An Improved Approach to Modern Techniques for Computer Numerical Control (CNC) Machine Operation

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Abstract — *In modern manufacturing systems, the complex nature of industrial processes, the need for quality products to continuously shorten lead times and the effort to achieve greater productivity is pushing both researchers and practitioners to achieve enhanced process control of the manufacturing method of Computer Numerically Controlled (CNC). Existing companies do not use cycle time for efficiency to check mate the activities of their staffs whether they are truly utilizing the working hours, which results in low productivity. CNC machines are classified into milling, lathe, drilling, routers etc. which uses a computer to electronically control the motion of one or more axes on the machine. In this work, a novel model was developed to improve modern technology of CNCs. Furthermore, Structured System Analysis and Design Methodology (SSADM) is used in this approach. The developed system was implemented with MAZATROL CNC simulator. The results obtained demonstrate that the MAZATROL CNC simulator is a perfect addition to the classroom and an essential component for maximum exposure to MAZATROL CNC controls when the actual time of the machine is reduced. This work could be beneficial to major players and stakeholders in the Oil and gas sector (upstream and downstream inclusive), to production and manufacturing companies, to SMEs and to any other organization that deals on extracting current CNC information.*

Keywords — *Modern Techniques, Computer Numerical Control, Machine Operation, Mazatrol CNC Simulator, Milling, Lathe, Drilling, Routers.*

I. INTRODUCTION

In modern manufacturing schema, the complex nature of industrial processes, the need for quality products to constantly minimize lead times and the desire to achieve higher profitability require both researchers and practitioners to gain enhanced process control of the computer numerically controlled (CNC) production system. CNC stands for Computer numerically Controlled. This refers to any machine tool (i.e. mill lath, drill press, etc.) that uses a computer to control the movement of one or more axes on the device electronically. The production of NC machine tools began with a program funded by the US Air Force in the early 1950s, including MIT and several machine tool manufacturing companies. The need to produce complicated jet aircraft components was recognised for machines Computers replaced the more inflexible controllers used on the NC devices as computer technology evolved; hence the beginning of the CNC era. CNC machine machines use software programs to provide the required guidance for regulating axis moves, spindle speeds, tool adjustments, etc.

NC has been used in industry for more than 40 years. To put it simply, NC is a way of running a processing system automatically based on a code of letters, numbers and special characters. A complete set of coded instructions is considered a program to execute an operation. The algorithm is converted into equivalent electrical feedback signals to the motors running the machine. It is possible to configure NC machines manually. If a computer is used to create a program, the process is known as computer-aided programming.

According to [1], “a CNC machine is an NC machine with the added feature of an onboard computer”. The onboard computer is often referred to as the Machine Control Unit (MCU). Control systems for NC devices are typically hardwired, which ensures that the actual electrical components that are integrated into the device which controlled all system functions. However, the onboard computer is "soft" wired, which means that at the time of production the machine functions are stored in the computer and will not be removed when the CNC device is powered off. Computer memory that holds such information is known as ROM or read-only memory. The MCU typically has a component programs alphanumeric keyboard for Manual Data Input (MDI) operator. These functions are stored in the RAM or part of the computer's random access memory. The control will play them again, edit, and process them. Nevertheless, when the CNC computer is switched off, all programs stored in RAM are missing.

This study addresses major problems in present CNC machines. In the case of an extreme power failure, most manufacturing industries are facing problems in location management of the vertical axis during machining on CNC machines. Thanks to friction and gravitational force on the vertical axis in CNC machines, the axis drops downwards. In the event of die and mould supplication, where work precision is perceptibly quite large, the damages caused due to this problem are very expensive when the material being machined is titanium or other costly materials. In order to avoid this problem, it is obligatory to stop the axis run away immediately.

