Feasibility Study and Prototyping of Portable CNC Tube Notcher

AYURG | Natural Sciences & Engineering (NSE) | *Tags: Group Project, Design/Build*

This cover page is meant to focus your reading of the sample proposal, summarizing important aspects of proposal writing that the author did well or could have improved. ***Review the following sections before reading the sample****. The proposal is also annotated throughout to highlight key elements of the proposal's structure and content.*

Proposal Strengths	Areas for Improvement
The researchers explicitly identify gaps in knowledge and make claims for why it is important to fill these gaps using evidence from past research to support their assertions.	The specific aims of the project would be better situated within the proposal if the researchers added a sentence or two connecting their aims and methods back to the research question explicitly.
The researchers identify and define their metrics of success. In other words, they indicate how they will know when they have answered their research question based on the methods proposed.	A conclusion section is not needed at the end of a proposal. In general, you do not need to repeat yourself in the proposal or summarize what has been previously stated.
Each group member has a distinct role within the methodology and a distinct preparation section to match	While some aims are present, rephrasing to create or including an explicit research question would strengthen the proposal. If in the first paragraph, the question could be broader with the following background section serving as a funnel that adds more specificity.

Other Key Features to Take Note Of
Group projects are allotted 1 additional page beyond the 2-page limit for every person added to the project. Each group member should have a distinct role in the project and write a distinct preparation section.
All Academic Year URGs require a budget. There is no required format; however, we do provide a template on our website. The scope of the proposal should focus on what the funding covers.
While the end product of research can be a physical product, the research proposal must ultimately center around the research questions that will be answered by going through the process of producing that product.
This proposal has been deidentified, but you should use your names when referring to yourself and group members in a group proposal.

No need for section headers

Introduction

The focus of the project is clear within the first paragraph

We are proposing to investigate the feasibility of creating a small, portable prototype of a Computer Numerical Control (CNC) tube cutter for cutting steel tubing. A CNC-controlled tube cutter uses a computer with a special software package to control motors and other machine components to cut steel tubing to precise lengths with complex end-geometry. As technology has advanced, CNC machines are being used in an expanding variety of applications. Full-size CNC machines using both laser and plasma technology are being used to cut tubing into increasingly complex shapes with precision. With the advent of lower-cost mechanical components and control solutions (for example, Arduino and Rasberry Pi) some CNC machines have been made smaller and more portable, while reducing their functionality to one or two specific tasks. Our proposed research is to investigate if the functionality of a high-end CNC plasma tube cutter can be implemented in a simplified, low-cost, portable solution.

While aims are present, an explicit research question would strengthen the proposal

Background

Coping or notching tubes is a fairly common practice that is done in many different ways by a number of different users. Custom frame manufacturers for motorcycles or roll cages, commercial bike manufacturers, and furniture makers are just a few examples of people who cope tubes regularly. Still more users in the form of amateur fabricators, hobbyists, or "makers" may need to notch tubes as part of a project or new design.

In addition to regular users of tube coping, there is also extensive research in the field. For example, an article published in the MATEC Web of Conferences Journal examines the pro's and con's of different cutting techniques in precision stainless steel tubing commonly used in the automotive world (3). One machine that can be used to cut tubing is a CNC controlled robotic arm. This technique is covered in research by Robert Bogue. These CNC robots have many capabilities, as described in the article, they can be used to perform complex cuts on tubing with plasma and laser cutters (2). Plasma tube cutting is a standard for thin-medium walled tubes. It tends to be a more affordable and slightly less accurate alternative to laser cutting.

With the increasing modernization and mechanization of today's world, CNC technology is being adapted and used in new ways every day. One common task of this research, as we are attempting, is to make a CNC machine--even one that performs one specific task--portable. Research by Zhang, Gao, and Qian, describes the use of a parallel manipulator as a portable CNC machine. This machine would be capable of traditional 3-axis machining as well as possibly acting as a CNC Coordinate Measuring Machine (CMM) (6). Additionally, research is being done in collaborations with nuclear power plants in order to produce portable CNC machines for specialized applications in plant maintenance. These machines will mainly be used for boring holes, and cutting threads (4). One issue with these portable CNC machines is the control unit, as the control panel for a full-fledged CNC machine is usually large. The journal of Mechatronics, Electrical Power, and Vehicular Technology published a paper describing one possible method of controlling such a portable CNC machine using two separate processors as well as a motor driver (5).

Identifies gap in knowledge

Justifies why gap should be filled

Commercial CNC controlled plasma tube notchers are complex machines, and are able to be easily adjusted to create different cope geometries and accept different diameter tubing. However, these CNC machines can have very large price tags. For example, CNC laser machines or mills can cost hundreds of thousands of dollars and even the much simpler BendTech Dragon CNC plasma tube notcher costs $16,000 (1). Additionally, even small CNC machines can have footprints of 40 square feet and weigh thousands of pounds. Even at the smaller end, the Bend-Tech Dragon comes in bed lengths of 12 to 20 feet (1). These machines certainly do not meet the

Identifies gap in knowledge

requirement of portability. This issue could be avoided if the machines were easy to transport and store, but unfortunately due to their large weight, size, and lack of modularity that is not the case.

