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Design and Approach of CNC Foam Cutter

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***Abstract*— Foam is widely used material in various industries for multiple applications. Similarly in the UAV industry which is one emerging industry across globe uses different foams for UAV design, pattern making, UAV manufacturing and many more. Some Foam are lightweight with certain rigidity which makes it suitable for small UAV aircraft. In the early stages of development of aircraft various design iterations are done using foam by UAV designers. To save time of this foam cutting process & improved precision accuracy in cut. This can be achieved using Computer numerical control Foam cutter. This design CNC foam cutter aims to resolve mentioned issues & provide feasible solutions for cutting foam in wing shapes. This study will explain the design and approach of CNC foam cutters.**

Keywords— CNC Machine, Hotwire Cutter, Foam Cutter, UAV, CAD Design, G-Codes.

I. INTRODUCTION

Different Foams are widely used in various industries like packaging, insulation, architectural, signage, decorations etc. for multiple applications. UAV Industry & Aeromodelling are industries in which different foam are extensively used for designing, prototyping, scaled model, manufacturing, pattern making etc. UAV Industry is an emerging industry from last decade with various applications in the field of surveying, surveillance, data acquisition, deliveries etc. UAV is booming globally & many start-ups are based around this technology. As it is still growing there is constant demand for development in UAVs to meet desired output, performance, and cost-effective solutions. In this process of development most of time is consumed by designing & making of model out of foam or in the cutting process. Traditionally foam cutting is done manually with the help of hotwire or using a cutter. It needs certain skills to achieve precision in cut & smooth surface finish. This foam cut determines the performance of the model in real life situations and also aids the designer in analysing problems & gives them parameters to reiterate the design. There is constant trial & error of the foam model to bring out optimum results. This process of making prototypes consumes lots of time & energy. Also, time is the most crucial aspect in research & development. This study aims towards the design of computer numeric control Foam cutter which will hasten rapid prototyping, save time, improve foam cuts, cost effective design [1].

1. Manufacturers use foam moulding processes. This process is suitable for mass production, to produce

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many identical parts, like fuselage or wings (in case of RC models). Hobbyists that prefer to make their models at home with hand tools are usually limited to much simpler shapes that are obtained via bending plain Styrofoam sheets around multiple cross-sectional elements.

2. Another method adopted is layered object manufacturing (LOM) technique used for rapid manufacturing. They build their models from thick (approximately 30-100 mm) layers of XPS that were cut with hot wire and glued together to form the intended object. Hot wire (heated with electric current) must follow precisely contours of cross sections which is achieved with templates glued on both sides of each layer, it needs skill and labour in order to achieve the desired result. The current research is an attempt to build a system that can serve similar needs (but not limited to) of flying aircraft modellers [2].
3. A member of RC Groups forum has made a numerically controlled hot wire cutter that uses dev Wing Foam software for cutting long one-piece wings. Hans Seybold from Germany has made a NC hot wire cutter with 4 degrees of freedom. He used a unique mechanical layout where a bow with hot wire is positioned in space with 4 filaments of variable length controlled by 4 stepping motors. He also developed a program to drive the bow along a desired route which uses plain text description of all coordinates of the shape. All information is available for free on the internet at Hot-wire cutter by Hans Seybold [3].
4. Probably the most advanced technology is used in the Aero Tetris Company located in Russia. They use a 6 axis NC machine which allows achieving accuracy of 0.09-0.5 mm with wire inclination up to 165 degrees. During the cutting process speed and temperature are varied. The company sells sets of Styrofoam parts for building large models. This design has some problems which are discussed further.

II. STUDY OF EXISTING SYSTEM

Foam cutting is done either manually or by using a numeric control machine. Manual Foam cutting has several drawbacks and requirements. 1. To cut foam in particular shape there is need of precise templates from a hard material (like ply, acrylic sheet), they should be firmly attached to the flat surface of the foam. 2. In aircraft design the weight is an important aspect, but making a hollow cross section is a bit hard 3. Manual flow of hot wire over foam is not smooth, which leads to uneven surface finish.

Various attempts are made to implement modern technology into this field. Few members of RC groups forum had shared their experience in building a numerically controlled hot wire cutter that uses paid software like DevWing foam software or cutting wing. One of the designs shared by German designer Hans Seybold has made an NC hot wire cutter with 4-degree freedom. He used a unique mechanical layout where a bow with hot wire is positioned in space with 4 filaments of variable length controlled by 4 stepping motors. He also developed a program to drive the bow along a desired route which uses plain text description of all coordinates of the shape. All details available on the internet. There are other Numeric Control hot wire cutting machines which have 4 axis-controlled systems to control movement of wire. These CNC are either costly or require large working space.