II. RELATED WORKS

Venkata et al. [2] researched on the study of Computer Numerical Control (CNC) machines in which they highlighted different applications of CNCs, especially in different processes such as facing, spinning, dipping, digging, boring and knurling to boost production in order to minimize production time and also to increase efficiency in conventional lathes and CNC machines by coding the software on STC-25 CNC lathes. However, the work could not further discuss individual advanced techniques for training large-scale Lathe CNCs models and also recently developed method of generative models

Dhandapani et al. [3] looked at Investigation on effect of material hardness in high speed CNC end milling process. The research analyzes the impact of material properties on surface roughness, product removal rate and device wear for different ferrous and nonferrous materials on high-speed CNC finishing processes. The challenge of material specific decision on the process parameters of spindle speed, feed rate, depth of cut, coolant flow rate, cutting tool material, and type of coating for the cutting tool for required. The task of material-specific decision on the process parameters of spindle speed, feed rate, cutting depth, coolant flow rate, cutting tool size, and cutting tool form for the required quality and output quantity. Generally, decision made by the operator on floor is based on suggested values of the tool manufacturer or by trial and error method. However, there was no adequate comparative analysis of the system with other existing ones.

Mohd [4] researched on Computer Control Machines: An Account Programming Methods and Techniques. According to the work; A Computer Numerical Control (CNC) machine tool is basically the same as a conventional machine tool. In terms of machining, the practical capacities of CNC machine tools often vary slightly from those of traditional machine tools. There were quite some percentage error levels in the developed programming methods.

Sergej et al. [5] researched on the development of a cross-platform CNC kernel for multi-axis machine tool. The study proposes an approach based on platform-independent libraries to create a scalable CNC kernel. Open architecture CNC system offers abstraction levels in the kernel to implement various HMIs, accept different versions of the program language, and use different field buses. An example of cross-platform CNC kernel adaptation is demonstrated with multi-channel and multi-axis machine tools. However, the work failed to show improvement measures on the already achieved 2.2% error rate on average

The Metrological Control of selected surface types of the mechanical part was studied using the on-machine measuring system. The paper focused on investigating on-machine measuring systems for a multi-axis CNC milling machine [6]. The work aims at choosing the correct measurement parameters for on-machine measuring systems to ensure precise and accurate quality control of the mechanical component. Theoretical information and overall concept of research were also presented. However, there was no adequate comparative analysis of the system with other existing ones.

Asif [7] looked at features and application of CNC machines and systems. According to the work; The invention of Computer Numeric Controlled (CNC) machines is an excellent contribution to the manufacturing industries. It has made it possible to simplify the machining processes with versatility in limited output to accommodate low to medium batch sizes. The CNC technique was initially applied to simple metal cutting machines such as lathes, milling machines, etc. etc. However, the performance evaluation of the work showed some deficiency in lifecycle assessment (LCA) and speed.

Rajendra et al. [8] researched on Comparative Study of CNC Controllers used in CNC Milling Machine. According to the work; the quality of finished work piece depends on the relative positions between the work pieces, cutting tool, machining process parameters. It can be achieved if a CNC machine tool possesses sufficient strength to withstand the cutting forces, stiffness against deformation and capability of CNC controller. CNC controller is the heart of the CNC machine which controls most of the functions of CNC machine. However, there was no adequate comparative analysis of the system with other existing ones.

Kartik [9] looked at modern techniques in CNC Machines: A Review. The paper describes modern techniques of Horizontal and vertical CNC machines, manufacturing problems for different processes, axis positioning problems, motion error inspection methods. Solution for above problem is also given to some extent. There was no Program implementation to further shed more light to the work

Manish et al. [10] looked at Literature Review for Designing portable CNC machine. The paper addressed various author's literature review who tried to build the smaller CNC machines. CNC technology today plays a major role in sectors. CNC machines are the main platform for the industry to offer good quality products. CNC machines are basically automated devices based on code letters (NC etc.), numbers and special characters. The numerical data required for manufacturing a part provided by machine is called CNC (Computer Numerical Controlled). There was no Program implementation to further shed more light to the work

Sriranga [11] discussed the design and fabrication of 3-axis CNC Milling Machine. Computer Numerical Control or CNC device is a typical system where an operator decides and changes different parameters of machines such as feed, cutting distance, etc. The slide movement is regulated by hand, depending on the type of work. It is also a complex and scalable variant of a Soft Automation and its implementations include many types of machine tools, although it was initially developed to control the movement and operation. However, the performance evaluation of the work showed some deficiency in lifecycle assessment (LCA) and speed

Jason [12] looked at synergies of hybridizing CNC and additive manufacturing. CNC and AM's compatible and complementary nature implies they do not need to be mutually exclusive and should not be. To fully exploit the possible synergies of additive and subtractive technology, CNC and AM fitted hybrid machine tools allow the use of both technologies to the fullest extent appropriate. Furthermore, the paper demonstrated hybrid CNC machines equipped with laser cladding capabilities. This combination provides an ideal platform for high-value part repair, refurbishment and modification. However, there was no adequate comparative analysis of the system with other existing ones.

