-use software suites that allow you to program a part quickly and have access to FlowCUT, FlowPATH, and FlowNEST. FlowNEST is a 2D geometric nesting module that allows parts to be fit into scrap areas of other parts, providing efficiency and optimization to the process. It is part of the FlowMaster software produced by Flow International Corporation (Corporation, 2005). FlowNEST automates the process of merging DXF files of individual parts into a larger file, which is appropriate for cutting. Additionally, it enables you to store the quantity and types of nested parts for future use (Corporation, 2005). In this paper an approach is proposed to combine the components of the nesting software and a generated graphical user interfaces (GUI) into a joint inventory tracking system that can be utilized to optimize production and lower material waste and costs. By incorporating GUIs, which enable user interaction with software, it becomes possible to establish a database for storing leftover copper sheets from previous projects. This creates a user-friendly interface for effectively managing the usable space of remnant sheets. An additional option is provided for inventory tracking apart from the Enterprise Resource Planning (ERP) system, which presently relies on weight as the sole criterion for monitoring inventory.

2.2. Nesting and GUI Integration

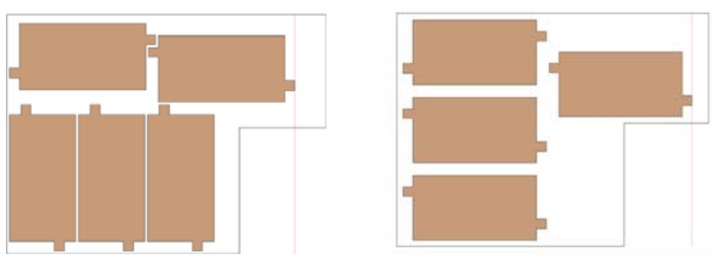
Nesting is the process of fitting multiple shapes on a work-piece before the start of the manufacturing process (e.g. copper sheets) (Berg et al., 2022). The configuration of the shapes minimizes material waste and allows you to have an optimized ma- terial utilization. Within metal processing and manufacturing, specifically in sheet-metal cutting, shearing and stamping, many approaches have been proposed with the goal of minimizing waste material and automating the part layout planning process (Canellidis, 2013). The proposed approaches commonly revolve around algorithms that incorporate nesting techniques. Nesting algorithms place shapes in a manner that the difference between the total area on a sheet and the sum if their areas is minimal (Berg et al., 2022). By employing an effective nesting technique, the objective is to enhance the utilization of inventory, which encompasses overseeing the procurement of raw materials, components, and completed products (Hayes, 2022). The incorpo- ration of a graphical user interface (GUI) into the nesting functionality offered by FlowNEST enables the creation of a database that can store remnant sheets leftover from previous projects. Amphenol utilizes a weighted average cost accounting approach, which emphasizes the importance of maximizing the use of existing stock materials. By optimizing inventory usage, businesses can determine the precise amount of stock-keeping units to purchase, ensuring timely order fulfillment while minimizing the risk of shortages or excess inventory. Amphenol's ERP System, Microsoft Dynamics 365, allocates copper inventory directly to the waterjet machining process. Unaccounted inventory is approximated using part size estimations, leaving a gap in information of the inventory they have left to consume. Creating a database for remnant sheets provides an alternative automated tracking system that enables efficient utilization of both new and leftover sheet materials, with a focus on a standardized process. This moves away from manually nesting the parts onto a remnant sheet when space is left to consume. You can track the inventory of remnant sheets in real-time and quickly identify available stock for new projects, thereby reducing waste and saving costs. A standardized process can also help to reduce confusion and miscommunication among team members, resulting in more efficient and effective use of materials.

2.3. Waste Reduction

Waste reduction is a critical component of the project, as it not only reduces the environmental impact of production but also improves efficiency and reduces costs. By identifying and altering non-value added processes, production can be streamlined and productivity can be improved. Providing material efficiency optimizes the use of raw materials and reduces scraps, resulting in the reduction of waste in manufacturing. Currently, Amphenol holds a process to repurpose the skeleton sheet material that is left from production. The accumulated skeletons are stored until a sufficient amount has been reached to transport them for repurposing. This approach not only results in financial reimbursement for the company but also provides an efficient solution for the disposal of residual materials. However, it is important to note that while the accumulation and repurposing of residual materials may be an effective waste reduction strategy, there are other factors that must also be considered. For instance, the manufacturing of parts on multiple sheets due to the lack of optimized sheet use may result in increased energy consumption, which can offset the benefits of waste reduction. Therefore, it is imperative for manufacturing firms to adopt an approach to waste reduction that considers all aspects of the production process, from material utilization to energy consumption, in order to achieve a sustainable and efficient manufacturing system. Within manufacturing industries organizations have resorted to improvement tools that allow for modification and in turn achieve profitability to make them sustainable (Pérez-Pucheta, 2019). The customization's offered by Amphenol have impeded production planning, necessitating the organization to explore novel methods to enhance their production processes. It is imperative that production maintains its quality while also ensuring that prices remain competitive. The process to be integrated resolves to achieve this.