Identifies gap in knowledge

For low volume applications, hand tools such as drill presses, hole saws, and hacksaws are possible ways of coping tubes. These techniques end with tedious and time intensive work using abrasive (i.e. sandpaper) to get the cope to fit properly. While they low cost, take up relatively little space, and are portable they still lack the critical functionalities of a CNC tube notching machine.

Identifies gap in knowledge

The project is situated in past work from a different field as a “proof of concept”

The issue at the heart of this research is to keep the functionality of a machine such as the BendTech Dragon and modify it to be portable and storable. Similar things have been done for other machines to make them more compact. A common example would be the portable or compact washing machine. This device takes all of the functionality or its larger counterparts and shrinks it down to a smaller size to make it easier to move around. Additionally, it functions off of common power and water sources and does not require the installation of any specialized attachments or mounts. The question we are trying to answer with our research is whether or not it is possible to do this with a CNC plasma tube cutter.

Background leads to specific goals of 8-week project

In the past, one reason that this research has not yet been completed is that there was not a great need for such a machine. However, with the increasing popularity of the maker movement, as well as the societal trend toward specialization and lean manufacturing, the development of modular, small, portable CNC machines is of increasing importance. By generally following the methods described in the research of Saputra, Atmaja, and Prawara (breaking up the machine from one large component into a more modular approach) we believe that a prototype of a portable CNC plasma tube cutter is feasible.

Justifies why gap should be filled

Methodology/Preparation

Group members have been deidentified

This research is being done as a Mech_Eng 399 Independent Study class under Professor Michael Beltran of the Mechanical Engineering Department. Three students, Student 1, Student 2, and Student 3 will be conducting this research. The overall project is broken down into three sub-areas--mechanical, electrical, and software. Each of the three members of our team will be leading one of these subsystems. Student 1 will lead the software division, Student 2 will lead the mechanical division, and Student 3 will lead the electronics division. All three are essential in ensuring the success of the design.

Each group member has a distinct role

The mechanical sub-system consists of several major components including a machine base, motion platform, mechanical safety components, cutting head, workpiece holding, and workpiece support features. The mechanical components will be designed using our previous machining knowledge as well as resources from the Prototyping and Fabrication Lab in the Ford Motor Company Engineering Design Center. The base plate would serve as a steady platform for the machine. On the base plate, a motion platform is built to allow both rotational and linear movement of the tube as it is cut. The platform will be at least 3.5 feet long, since that is the length of the longest tube that most users would need. For safe operation, a hard stop will be implemented, in order to prevent the motion carriage from moving too far. Metal shielding will be used to prevent sparks from escaping the cut area. A bracket will attach the plasma cutting head to the machine. Because a controllable vertical axis isn’t being used, a slide with a set screw would be used to allow for height adjustability for various diameter tubes. To hold the tube, a lathe chuck will hold the tube securely, without crushing it. The electronics division of the project consists of several primary subsystems including the motors, motor drivers, power supply, electrical panel, position sensing, and safety systems. This prototype will utilize two

Should connect parameters/methods explicitly back to the research question

Justifies steps of methodology to show why a step is taken separate motors. One motor will be used to drive the rotational axis for the tubes and the second will be used to drive the linear motion of the cutting head. Stepper motors in an open-loop control system will be used. A motor driver will power these motors using the outputs from the software package to turn the motors at the appropriate times and speeds. The prototype will need to have a power supply in the 12-24 volt range to supply power to the actual motor as well as power in the 5-12 volt range to power the processing components of the system. The power supply for the plasma torch will be separate from the CNC machine's electrical panel. The prototype will consist of several safety systems to protect both the user and the device itself. Standard emergency stop switches will be used to halt the machine at the user's discretion. Limit switches will be used to prevent the machine head from over travelling and/or crashing. Fuses and relays will be used to prevent damage to the system from an overcurrent or overvoltage.

Should connect parameters/methods explicitly back to the research question

Justifies steps of methodology to show why a step is taken

The software section of the project consists of the elements that allow the mechanical machine to be controlled by the computer. The process starts with a G-code (a common programming language used by CNC machines) program generated by the user. Ultimately, the motors on the tube cutter will be driven by a motor driver connected to an Arduino running an open-source software called "Grbl." The Arduino will communicate with the motor driver in order to generate the requisite machine motion. The process between the G-code and the Arduino is the main focus of the software section. In order that our machine be as portable as possible, the control panel will be an application installed on the user's laptop. The program will be written using Visual Basic.NET and will control the Arduino. It will pass the G-code file line by line to the Arduino through serial communication. It will also display the position of the machine, allow users to operate the machine manually, and contain all relevant functions of a standard non-portable CNC machine.

In order to quantify the success of the prototype, the following metrics will be used. The machine must be able to cut the tubes such that they fit together with gaps no larger than twice the wall thickness of the tubes being cut. This means an allowable tolerance of +0.000",-0.070". In order to meet the portability requirement, the machine must weigh less than 100 lbs, not including the plasma cutter. And hence, be movable by no more than 2 people. The machine must not take up more floor space while being stored than 5 square feet. The machine (not including the plasma cutter) must run off of standard household (110V) electrical power. Lastly, the machine needs to be controlled using a standard windows laptop.