A. *Need of project*

Project aims to solve the need of UAV designer, hobbyists in solving their problem in designing, cutting out wings from blocks of foam.

1. To improve the accuracy of the foam cutting Process.
2. To save time & resources where repeatability is demanded by hastening process.
3. To design cost effective machine with easily available parts.
4. To design Easy to use machine
5. To make feasible design for hobbyist and UAV makers.

III. METHODOLOGY

A. Design of system

Computer numerical control machine processes the work piece to desired shape or specifications by following coded instructions without a manual operator directly controlling the machining operation. This design of foam cutter is based on CNC. This system will resolve all the identified problems. Generally, CNC systems include two or more axes around which tools move as per given instruction. These axes are controlled using different mechanisms of threaded rod and motor, belt & motor etc. Microcontroller is Control unit of a machine which controls movement of motor & mechanism. This is controlled using an interface or software through which the operator can send code. CNC works G code & M codes. This G code can be generated by using open-source software. This is general overview of CNC machine on basis this data, proposed CNC foam cutter will be designed which will determine the mechanism, structure, tool, electronics.

B. Mechanism

Proposed design will consider 4 axes defined as XYUZ to control feed rate of the tool. X and U are horizontal and YZ vertical. This is important for design software which needs the correct letters assigned to generate the g-code. More on this later, depending on the software there are a few ways to assign this. This is a motor and shaft driven mechanism in which Stepper motors are coupled to threaded rod on which a carriage will be mounted to hold the vertical axis with the same motor & shaft mechanism with supporting aluminum profile attached to it. It is a 4 Axis machine with two sets of mutually perpendicular axes separated by a certain distance. Hotwire will be held by two vertical arms which can move in all four directions. This hotwire will be in constant tension with the help of a spring attached to one of the vertical arms. Tensioning is done to keep hot wire tight through the cutting process & prevent any unwanted errors in cutting process & prevent any unwanted errors in cutting process. Below is figure of this mechanism.

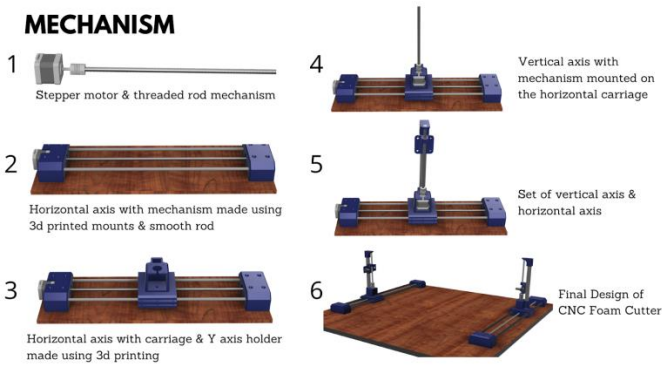

Figure 1. CAD model of mechanism

Left gantry is XY and Right gantry is UZ here is pair of horizontal & vertical arm blue part in Image are 3d printed carriage and mount for holding motor, aluminium extrusion

Stepper motor used for this design is Nema 17 with 4.8 kg cm torque, 1.5 A rated current & 1.8° angle i.e. 200 steps. Threaded rods used are of 8mm diameter with 1.5 mm pitch. This mechanism is sufficient enough to achieve controlled feed rate for the tool. Stepper motor gives precise positioning which meets the primary need of this design.

This complete assembly & structure of cnc machine is made using 3d printed parts & Aluminium extrusion as shown in figure. This design is made in cad software.

Dimension

Horizontal axis length = 500mm

Vertical axis length = 250 mm

Length of wire = 500 mm

Aluminium profile = 20 mm × 20 mm.

C. Microcontroller & stepper drivers

Microcontroller is used to control this motor via a stepper driver. Microcontroller is the main processing unit of this design which is first loaded with coded programs i.e., G code through interface i.e., pc or laptop. This code is generated using software explained in further part. Microcontroller generates control signals as per code which is given to the stepper driver.

The stepper motor is a digital input-output device, where these control signals appear as digital pulses rather than analogs voltages. This digital pulse sent to a stepper motor driver makes the motor increment by one precise

angle of motion. In this way the motor is driven by a microcontroller & stepper driver. These motor increments are called steps. These steps can be increased further to achieve high precision in cut. This done by micro stepping stepper drivers Steps per millimetre gives the number of steps that electronics need to generate to move the axis by 1 mm.

