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A FRAME WORK FOR SEAMLESS INTEGRATION OF DESIGN AND MANUFACTURING USING CNC

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Abstract: **Machining is an important manufacturing process that is used in a wide range of applications. From aerospace applications to the manufacturing of energy systems we see a major reliance on machining. Nowadays, CNC machining is found in many industries to aid production by manufacturing process. CNC machining is absolutely essential for manufacturing and it is important. Some major benefits of CNC machining is manufacturing are greater efficiency, more accuracy and fabrication. In this project focus on gaining an improved understanding of the mechanics of machining and different factors that contribute to part quality. The aim of this work is to develop a frame work for seamless integration of design and manufacturing using CNC machine. For this process involves some steps. The selection of the component and design a 3D model of the component using CATIA software is presented here. Later generate the tool paths and program (contains G & M codes) using Dell CAM software. A post processor is used to converts the CAM data into specific commands that can be read a machine controller to move the cutting tool along the programmed paths. After the basic selections and decisions the preparation of a program will be done. After the lots of observation will go for fabrication of component using CNC vertical milling machine to achieve a designed shape with smooth finished surface, high accuracy and less machining time which directly increases the productivity.**

Keywords: **Machining, CNC, CATIA, CAM, G & M Codes.**

I. INTRODUCTION

Conventional Computer numerically controlled (CNC) machining is a technology which has been in existence for some decades and is reaching what appears to be an apex, much in tune to the long history of machine tool evolution. This is important as one may realize that while it is an integral step to the industry of tomorrow, it is the culmination which has set the manufacturing industry in an entirely new direction. Development of Computer Numerically Controlled (CNC) machines is an outstanding contribution to the manufacturing industries. It has made possible the automation of the machining process with flexibility to handle small to medium batch of quantities in part production. Initially, the CNC technology was applied on basic metal cutting machine like lathes, milling machines, etc. Later, to increase the flexibility of the machines in handling a variety of components and to finish them in a single setup on the same machine, CNC machines capable of performing multiple operations were developed. A CNC machine is a motorized maneuverable tool and often a motorized maneuverable platform, which are both controlled by a computer, according to specific input instructions. Instructions are delivered to a CNC machine in the form of a sequential program of machine control instructions such as G-code and M-code, and then executed. The program can be written by a person or, far more often, generated by the graphical computer-aided design (CAD) or by the computer-aided manufacturing (CAM) software. CNC is a vast improvement over non-computerized machining that must be manually controlled (e.g. using devices such as hand wheels or levers) or mechanically controlled by pre-fabricated pattern guides. In modern CNC systems, the design of a mechanical part and its manufacturing program are highly automated. The part's mechanical dimensions are defined using CAD software and then translated into manufacturing directives by computer-aided manufacturing (CAM) software. Most new CNC systems built today are completely electronically controlled. Most CNC machines use Siemens or Fanuc made control systems. For Fanuc generally the coding is done by using G codes and M codes. G codes are used for machining operations and movement of the tools whereas M codes are used for controlling the spindle movement like on/off, rotation in clockwise or anti clockwise direction and also for tool change operations. The literature review and analysis set out the design and manufacturing of a component using 3 axes CNC milling machine which could work on its own to produce very accurate and high precision components with less time taken and with less human interventions also a conveyor belt system for transmission and pick and place objects and sorting and segregating of objects like ideas were proposed by different experts in their researches made the team curious to go in more depth of the concept so our team decided to design such model in which a component manufactured through CNC machine and pick and place objects from conveyor belt which itself is made automated which can start and stop on its own for that we collected data we sensed that different sensors and micro controllers will be required like ultrasonic sensors to stop conveyor belt as soon as a product encounters it and then a robotic arm will come to pick an object and place it in a predetermined position in storage locations. We analyzed different methods and different perspective of authors of robotics and considering the workspace we decided the manipulator attributes and robotic arm configuration like link length and joint values. The CAM software generates the G & M codes through post processing the tool paths and its programs and which are used to run the CNC machine. Here Auto desk form mill software is used to generate the programs for the CNC machine. The program which is generated by this software is called NC program. After that a post processor converts tool paths and program created in CAM software to specific commands that can be read by a machine's controller to move the cutting tool along the programmed paths as shown in figure 1.