Xionghui et al. [13] Researched on the optimization design of spindle load of CNC machine tools. The paper described the finite element machine tool spindle and attachment model, detailed simulation of boundary conditions, constraints and external loads, and study of static and dynamic spindle characteristics, spindle optimization architecture based on ANSYS software. There was no Program implementation to further shed more light to the work

Valvo [14] looked at CNC Milling Machine Simulation in Engineering Education. According to the work; an effective CNC milling machine simulator has been presented. It was developed by an international community in EMC2, free Opens Source NC software running in Linux environment. It can be mounted on a popular PC and can: monitor a CNC machine; read component programs; show the direction of the tool; give the cutting method instructions to the CNC machine. It can be installed on a common PC and is able to: control a CNC machine; read part programs; display the tool path; send instructions to the CNC machine for the cutting process. However, the performance evaluation of the work showed that there was an error rate of 27.75% in areas of Life-cycle assessment (LCA)

Pankaj [15] researched on Experimental Investigation of parameters of CNC Turning by Taguchi-based Grey Relational Analysis. The AISI H13, a chromium-based hot work tool Steel has a wide range of applications in aluminium casting and extrusion dies, welding dies, hot nut tools, hot header dies, extrusion mandrels, plastic moulds, cores, die holder bases, hot press dies and specially hot work punches etc. In this work, the optimization of two parameters of reaction (surface roughness and material removal rate) by three parameters of machining (cutting speed, feed rate and cutting depth) is investigated in high speed H13 turning under dry conditions. Taguchi's L'18orthogonal array and analysis of variance (ANOVA) are used for individual optimization. However, there was no adequate comparative analysis of the system with other existing ones.

Chunshan [16] researched on the failure rate experimental study of special CNC Machine tool. Based on machine failure distribution function and reliability function, a special CNC machine tool failure rate of the single sample was given. How to establish the special NC machine tool failure distribution function is the key. However, there was no adequate comparative analysis of the system with other existing ones.

A research on development of CNC program for piston production. The work illustrated that the development of a Computer Numerical Control program for the machining of a piston is a work that involves the casting and machining of a piston on a numerical control machine tool. A Computer Numerical Control (CNC) can be described as a method for automating and controlling machine tools through the use of Software embedded in a micro-computer. There was no Program implementation to further shed more light to the work

Lucian et al. [17] looked at reducing the risks during the purchase of five-axis CNC machining centers using AHP method and fuzzy systems. The work developed a method for decision making process especially in the selection between different 5-axis CNC machining and technological centers with similar technological capabilities. However, there was no program implementation to further shed more light to the work.

III. MATERIALS AND METHODS

A. Analysis of the Existing System

The study analyzed the Existing System of Gas Cutting Technology using CNC Machine in the Oil and Gas Sector. Lucian et al. [17] analysis illustrated that machine for cutting plate are often called flame cutting machines or burning machine, and most of these have sophisticated computerized or optical guidance and multiple cutting stations. This allow for fast and accurate cutting of complicated shapes. The technique is rather basic, but it's often as much an art as science to do it really well. Flame cutting requires a careful balance of oxygen flow cutting, flame preheating and pace cutting. If either of these considerations fails to match the cut price. Further analysis of our feasibility study on the Existing System showed that experiments were conducted to determine the appropriate settings of cutting parameters, nozzle size, acetylene pressure, heating oxygen pressure, cutting oxygen pressure and cutting speed to obtain the high quality cuts for unalloyed steel up to 0.3% carbon using oxygen with purity of 99% minimum for different sheet thickness, as shown in Fig 1.