Microcontroller used for this design is Arduino at mega 2560, Stepper driver shield RAMPS 1.4 & stepper driver DRV8825.

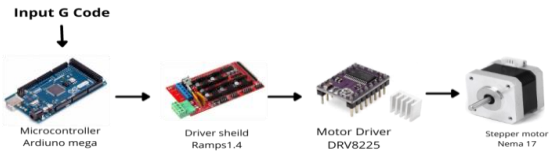

Figure 2. Control unit

D. Software

The CNC system uses G Code to control or automate the movement of tools & axis. To understand this G code firmware is uploaded on a microcontroller. Firmware will interpret the G code and generate a control signal for the stepper driver. An open source GRBL firmware is used in this microcontroller. This firmware is modified according to the design of the foam cutter in this modification XYUZ axis are defined along with length of each arm, steps per mm. This modification can be done using a compiler of microcontroller i.e., Arduino ide or using user Interface software made for this CNC foam cutter.

E. Software to generate G code

As this design of machine primarily aims towards cutting of wings & UAVs parts. There are few free software or sites available online to generate G code as per the given wing geometries. In this program it needs the inputs like

1. Aerofoil of wing in .dat file format
2. Set foam block size that will be cut
3. Feed rate of tool
4. Wingspan is the primary or common input given in all software. On the basis of these inputs G code is generated in. ngc or .nc format depending upon software being used. Software for designing foam cuts is Jedicut, Wing G-code Generator & paid software like DevCad.

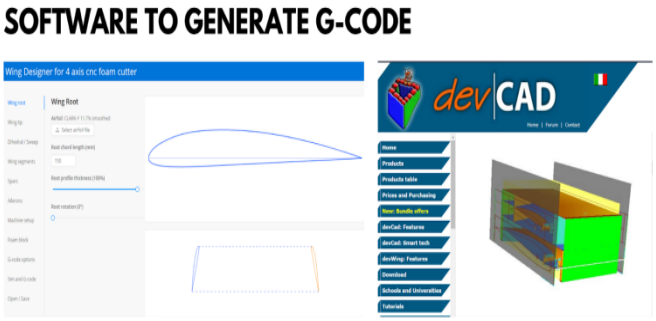

Figure 3. Wing Designer

E. Tool-Hot wire of Nichrome

Tool-Hot wire of Nichrome (.4 mm) is used as a cutting tool for this design. In this Temperature of hot wire is regulated using a variable power supply which will be a cutting. This Current carrying wire will vaporise the foam. In the cutting process hot wire heated by passing current is directed through a block of Foam. Wire will be heated at 200°C, as polystyrene foam melts at around 200°C, but attains its flowing state at 100°C. This heated wire will vaporise the foam at the cutting location. This slightly melts the surface of foam & leaves an open gap at the cut location. This gap is called kerf. Width or thickness of Kerf depends upon the cutting temperature and cutting speed. It varies with variation in temperature and cutting speed. In this way hot wire will foam by vaporising it [4].

Figure 4. Nichrome wire as a cutting tool

Power system CNC will work on 12v 30a power which will power 4 four stepper motors, microcontroller, hot wire, stepper driver.

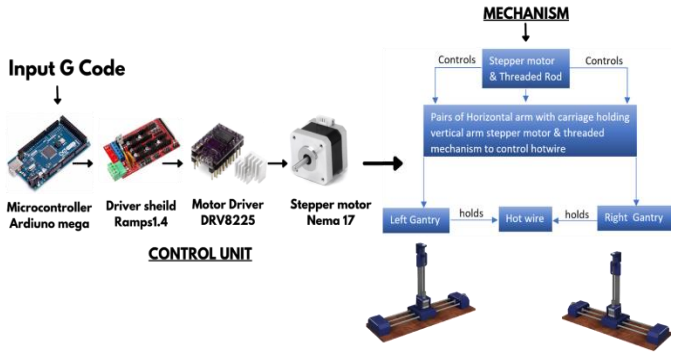

Figure 5. Working flow chart of CNC Foam Cutter

Figure 6. Software (GBRL Hotwire mega)

Figure 7. Input G-Codes and Output

IV. Conclusions

Design of this CNC foam cutter Machine will be feasible & cost effective for makers or hobbyists. This design can be made with easily accessible parts & components. Open-source software used for G code generation will be an additional benefit to save time & cost of development. This design will resolve challenges & will be a solution for accuracy, precision, for situations were constant

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