

# **Dec 15, 2015 MFE/MTE 520 ME 543**

## **Axiomatic Design of Manufacturing Processes**

On December 15, 2015, Professor Chris Brown's Design and Analysis of Manufacturing Processes students presented innovative products and processes, competing for a \$2500 cash purse. Depth and breadth of the invention or innovation impact play an important role in the judge's decisions. All projects incorporated axiomatic design principles.

We thank our judges Dave Escobar (Metso), Torbjorn Bergstrom (WPI), and Bob Boulay (Metso) for their participation, insight, and questions.

The MFE/MTE 520 ME 543 course covers the axiomatic design method, applied to simultaneous product and process design for concurrent engineering, with the emphasis on process and manufacturing tool design. Basic design principles as well as qualitative and quantitative methods of analysis of designs are developed. The second half of the course addresses methods of engineering analysis of manufacturing processes to support machine tool and process design. Basic types of engineering analysis are applied to manufacturing situations, including elasticity, plasticity, heat transfer, mechanics and cost analysis. Special attention will be given to the mechanics of machining (traditional, nontraditional and grinding) and the production of surfaces. Students, work in groups on a series of projects.

### **1st Place - Axiomatic Design of a Selective LASER Sintering (SLS) Machine Tool**

Team members: Monica Preston and Bryan Manning

The purpose of this project is to partially design a selective LASER sintering (SLS) machine tool that decouples size and orthogonality of a LASER beam spot from positioning in order to deliver spatially-independent power per unit area ("flux") to powder. Controlling flux is crucial because it affects the mechanical properties and tolerances, and by extension, the overall quality of the built part. Current SLS machine tools commonly use a galvanometric scanner which, although fast, does not deliver spatially-independent flux due to physical and geometric limitations. The innovation: an independent beam delivery system attached to a gantry motion platform to rapidly deliver spatially-independent flux.

### **2nd Place - Paper Circuit Maker Attachment for a 3D Printer**

Presenter: Norbert Mongeon

The purpose of this paper is to design an attachment for a 3D printer to print conductive traces on a paper substrate. The attachment will allow for CNC accuracy and speed, therefore, aiding circuit prototyping and paper electronic production. Axiomatic design played a vital role in determining the physical integration of the product. By applying the axiomatic design process, a

reliable mechanism was designed that fulfills its functional requirements while portraying the customer's needs. Success was measured with compliance to the axioms and correct formulation of the functional requirements.

### **3rd Place - Knife Sharpener**

Team Members: Jason Zelle and Andrew Vickery

Our design, a knife sharpener, was created with weight, size, ease of setup and use, cost, and maximum control of the system during use. Current sharpeners are designed with aesthetics, portability, and speed of use in mind, while having deprioritized the amount of informational input needed from the user to produce an acceptable edge, thus decreasing the probability of producing an acceptable edge. Key aspects of the design include controlling the position, feed, and blade sharpness index (BSI) such that the blade is able to easily cut, but still rugged enough to survive an acceptable amount of use. Our design is innovative in its attempt to reduce the amount of skill, and coordination, of the user. This is done by controlling all variables of both the feed and the force on the honing stone, other than the knife's movement through the device.

### **4th Place - Control of Laser Cutting Geometric Quality**

Team Members: Shen Tain, Yuanzhou Yang and Botong Li

Customer Need: Laser cutting is finding increased utilization in high-precision manufacturing where the geometric quality of cut is of utmost importance. Current Issues in Laser Cutting: Most laser cutting machines have the same nozzle for Laser Beam and Assist-gas Jet. And, at the same time, the choice of assist gas impact both oxidation and resolidification on the kerf. So we decompose those requirements and make key FR-DPs as listed below: FR1: Control the formation of kerf DP1: System to control the formation of kerf FR1.1: Control the energy distribution in depth DP1.1: Laser focusing system FR1.2: Control the output energy distributed per unit cutting length DP1.2: System to control the output energy distributed per unit cutting length FR2: Prevent unwanted geometric change on kerf DP2: System to prevent unwanted geometric change on kerf FR2.1: Prevent re-solidification of melted part on kerf DP2.1: System to prevent re-solidification of melted part on kerf FR2.2: Prevent oxygen contact with kerf DP2.2: System to prevent oxygen contact with kerf 3. Our solutions and innovations For FR1, formation of the kerf (= control energy along cutting edge ( ) \* distribute energy in depth ( ) / focus radius (m)). So that we can decompose FR1 into FR1.1 and FR1.2 by the theme of energy without coupling DPs. For FR2, Re-solidification + Oxidation = unwanted geometric change. So we split FR2 into FR2.1 and FR2.2 and provide uncoupled DPs to those FRs.