The process characteristics were drawn from the experimental data for cutting speed, heating oxygen, and cutting oxygen with respect to sheet thickness to obtain the best-fit curve equations. One of the simplest ways to break steel is to use a stream of pure oxygen to essentially melt a hole in it. This process, called flame cutting, cutting or burning oxygen, is an economical steel cutting method that offers good sided safety margins. Flame cutting is a true chemical combustion process; the material is not simply melted away, but instead of leaving ashes as a combustion product, burning steel leaves behind a material called slag, which is basically iron oxide. Steel is unique because the slag it creates melts at a slightly lower temperature than the parent metal. The slag is produced as a liquid in combustion heat and when aided by the release of more air, it is quickly blown away as a fine mist. This is a key factor that causes the uncut metal to remain intact, with a flat, square cut profile, thus causing the neighboring material to begin to burn. The widely used cutting torch gives the steel a fiery blaze, but this flame does not do the definite cutting. That is done by a high-pressure jet of pure oxygen, which is delivered at the center of the preheat flame. To start a cut, the user brings a flame close to the steel plate, using a cutting torch, which burns a mixture of fuel gas and oxygen to create a very hot preheat flame. The steel is heated to its kindling temperature at least 1500° F about a bright red to orange color on steel.

The extra supply of high-pressure oxygen is powered on when hot enough. The stream is aimed right at the hottest spot at the steel sheet. The metal will start to burn the second the oxygen reaches it, and the slag will be blown out of the way by the speed of the flow of the cutting oxygen, creating a hole in the metal throughout the process. The initial burning through the steel gives off enough heat to preheat the adjacent metal through its entire thickness. The chemical equation for complete combustion of iron with oxygen is $3Fe + 2O2 = Fe304 + 267{,}000$ calories. The Fe304 product is a black iron oxide. The technical name for it is ferrous ferric oxide. It is the main component of the black dust, which settles in the shop floor after cutting. The oxygen needs to be nearly pure, and the cutting process becomes impossible if the purity is below 90 percent. The oxygen consumption will vary considerably depending on whether the process is optimized for speed, quality of economy. The heat generated by combustion is more than adequate to heat the adjacent steel to ignition temperature so that the burning can continue. Most of the heat will flow out of the cut region with the slag, but a significant portion will heat the adjacent uncut metal. Usually, the heat hitting the work piece creates two problems; a warping propensity and a heat-affected region that upsets the steel's properties. It is because the steel is melting so quickly and unevenly. The heat-affected environment affects the steel's grain composition and helps to harden the steel or produce tiny cracks in the cut edge. Such variables may affect machinability or weldability, and may even cause the cut component to fail. You can use the different methods to mitigate such results. These include preheating the steel before cutting of annealing it afterward; either a localized source of heat from a special torch may be used.

B. Explanation of the Existing System Architecture

The following components of the Existing System Architecture include:

1) ***Torch:*** This is a blow-pipe by which metal is pre-heated with a flame and then oxidized rapidly and removed by a jet of oxygen issuing centrally through the pre-heating flame.

2) ***Optimum Torch Height:*** This can simply be defined as the distance between the torch and work-piece.

3) ***Work-Piece:*** This is defined as an object being worked on with a tool or machine.

4) ***Lift Motor:*** This is a form of vertical transportation between building floors, levels or decks commonly found in machines. It also electrically controls lifting processes.

5) ***Plasma Torch Lifter:*** This is a device for generating the flow of plasma. Furthermore, the plasma torch lifter is controlled by the Hypertherm Sensor. In other words, all plasma process parameters are set and automatically maintained during the cutting cycle.

6) ***Motor Drive Amplifier:*** This is a linear "push-pull" current amplifier. It provides high input impedance; hence it draws little current form the input control analog voltage.

7) ***Arc Voltage Control Logic:*** This is a compact, lightweight, weld torch manipulation control system that is comprised of the micro-controller based automatic torch control and a stepper motor-driven linear slide assembly.

8) ***Arc Voltage Command:*** This is the voltage that appears across the contacts during arcing period. At current zero, the arc voltage rises rapidly to peak value, and this peak voltage tends to maintain the current flow in the form of arc.