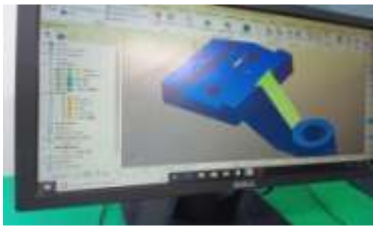

Fig. 1 Component using CAM Software

The literature study is carried out from various research papers and explained about the history of first CNC machine to present machines and its evolution. At bantam tools created desktop CNC (computer-numerically controlled**)** machines with reliability and precision. We set out on a journey to explore the history of CNC [1, 2]. The comprehensive story hasn't been told, and we feel it should be, so we invested the time to research it. What we found was an intriguing story of the human quest for increased efficiency and precision through machinery [3]. In 1775, John Wilkinson's boring machine was the solution to accurately boring cylinders for steam engines. James Watt is credited with creating the steam engine that powered the Second Industrial Revolution in England, but he was having issues obtaining consistent precision in his steam engine cylinders — until Wilkinson crafted his engine cylinder boring machine, based on the design of his original cannon-boring machine. In 1725, French textile worker Basile Bouchon invented a way to control looms by using data encoded on paper tapes through a series of punched holes. While groundbreaking, this method was fragile and still required an operator. In 1805, Joseph Marie Jacquard adopted this concept but strengthened and simplified it by tying punched sturdier cards in sequence, thereby automating the process [3 – 5]. These punched cards are widely regarded as foundational for what was to become modern computing, and signaled the end of the cottage industry in weaving. Interestingly, the Jacquard loom was met with resistance by the silk weavers of the time, who feared this automation would rob them of their jobs and livelihood. They repeatedly burned the looms that were put into production; however, their resistance proved futile as the industry recognized the advantages of the loom. By 1812, in France, there were 11,000 Jacquard looms in use. Punched cards developed throughout the second half of the 1800s and found many uses, from telegraphy to self-playing pianos [6 – 10]. In the latter half of the 20th century, punched cards were first used for data input and storage in computers and numerically controlled machines. The original format featured five rows of holes, while subsequent versions had six, seven, eight or more rows. A servomechanism is an automatic device that uses error-sensing feedback to correct the performance of a machine or mechanism. In some cases, the servo allows control of large amounts of power by a device with much lower power. A servomechanism is comprised of a device being controlled, another device that gives commands, an error detector, an error-signal amplifier, and a device to correct the errors (the servomotor). Servos are typically used to control variables like position and speed and are most commonly electrical, pneumatic, or hydraulic. The first electric servomechanism was created in England by H. Calendar in 1896. By 1940, MIT had created a dedicated Servomechanisms Laboratory, which grew out of the Department of Electrical Engineering's increased attention to the subject. In CNC machining, servos are essential to attaining the required tolerances of the automated machining process [11 – 14]. Born out of the MIT Servomechanisms Lab in 1956, as a brainchild of the Computer Applications Group, automatically programmed tools is an easy-to-use, high-level programming language intended specifically to generate instructions for numerically controlled machine tools. APT was the language created to work with MIT's first NC machine, one of the first in the world. It went on to become the standard for programming computer-controlled machine tools and was used widely through the 1970s. Development of APT was sponsored by the Air Force, and it was eventually added to the public domain. The head of the Computer Applications Group, Douglas T. Ross, is known as the father of APT. He also later coined the term "computer-aided design" (CAD) [15 – 17]. Automated storage and retrieval system (AS / RS) are warehouse system that are used for the storage and retrieval of products in both distribution and production environments. In industries AS /

RS systems are the main task that designed for automated storage and retrieval of things in manufacturing where their application vary widely from simple storage and retrieval system for small parts to central systems where production, assembly, and manufacturing operations are concentrically located around them [18].