### **Honorable Mention - Analysis of Ultrasonic Wirebond Process**

Presenter: Conor Naughton

In the field of manufacturing of power control devices, the wirebond electrical interconnection is the most significant source of reliability concern. The reason for this concern is the fact that it is most often identified as the root cause of failure when there are issues in the field. In high

reliability applications such as military, aviation and space exploration, the need for this process to be performed with high confidence is extreme. In modern high-reliability electronic device manufacturing, there is a significant amount of tests and monitors put in place to build this confidence throughout the process but especially targeting the wirebond. In this paper, a piece of equipment is designed using the principles of axiomatic design to perform the wirebond process and ensure the reliability of the final product. An innovative in-line reliability test is suggested as well as several general process improvements.

## **Honorable Mention - Automated System to Ensure Quality Control of an NFL Football**

Team members: Jason Lackie, Joseph Brown and Ethan Barrieau

Quality control is paramount to the success of any manufacturing enterprise. The principles which have long been practices across manufacturing industries lend themselves to integration into more commonplace facets of society. The purpose of this project is to extend quality control practices into the game of American Football. The commissioner of the NFL mandates that certain standards be adhered to with regards to football pressure, dimensions and weight. This project addresses an automatic process to verify the dimensions and weight as well as compensate the internal pressure of a football to external atmospheric conditions. This design is deeply rooted in the principles of axiomatic design. Through utilization of the independence and information axioms, the team identified the best design for automated quality control of a football.

## **Honorable Mention - Integrated Milling and Turning Machine Tool**

Team members: Rachel Harrison and Adam Lemoine

The project objective was to design a machine tool that integrated both milling and turning operations using Axiomatic Design Theory. This work is important, because the integration of machining operations reduces work piece setup changes, and it allows for an integration of part geometries that are axis symmetric and non-axis symmetric. There were two key stakeholders identified in this work, and each stakeholder has their own customer needs. The customer needs of the machine operator include controlling the amount of setup changes, providing a successful machining operation, and maintaining all safety factors common on both operations. The customer needs of the product client include integrating axis dependent with non-axis dependent geometries, and maintaining product specifications during the integrated process. These customer needs were used to decompose the design problem into two broad functional requirements; “Provide machine tool motions that integrate axial and non-axial part geometries,” and “Provide proper interaction between the tool, work piece, and machine.” In order to satisfy the two functional requirements respectively, a mechanical system will need to provide the proper motions of the cutting tool and the work piece, and a specific configuration between the tool, work piece, and machine tool will need to be established. This work is innovative because it illustrates a clear order of adjustment of the lower level functional requirements that satisfy the two upper level functional requirements, and the two upper level functional requirements can be clearly translated back to the customer needs of the machine tool operator and the product client.

## Honorable Mention - Cider Press Tractor Attachment

Team members: Kelsey Stergiou and Mikhail Morozov

This project outlines the design of a tractor-powered cider press that is mobile and able to be operated by a single person. The overall function of this equipment (FR0) is to convert fruit into juice. Previously, tractors have been used to power separate machines by means of a belt attached to the tractor's motor, which is unable to be moved and needs multiple people to set up and take down. The approach used for this product was to identify separate mechanisms that could be brought together into one product and could be more easily operated by an individual. Following the energy exerted on the fruit was the theme of the decomposition with the main steps being "gather fruit" and "extract juice from fruit". This function was realized through a hydraulic tree shaker that removes fruit from trees, a conveyor belt that picks fruit up off the ground, a grinding mechanism that breaks down the fruit structure, and a continuous belt press that squeezes liquid juice from the ground fruit. Coupling is avoided in this design by assigning a separate system to fulfill each step of the process in a continuous sequential flow. Functional metrics based on throughput are assigned to each step of the process to gauge the success of fulfilling the overall goal (FR0) and ensure a collectively exhaustive, mutually exclusive decomposition. Information is reduced by matching up the operating speeds of the sub-systems so that the process is autonomous and continuous while the tractor is in motion. Innovation is achieved in this project by combining all the steps of cider production into a single tool that does not require a team of users to operate.



Monica Preston and Bryan Manning



Norbert Mongeon



Andrew Vickery and Jason Zelle



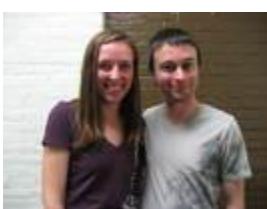
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