3. Methodology

The approach taken to improve this process was to enable the engineering team to utilize their current nesting optimization software, FlowNest, on sheet material of irregular geometry. This ability would not only decrease scrap percentage created but also allow the team to consume inventory in the ERP as material is used as opposed to projections. This was to be accomplished through the development of an application, written in python, where users can access real time information about available sheet material. The manufacturing engineering team, responsible for laying out production parts, will have access to this application so they can optimize layouts for specific sheet geometry. They will be able to view and extract drawing files of the geometry for all rectangular or irregular shaped sheet material. This file can be imported into their current nesting optimization software and used as a template for parts to be cut. Figure 1a is an example representation of how the nesting optimization software would lay out sample part A. Comparing this to the potential manual layout seen in figure 1b, it can be seen that there will be an increase in yield therefore utilizing a greater percentage of the sheet. On top of this improved yield, the size of the sheet cut will be a known value which can be automatically recorded by the ERP system.



(a) Figure 1a: Nesting (b) Figure 1b: Manual

Figure 1. Comparison of batching using nesting optimization software and a possible manual nesting layout

The procedure for the engineering team to manage material flow will be as follows. Users will first open the interface in Figure 2a and filter the database of available sheet material by the thickness required for a given part. Of the sheet sizes available, one will be selected based on the size of the parts to be nested. This selected sheet geometry will be extracted and imported into FlowNest for part layouts to be created. After parts have been laid out a sheet to be cut, the software tool, FlowNest, allows the users to directly download the drawing of the remaining sheet material. Returning to the created application, the user will select the sheet which will be cut and navigate to the "cut sheet dialog" in Figure 2b. Within this dialog, the user uploads the geometry of the remaining sheet.. The difference in area between these two files will be calculated and sent to the ERP system as the material consumption for the given manufacturing order. Finally, after completing the consumption calculations the partial sheet geometry is saved back to the applications database for future part layouts.

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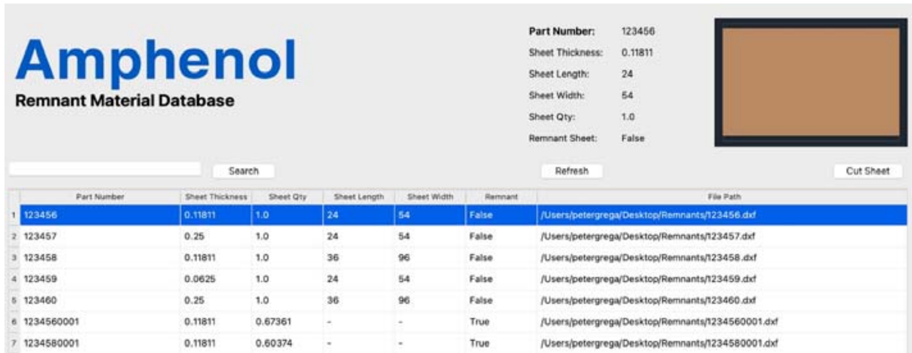
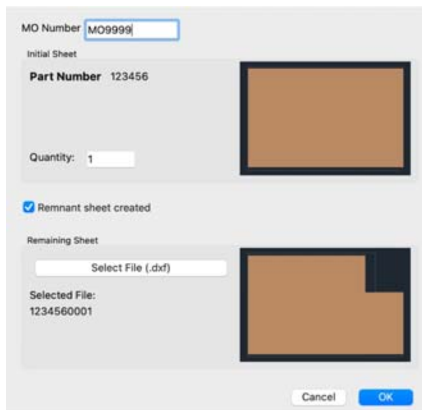


(a) Main Interface Window



(b) Cut Sheet Dialog

Figure 2. Interface Visuals

The final aspect for implementation of the proposed process adjustment was identification of the stock material. There must exist a common link between information within the application and on the shop floor. Figure 3 depicts the removable label generated on each manufacturing order document. As a sheet is used, the sheet number stays the same with increasing sub iterations seen under the Sheet # column. The Job # column is used for cross-reference identification; each code represents the date combined with a letter to show a job given that day. For example, 402B is the second job of April 02. Due to the low volume environment of Amphenol, this code indicates what exact job was used on the sheet, even if several different jobs are performed on one sheet. Sheet % refers to the remaining percentage of the sheet; the sheet begins complete at one and approaches zero as it is further used. This documentation will assist integrating of floor information with both the created application and ERP system.

Remnant Sheet Documentation					
Sheet #	Job #	Sheet %	Weight	Parts Produced	Time
123456	402A	1	145lbs	48	8:39AM
123456-0001	402B	.8672	92lbs	12	9:12AM
123456-0002	403C	.5514	46lbs	23	2:04PM
123456-0003	403D	.2169	28lbs	7	3:37PM
Notes:					

Figure 3. Sheet Material Identification

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The methodology of the study used to analyze this process change involved weighing copper sheet material before and after the water jetting process. Each sheet in the study was weighed three times. The first being the weight of the sheet prior to any water jetting, the second was the weight of the sheet after cutting with parts still connected to scrap, and last was the remaining sheet after parts have been removed. With these weights, calculations of the actual consumption of copper to produce each part will be made. To evaluate the effectiveness of the proposed process the same parts will be nested using a browser-based nesting tool and drawings will be created of the remnant sheets. These drawings will be uploaded into the interface and the calculated consumption will be recorded. For each sample, the percentage of scrap material created will be recorded for both processes. The effectiveness of the proposed process will be measured based on its ability to accomplish two objectives, accurately report material usage and reduce the percentage of scrap material.