II. METHODOLOGY

The objective of this research work is to manufacture a complicated designed profile by using CNC milling machine. The designed profile is carried by a robot from source location to destination location (interfacing process) through conveyor belt system (material handling) and places them at required location (AS & RS). Like most conventional mechanical CNC machining process, the milling process utilizes computerized controls to operate and manipulate machine tools which cut and shape stock material. CNC machining is a versatile, high precision traditional manufacturing process. It is a subtractive process (remove of some material from solid block of material) to create a finished part. Material selection is an important part of any manufacturing process. The main categories of material used in CNC machining are metals, plastics, ceramics, composites and wood. In general the most common metals of use with CNC machines are aluminium, stainless steel, brass, carbon steel, titanium and plastic. For the machining we are using aluminium alloy because of its less cost and light weight and good machining and work flow is shown in figure 2. Although all types of aluminium grades are used with the CNC machines. This is primarily due to the matching properties of 6061 and 7075 grades of aluminium. Aluminium and its alloys have a very good strength to the ratio and are resistance to corrosion. Due to these characteristics and grades it has a wide set of applications in industry. The 6061 aluminium grade is usually used for manufacturing auto parts, aircraft components and various other applications. The chemical composition and physical properties had shown in table 1 and 2. Some of other specifications are Weight of block = 3000 grams, Grade = 6061 alloy, Tensile strength = 42000 psi, Yield strength = 276 MPa and, work material dimensions = 56*118*63 mm. The 3D CAD system CATIA V5 was introduced in 1999 by Dassault Systems. Replacing CATIA V4, it represented a completely new design tool showing fundamental differences to its predecessor.

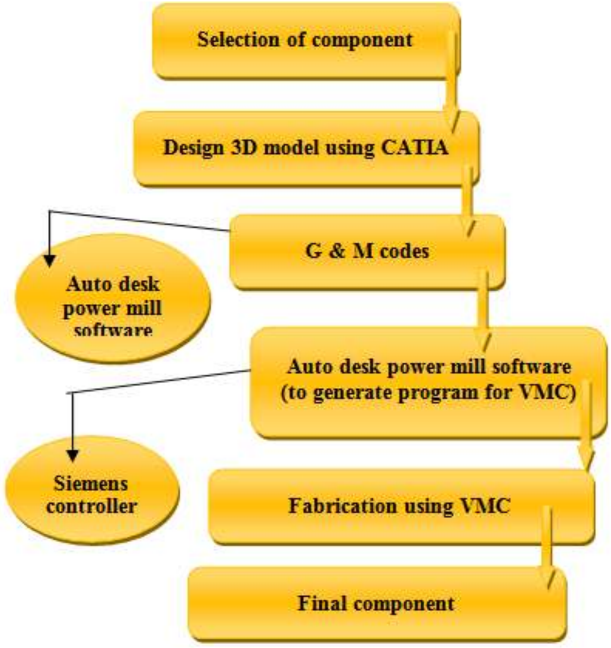

Fig.2 Work flow process for CNC machining

Table 1 – Chemical composition of Aluminum alloy

Element	Content (%)
Aluminium	97.9
Magnesium	1
silicon	0.60
copper	0.28
Chromium	0.20

Table 2 – Physical properties of Aluminum alloy

Properties	Metric
Density	2.7 g/cm^3
Melting point	588 °C

CATIA (Computer Aided Three-dimensional Interactive Application) is a multiplatform CAD/CAM/CAE commercial software suite developed by the French company Systems. CATIA is the cornerstone of the Dassault Systems product lifecycle management software suite. The CAD model has been created in the workbench of the CATIA v5 software according to the dimension. It is widely used by multiple industries as effective software for sketching and rendering technology, market compliance, and of course, active collaboration.

III. RESULTS AND DISCUSSIONS

The code developed for component fabrication is as follows. Siemens is a series of programmable logical controller and automation system developed by Siemens. It was introduced in 1958. This software is used for industrial applications and production. This is used for both milling and lathe machines. It creates detailed instructions (G & M codes).