Metrics of success are given

Researcher Backgrounds

Each student has a distinct preparation section

Student 3 will be heading up the electronics portion of the design for this project. They are majoring in Mechanical Engineering but also has taken several relevant classes that give them the background and skillset necessary to lead this portion of the design. A trio of classes, ME 224, ME 233, and DSGN 360 make up the bulk of Student 3's electronics experience. Two classes ME 233 and ME 224 focus on the design of circuits and simple machines that can be used for experimentation and testing. In ME 224 they were part of a team that designed a reaction time testing machine that simulated steering a car. DSGN 360 is a robotics design competition with the goal of creating an autonomous robot capable of evading a human controlled "hunter" robot while moving through a course riddled with obstacles. Their team won first place in this competition. Student 3 is also the Chief Engineer for the NU Baja SAE team, a student manager of the prototyping lab, and a lab assistant in the rapid prototyping lab. These experiences will allow them to make significant contributions specifically in the fabrication of mechanical components and the software and coding necessary for motor controls.

Student 1 will be leading the software portion of the design for this project. While they are majoring in Mechanical Engineering, they has experience in the CNC software industry that makes them fully capable of leading the software design. Relevant coursework for Student 1 includes ME 233, ME 363, and a previous ME 399 Independent Study. For their ME 363 final project, Student 1 and a partner developed a shock dynamometer (a device for measuring properties of shock absorbers on vehicles). They were in charge developing the data collection system based on the Arduino. For their ME 399 Independent Study, they worked on, among other things, a data acquisition system and control system for an engine test center. In addition, Student 1 has experience working for GF Microlution, a company that produces high-precision, micro-manufacturing and machining centers. Their work at Microlution involved machine software; they has worked with Visual Basic on machine software projects, and with multiple varieties of CAD and CAM software including building and editing machine environments and post-processors that generate G-code.

Student 2 will be leading the mechanical portion of the design and is majoring in Mechanical Engineering. As the Chassis Lead of the NU Formula SAE team, they have experience with machining, welding, and in tube frame design and manufacturing. From taking ME 340-1, ME 340-2, ME 390, and ME 315 Student 2 has knowledge of manufacturing processes and has manufacturing skills. ME 390 is a class about dynamic systems in the physical realm, and teaches students about causality, dependent and independent storages, and state. ME 315 provided Student 2 with skills to analyze mechanical power transmission systems. From classes and their experience on the Formula SAE team, they have the experience and means to lead the mechanical portion.

Conclusion

No conclusion/ summary needed

In conclusion, while there are currently CNC-controlled tube notchers on the market, creating one on that meets our requirements would allow us to gain further knowledge and understanding of how these machines work. We would be able to learn how G-code is interpreted by machines, how to create a user interface to allow users to change different machine settings, how to minimize component tolerances to increase the accuracy of a machine, and how to efficiently and compactly design an electrical panel for such a machine. As members on vehicle teams, we constantly use machines that are CNC-controlled, and could benefit from a deeper understanding of machine technology. Furthermore, completing the design and prototype a tube notcher that meets the specifications and needs of both Baja SAE and Formula SAE would give us the opportunity to refine and combine current technologies to meet new criteria, a valuable skill for any engineer. In addition, by designing this machine and software package with the financial and physical space constraints we currently have as students, we will need to explore methods of CNC machine design and construction not considered by the multi-million dollar corporations who currently produce CNC machines in large-scale production.

The skills developed through this research will contribute to making all of us into better engineers. All three students involved in this project plan to enter the field of product development or other mechanical engineering related topics upon graduation, and completing this research would allow us to be more effective in these future endeavors.

Works Cited

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4. Rentz, Lawrence. "CNC machines go mobile." Power Engineering, Oct. 2010, p. 20+. Academic OneFile

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Category	Item	Quantity	Per Item Cost	Total Cost
Mechanical Prototype Supplies				
	Steel plate for machine base	1	$200.00	$200.00
	Sheet metal for machine body	2	$40.00	$80.00
	Chuck to hold tube	1	$300.00	$300.00
	Linear Motion Rails	3	$120.00	$360.00
	Linear Motion Cart	3	$50.00	$150.00
	Plasma Cutter	1	$1,500.00	$1,500.00
	Total			**$2,590.00**
Electrical Prototype Supplies				
	Electrical Enclosure	1	$100.00	$100.00
	Wire	1	$60.00	$60.00
	Fuses	5	$10.00	$50.00
	Emergency Stop Button	1	$80.00	$80.00
	Limit Switches	3	$10.00	$30.00
	Motor Driver	1	$200.00	$200.00
	Total			**$520.00**
Software Prototype Supplies				
	Arduino Mega 2650	1	$38.00	$38.00
	Arduino UNO	1	$22.00	$22.00
	Total			**$60.00**
Total				**$3,170.00**

Possible Funding Sources		
	Academic Year Undergraduate Research Grant	$3,000.00
	Segal Design Institute Norman Design Fund	$170.00