4. Results and Analysis

4.1. Current System Results

The experiment designed by our team gave insight into the current accuracy of Amphenol's method of estimating copper. Our team collected data on the copper sheets before and after the sheet went through the cutting process. Our team collected data on the initial sheet weight, the weight of scrap material, and the weight of the individual parts. By calculating the difference between the initial sheet weight and the weight of scrap material plus individual parts, we were able to find the amount of copper lost during the cutting process. After a sufficient number of samples were collected, our team compared our data to Amphenol's current method of calculating copper consumption. There appeared to be a significant variation between both calculations, Amphenol's estimated use of copper was higher than the actual usage. Calculations are based on how many parts one sheet can produce: if a whole sheet can produce 10 parts, then each part is said to have used 1/10th of a sheet. A notable quantity of unused copper (scrap) persists subsequent to the cutting procedure. Amphenol's ERP system indicates that an entire sheet is utilized, despite the fact that in reality, there may be a considerable amount of scrap that could be repurposed for another project, causing the discrepancy. This aforementioned situation results in an issue: if Amphenol decides to use the scrap material for producing another MO, its system does not show the scrap material, it believes that the whole sheet has been depleted by the last MO. Although Amphenol may know how much the scrap weighs, using the same calculation method results in a drastic difference between the actual and estimated consumption. Within the first analysis made when Part One was produced, it was expected to consume around 69.72 pounds of copper, but only 48.22 pounds of the copper sheet was used instead. This caused a 44.59% discrepancy, leaving the remaining 21.5 pounds of copper to be usable for Part Two. Part Two only weighed seven pounds, but consumed 21.5 pounds of copper, resulting in a -67.44% difference (approximately three times the estimated amount of copper). The overall variation between both parts combined was around 10.04%.

4.2. Proposed System Results

The method being proposed for estimating scrap material would ensure that the sheets are being completely utilized: nesting based on a MO rather than individual parts would result in greater accuracy in regards to the data of copper consumption. This process will help calculate not only the first MO, but also verify that the estimated weight of copper consumption is very close to the actual copper consumption. Applying the MO nesting method to these parts yielded the following results: the estimated weight consumption for Part One based on the MO was 57.4 pounds, while the actual consumption was calculated to be 48.22 pounds. This resulted in a discrepancy of 19.04%, which is much lower than Amphenol's calculation of 44.59%. The estimated weight consumption for Part Two, based on the MO, was 12.6 pounds, while the actual consumption was calculated to be 21.5 pounds, resulting in a -41.40% difference. This is over 25% less than Amphenol's larger discrepancy of -67.44%. Finally, the total difference for parts one and two were approximately 0.40%, which is significantly lower than that of Amphenol. After utilizing this new method on other samples collected from Amphenol, we observed a significant change in the quantity of scrap material; the change of procedure resulted in an average of 15.25% decrease in scrap. This decrease indicates a greater utilization in the copper sheets due to incorporation of nesting based on an MO.

4.3. Added-time for Engineers

While our method creates a smaller inaccuracy and decreases the quantity of scrap material, there is one prominent caveat: manual labor costs. Nesting parts based on a MO, which is a tedious and timely task, also translates to much more work for the engineers, who are very costly in comparison to the floor workers that operate Amphenol's machinery.

5. Conclusion

By using the developed remnant database and existing nesting optimization software, our client's objective of optimizing and tracking copper consumption can be achieved. We developed the remnant database and identification of stock material to provide resources for actively keeping track of the inventory, providing an effective use of materials and less discrepancies. With our current stage of data collection and analysis, the new process has demonstrated improvements in both waste reduction and reporting accuracy. As additional data is collected, the team expects to develop an approximation of how this process change will impact the client on a year by year basis. Ultimately, these improvements will increase the profitability of the company through increased value added utilization of resources and more accurate estimates of production costs.

6. Future Work

Additional work set to take place prior to the completion of the project consists of further analysis of process improvement. Due to the low volume and sporadic production the data collection phase has been an ongoing process. Continued collection of sample data from the production process will allow for a better representation of the impact of a process change. There is potential for future teams to enhance this project in various ways. One area of improvement would be to link the program developed to the Microsoft Dynamics GP ERP system. This change would automate much of the inventory tracking process and therefore reduce the process time. Another area of future work to build on this project would be researching the implementation of machine vision on the waterjet. The use of machine vision could identify the exact shape and size of remnant sheet material, and theoretically accomplish this with less input from the engineering team, allowing for a more efficient workflow given the engineers time to focus on other challenges.

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