This code once executed helps the CNC machine perform the required actions like cutting and drilling.

```
N120 G0G91G28Z0.0
N121 M6T5
N122 G0G40G80G49G17
N128 (TOOL ID :10 END-Top Flat F3)
N132 S4500 M03
N133 G00 G90G54 X33.0 Y0.0
N134 G43 Z10.0 H5
N135 M08
N136 G05 P10000 R8
N137 X-5.275 Y35.9965
N138 Z5.0
N139 G01 Z-45.0 F140.0
N140 X0.0 F1400.0
N141 X57.4177 Y36.0005
N142 G02 X60.9969 Y36.2665 I3.7096 J-25.7055
N143 G00 Z-40.0
N144 G01 X-5.275 Y30.9965 F4500.0
N145 Z-45.0 F140.0
N146 X0.0 F1400.0
N147 X57.796 Y31.0006
N148 G02 X60.9969 Y31.2664 I3.3046 J-20.3843
N149 G00 Z-40.0
N150 G01 X-5.275 Y25.9965 F4500.0
N151 Z-45.0 F140.0
N152 X0.0 F1400.0
N153 X58.2269 Y26.0006
N154 G02 X60.9976 Y26.2663 I2.8474 J-15.1101
N155 G00 Z-40.0
N156 G01 X-5.275 Y20.9965 F4500.0
N157 Z-45.0 F140.0
N158 X0.0 F1400.0
N159 X58.7403 Y21.0006
N160 G02 X60.9979 Y21.2663 I2.3079 J-9.8882
N161 G00 Z-40.0
N162 G01 X-5.275 Y15.9965 F4500.0
N163 Z-45.0 F140.0
N164 X0.0 F1400.0
N165 X59.4147 Y16.0007
N166 G02 X60.9976 Y16.2661 I1.6077 J-4.7345
N167 G00 Z-40.0
N168 G01 X-5.275 Y10.9965 F4500.0
N169 Z-45.0 F140.0
N170 X0.0 F1400.0
N171 X2.8134 Y11.0012
N172 X60.8646 Y11.0008
N173 X60.9969 Y11.2232
N174 G00 Z5.3125
N175 G01 X61.7719 Y-36.2665 F4500.0
N176 G00 Z-40.0
N177 G01 Z-45.0 F140.0
N178 X60.9969 F1400.0
N179 G02 X57.4207 Y-36.001 I0.1304 J25.9717
N180 G01 X0.0 Y-35.997
N181 G00 Z-40.0
N182 G01 X61.7719 Y-31.2664 F4500.0
N183 Z-45.0 F140.0
N184 X60.9969 F1400.0
N185 G02 X57.7987 Y-31.001 I0.1038 J20.6511
N186 G01 X0.0 Y-30.997
N187 G00 Z-40.0
N188 G01 X61.7726 Y-26.2648 F4500.0
N189 Z-45.0 F140.0
N190 X60.9976 Y-26.2663 F1400.0
N191 G02 X58.2292 Y-26.001 I0.0767 J15.3757
N192 G01 X0.0 Y-25.997
N193 G00 Z-40.0
N194 G01 X61.7729 Y-21.2651 F4500.0
N195 Z-45.0 F140.0
N196 X60.9979 Y-21.2662 F1400.0
N197 G02 X58.7422 Y-21.001 I0.0504 J10.1539
N198 G01 X0.0 Y-20.997
N199 G00 Z-40.0
N200 G01 X61.7726 Y-16.2647 F4500.0
N201 Z-45.0 F140.0
N202 X60.9976 Y-16.2661 F1400.0
N203 G02 X59.4161 Y-16.0011 I0.0249 J4.9999
N204 G01 X0.0 Y-15.997
N205 G00 Z-40.0
N206 G01 X61.7719 Y-11.2232 F4500.0
N207 Z-45.0 F140.0
N208 X60.9969 F1400.0
N209 X60.8646 Y-11.0012
N210 X0.4913 Y-11.0031
N211 X0.0 Y-10.997
N212 G00 Z5.0
N213 G01 X66.0 Y-11.771 F4500.0
N214 Z0.0 F140.0
N215 Y-10.996 F1400.0
N216 Y10.9986
N217 G00 Z200.0
N218 G05 P0
N225 M30
```

The Code or part program generated by Siemens controller is as follows:

```
N1 WORKPIECE(,"",,"BOX",112, 0, -63, -80, 0, 0, 118, 75)
N2 G17 G90 G94 G54
N3 T= "CUTTER 10"
N4 MO6
N5 M03 S2000
N6 G00 X0 Y0 Z5
N7 G01 X0 Y0 Z0 F1500
N8 POCKET3(100, 0, 1, -45, 90, 33.5, 0, 39, 14.75, 0, 2, 0, 0, 1000, 0.1, 0, 11, 60, 80)
N9 POCKET3(100, 0, 1, -45, 90, 33.5, 0, 39, 60.25, 0, 2, 0, 0, 1000, 0.1, 0, 11, 60, 80)
```