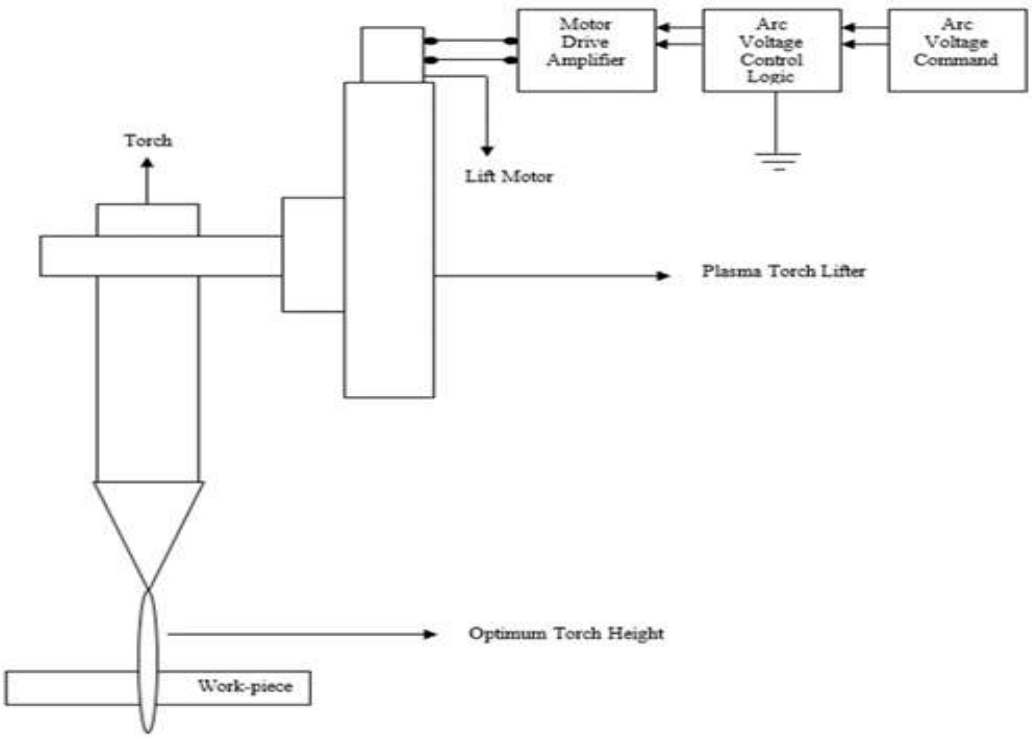

Fig 1: CNC Electrified Gas Cutting Machine (Source: Lucian et al, 2018)

C. Advantages of the Existing System

The following advantages of the Existing System include:

- The Existing System is very portable as no power supplies are needed. A cylinder for fuel gas, hoses, a torch, and a striker are all that are required.
- The Existing System can cut very thick metals with the right equipment and gas flows, steels, etc. Also, several feet thick can be cut using the flame cutting process.
- The Existing System also has low equipment costs.

D. Disadvantages of the Existing System

The following disadvantages of the Existing System include:

- There are some major anomalies still associated with the Existing System such as incorrect measurement in all dimensions, non-availability of proper Expert System build-up and development in order to work in a stable way. This is further justified through the lack in machine management and automated operations due to the application of obsolete CNC machines in the oil and gas sector.
- The Existing System is also at a disadvantage when it comes to material types that can be cut. In other words, the Existing System is generally limited to carbon steel, low alloy steels and cast irons.
- In addition, due to the heat involved in flame cutting, the metal edges being cut can often form a thin and brittle layer of solidified steel, known as the decarburized

layer. This may need to be removed based on the application.

E. Analysis of the Proposed System

In improving the Existing System as developed by [17], we developed an Optimized Parameter of CNC Flame Cutting Machine. The Proposed System is fully automated in terms of Control and Machining Simulation. It is also programmed to work offline. Furthermore, the aftermath of our in-depth feasibility study showed that; a standout amongst the most imperative non-customary machining strategies is CNC fire Machining. The high accuracy, completion, machining capability of any hard materials and producing mind-boggling form creates the demand in showcase. The CNC fire cutting technique uses a fire burning with an unusually small bore to create a traded curve of the work piece at a standard current thickness within the light drag. The strength and energy of the fire fly created by the fire softens, vaporizes and expels the metal from the spout impingement district. Secondly, the overall objective is to minimize total manufacturing costs by utilizing the advantages of the concept of tool sharing and loading duplicate tools due to a possible reduction in the tooling and operating costs of tools while maintaining priority viability, tool magazine capacity, tool life coverage and tool availability constraints due to tool contention between operations, since the lack of such vital constraints will lead to unworkable outcomes. In addition, the proposed approach can provide an effective tool for decision-making in the short term, as depicted in Fig 2.