N10 M05
N11 G01 X0 Y0 Z0 F1500
N12 T="CUTTER 5"
N13 MO6
N14 M03 S2000
N15 CYCLE62("BALU", 1, ,)
N16 CYCLE72("", 100, 0, 1, -63, 2, 0, 0, 1000, 100, 101, 40, 4, , 0.1, 1, 0, 0, 1, 2, 10)
N17 E_LAB_A_BALU: ;
G17 G90 DIAMOF;
GO X81 Y29 "GP1
G3 Y46 I=AC(99 655) J-AC (37.5).
E_LAB_E_BALU:
N18 G01 X0 YO 20 F1500
N19 M05
N20 T="CUTTER 5"1
N21 M06
N22 M03 S2000
N23 CYCLE62("BALU1", 1,.)
N24 CYCLE72("", 100, -45, 1, -63, 2, 0, 0, 1000, 100, 101, 40, 4, 81, 1, 0, 0, 1, 2)
N25 E LAB_A_BALU1: #SM 2: 41
G17 G90 DIAMOF:
G0 X53.5 Y0
G1 Y29;
X79.5 ;
E_LAB_E_BALU1:
N26 G01 X0 YO Z5 F1500
N27 M05
N28 T="CUTTER 5"
N29 M06
N30 M03 S2000
N31 CYCLE62("BALU2", 1,,)
N32 CYCLE72("", 100, 45, 1, 63, 2, 0, 0, 1000, 100, 101, 40, 4,, 0 1, 1, 0, 0, 1, 2)
N33 E_LAB_A_BALU2;
G17 GOO DIAMOF;
GO X54.5 Y75 ;
G1 Y46 ;
X79.5
E_LAB_E_BALU2:
N34 G01 XO YO Z5 F1500
N35 M05
N36 T="DRILL 22"
N37 M06
N38 M03 S2000
N39 G01 X100 Y37.5 Z0 F1500
N40 CYCLE82(100, 0, 1, -63.1, 10, 10001, 22)
N41 G01 X100 Y37.5 Z5 F1500
N42 M05
N43 T="DRILL 12"
N44 M06
N45 M03 S2000
N46 G01 X28 Y15 Z0 F1500
N47 CYCLE82(100, -45, 1, -63,, 1, 10, 10001, 22)
N48 G01 X28 Y15 Z5 F1500
N49 G01 X28 Y60 Z0 F1500
N50 CYCLE82(100, -45, 1, -63,, 1, 10, 10001, 22)
N51 G01 X28 Y60 Z5 F1500
N52 M05
N53 G18 G54
N54 T="CUTTER 5"
N55 M06
N56 M03 S2000
N57 CYCLE62("BALU3", 1,,)
N58 CYCLE72("", 100, -31, 1, -45, 1, 0, 0, 100, 100, 101, 40, 1, 0, 0.1, 1, 0, 0, 1, 2,)
N59 G01 X2 Y2 Z0 F1500
N60 E_LAB_A_BALU3: ;
G18 G90 DIAMOF;
GO 22.5 X-2.5;
G1 X66.5;
N61 M05
N62 M30

Nowadays CNC machines are widely used for manufacturing complicated parts and used for high production rate with accurate in less time. In this we are using 3 axes CNC vertical milling machine where the spindle is moved in horizontal direction. In this the spindle moves and work piece remains constant in its position. The movements of spindle in XYZ are as follows in figure 3:

The movement of the spindle in X direction is forward and backward movement
The movement of the spindle in Y direction is front and back direction. The movement of the spindle in Z direction is up and down direction.

Fig. **Error! No text of specified style in document.** CNC vertical milling machine

IV. CONCLUSIONS

CNC is a very popular method of creating parts. These machines have extreme precision at a fast rate. It provides the technology, precision, accuracy and consistent flow of procedures for a high production rate. For development of integrated CAD/CAM design and machining select a aluminium component having dimensions of

75×118×63mm after that designed a complicated profile by using a CATIA V5 software. CATIA is a computer aided three dimensional interactive application used to design 3-D models. The 3-D model which is generated through CATIA software is copy to auto desk form mill software which is used to generate programs (contains G & M codes) for different operations like roughing, finishing and drilling. After that the fabrication is done using CNC vertical milling machine contains Siemens controller. The controller helps to execute the program in a right manner. Concepts of different types of CNC machines, various types of tools and different types of operations and its programs are combined in this project. CNC machines are very complex and being able to efficiently operate one takes much time and practice, although most of the codes are similar but CNC machines are different from model to model. CNC milling is not easy at first but mastery of it allows you to create parts in a very short time period.

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