Also, the pre-heat flames develop best heating ability when the oxygen and fuel gas are properly balanced. Slight excess of oxygen often produces a hotter flame for piercing, but too much oxygen cools the flame. Slight changes in the proper ration will cause the maximum heating to occur a little further, or a little closer, to the tip face. The flame temperature is often at its highest if slightly too much preheat oxygen is used. This is called an oxidizing flame and can be convenient when pre-heating prior to piercing. Acetylene and heating oxygen pressures are adjusted so that heat produced by the flame is according to the sheet thickness and there should not be any imperfections in cuts. If the pre-heat flame is set right, there will be almost no melting of the top edge. The oxygen velocity and cutting speed have to balance the plate thickness. Too little oxygen may not have enough velocity to eject slag properly; too much may push slag out so fast that adequate combustion has not been completed and the slag will be very hard. The two main limitation on cutting speed are the quantity of pure oxygen available and the ability of the preheat flame to keep the top surface hot enough to continue the cut. The desired cutting quality is also a factor. Although the oxygen may have been pure as it entered the top surface of the steel, the cutting process dilutes the oxygen's ability to react with the steel because slag begins mixing with the oxygen as it travels through the cut. This slows down the cutting process. Use of a hotter preheat flame and a higher velocity cutting jet increases the cutting speed somewhat, but often the primary speed limit is determined by the time required to flush slag from the cut.

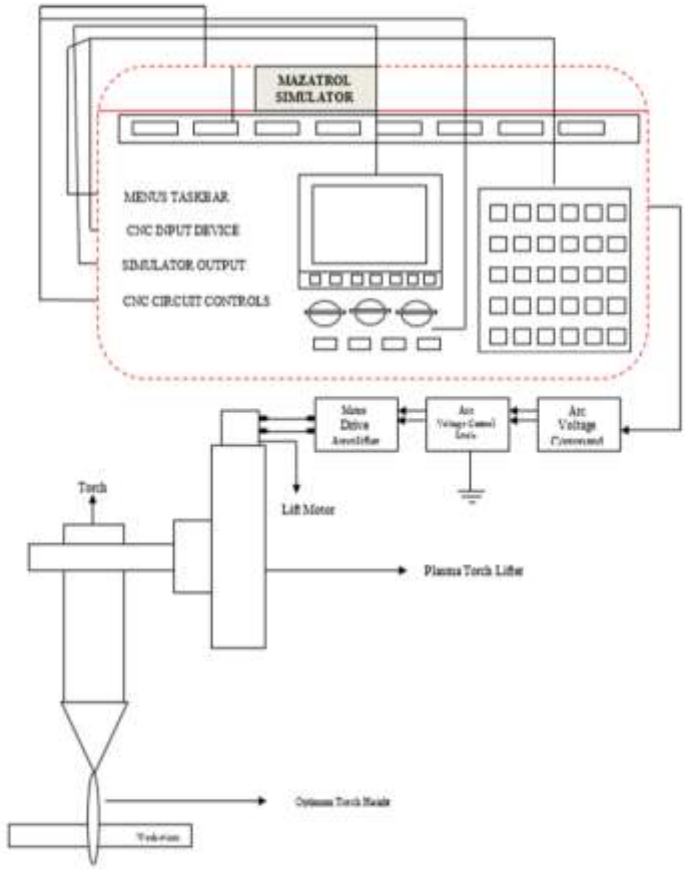

Fig 2: An Improved CNC Electrified Gas Cutting Machine using Mazatrol Simulator

F. Explanation of Proposed System Architecture

The following components of the Proposed System include:

1) ***Menus Taskbar:*** This component contains menus and attributes for performing specific tasks with the CNC machine simulator. The menu task bar contains the measure menu, file menu, option menu, view menu, switch panel menu, work-piece menu and checks for updates.

2) ***Simulator Output:*** This component displays inputted controls and commands of the system.

3) ***CNC Circuit Controls:*** This component is used for managing, commanding, directing, or regulating the behavior of the flame cutting machine. Furthermore, it can range from a single heating

controller to large industrial control systems which are used for controlling processes or machines.

4) ***CNC Input Device:*** This component is used for sending data into the system in order for efficient interaction and control.

5) ***Torch:*** This is a blow-pipe by which metal is pre-heated with a flame and then oxidized rapidly and removed by a jet of oxygen issuing centrally through the pre-heating flame**.**

6) ***Optimum Torch Height:*** This can simply be defined as the distance between the torch and work-piece.

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G. Advantages of the Proposed System

The following advantages of the Proposed System include:

- The Proposed System is fully automated in terms of Control and Machining Simulation. It is also programmed to work offline. Furthermore, it has high precision, completing, and the capacity of machining any hard materials and to create mind boggling shape builds its request in showcase.
- The Proposed System is very portable as no power supplies are needed. A cylinder for fuel gas, hoses, a torch, and a striker are all that are required.
- The Proposed System can cut very thick metals with the right equipment and gas flows, steels, etc. Also, several feet thick can be cut using the flame cutting process.
- The Proposed System also has low equipment costs. The Methodology for the Proposed System Design is Structured System Analysis and Design Methodology (SSADM). Structured Systems Analysis and Design Methodology is a system methodology for information systems analysis and design.

IV. DISCUSSION OF RESULTS

Figure 3 shows the front-end interface of FANUC CNC simulator. The FANUC CNC simulator is a perfect addition to the classroom and an essential component for maximum exposure to FANUC CNC controls with minimal system time. The simulator, based on the FANUC 0iF model, will allow a power-on user to move between milling and turning configurations to teach programming, navigation, and activity on the most common CNC control in the world. Easy settings make it easy for a new FANUC system to know how to work and edit details. The MGi conversational gui of FANUC allows users to create programs that can be replicated in 3D before transitioning to standard NC programs that can be used on machine tools with FANUC controls. Upload and download (read and punch) functions are made easier with the standard Flash ATA interface and USB interface, and Ethernet and Flash ATA card support DNC functions.

Fig 3: Frontend-Interface of the FANUC CNC Simulator

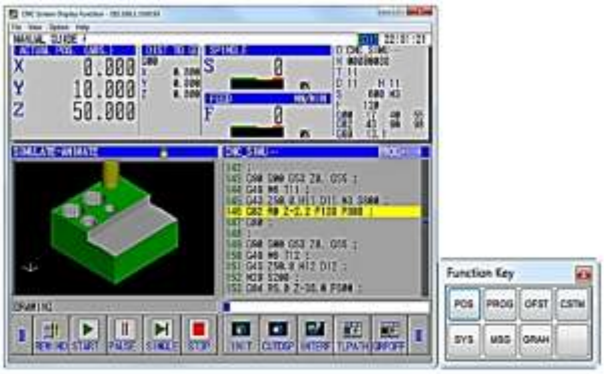

Fig 4: FANUC CNC Screen Display Function

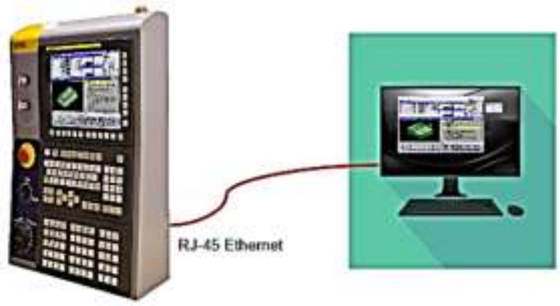

Fig 5: FANUC CNC Screen Display Software

Users can perform operations and programming exercises away from the machine and then simply take the program to the machine. Features such as the dual screen display of FANUC are standard features, so that additional PC program students can reproduce the simulator screen on a PC via the instructor-led class Ethernet connection on a projector. Process-oriented conversational programming for students transitioning to a smaller workspace or tool space, user-friendly conversational programming manual simplifies and improves their productivity. This creative component programming process environment centers the student on computer operations rather than just G-code, facilitating the execution of a job in the lowest amount of time available. The CNC Screen Display Function program allows the user to use the Ethernet connection to run and view the simulator displays and data on their PC screen in real time. The key control buttons allow you to switch between functions while all the relevant data will be displayed on the main screen, as depicted in Fig 4 and Fig 5 respectively.

Data can be modified, loaded, and saved, allowing tutor lead lessons to be taught on a large screen monitor to a larger group, while students are participating on their own simulators

V. CONCLUSION

The study discussed on an improved approach to modern CNC techniques. To achieve sustainable development, it is important to meet traditional demands for financial attention and environmental impact. A number of indicators are used in the production method in order to increase economic output in terms of time, cost and quality at different stages. It is very relevant to define criteria, signs and solutions in order to make manufacturing more environmentally friendly, as research based on CNC machining.

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