A REVIEW OF CNC MACHINE TOOL TYPES, APPLICATIONS, AND PROGRAMMING APPROACHES

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ABSTRACT

This review paper delves into the evolution, capabilities, and practical applications of CNC machines, which have revolutionized the field of mechanical processing. The paper provides an in-depth analysis of various types of CNC machines, including milling, turning, and multi-axis systems, highlighting their adaptability and efficiency in performing complex machining tasks. It presents the fundamental principles of mechanical machining and it also explores key aspects of CNC machine programming, emphasizing the significant role of ESPRIT TNG software in optimizing processing workflows. This advanced software enables intuitive and flexible CNC programming, providing users with powerful tools for simulation and G-code generation. This software offers comprehensive capabilities for simulation, toolpath generation, and seamless integration into diverse manufacturing environments. By integrating technical information, this paper aims to become a valuable resource for both specialists and beginners in this domain. The focus is placed on knowledge transfer and fostering innovation in computer-assisted mechanical processing.

KEYWORDS: CNC machines, hybrid CNC machine, machining feeds and speeds, CAM, ESPRIT TNG.

1. INTRODUCTION

CNC machines are essential in manufacturing, enabling high-speed machining of difficult materials and supporting the production of complex mechanical components. Their effective use requires a clear representation of machine motions and operational data, organized in a structured format to ensure precision, efficiency, and program flexibility.

The evolution of numerical control (NC) machines marked a decisive shift in machine-tool technology. The first NC systems, introduced in 1950 at the Massachusetts Institute of Technology (MIT), automated tool positioning and drilling cycles, significantly reducing machining time despite the high cost of early electronic components. Subsequent developments enabled tool motion during cutting, increasing program complexity and necessitating external storage media such as punched tape. A major milestone occurred in the early 1970s with the adoption of microprocessor-based control, establishing the current standard of Computer Numerical Control (CNC). Microprocessors enhanced program flexibility and permitted on-machine editing, thereby improving both usability and productivity.

A CNC system comprises a control unit and the machine. The control unit processes positional data through two main subsystems: a data-processing unit responsible for reading and verifying the machining program, and a motion-control unit managing movement commands, control loops, and auxiliary functions such as spindle regulation and coolant control.

Early NC machines evolved from conventional milling machines and lathes. Milling machines operate through a rotary cutting tool and planar feed motions, whereas lathes use the rotation of the workpiece combined with tool feed. Modern machining centers integrate these capabilities, allowing multiple operations, such as turning, milling, drilling, and grinding, within a single setup.

Lastly, defining part geometry requires two reference systems: the part reference system, which contains the geometric description and the machine reference system, typically Cartesian. Their physical

connection is established by the clamping device, while the numerical relationship is defined by the machining program.
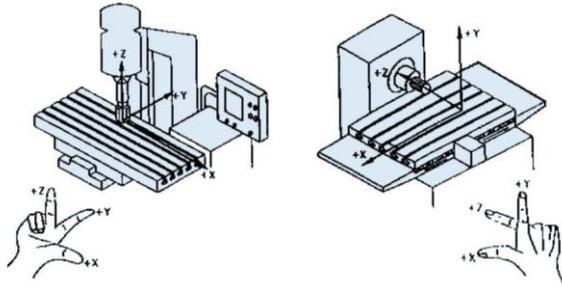
Fig. 1. *Rectangular cartesian coordinate system [1]*

Xu's book [1] provides a comprehensive overview of integrating computer-aided design (CAD), manufacturing (CAM/CAPP), and numerical control (CNC) systems. As one reviewer notes, Xu "has put together a comprehensive perspective of computer-aided design, manufacturing and numerical control, addressing their retrospective developments, present state-of-the-art review and future trends and directions". Xu emphasizes that modern manufacturing demands a truly integrated approach, „placing emphasis on product data exchange as well as product data management". Accordingly, the book „presents basic principles of product modeling and manufacturing while featuring contemporary industrial case studies", and even goes beyond traditional CAD/CAM to cover product data management (PDM) and product lifecycle management (PLM) issues. In short, Xu surveys both foundational theory and practical examples of case studies and prototypes, to show how CAD, CAM, and CNC can be seamlessly linked.

Zhang et. al. [2] provide a comprehensive review of CNC lathe technology. They emphasize that CNC lathes are the "industrial mother machines" of modern manufacturing, essential for high-precision turning of rotational parts. Achieving tight tolerances and superior surface finish in part production requires CNC lathes with high stability and accuracy. To assess the current state of the art, the authors conducted an extensive literature survey of domestic and international research on CNC lathes. This review includes comparative analysis of machine structures, which they conclude that CNC lathes remain the preferred machine for rotary-part machining. Building on this foundation, the paper analyses key technological issues, such as toolpath planning, process optimization, high-speed machining, and outlines future development trends in CNC lathe design and control.

In this paper, the study is focused on reviewing the types of CNC machines based on their kinematic architecture, functional structure, programming paradigms, and practical domains of application. The target of the present work is to provide a clear, application-focused classification of CNC machine tools and to synthesize best-practice information that

is useful both to specialists, including engineers, CAM programmers, and machine-tool designers, and to beginners, including students and technicians who require a compact and up-to-date reference.

2. PRESENTATION OF CNC MACHINES

Numerically controlled machine tools commonly have three numerically controlled axes, meaning that movements along the X, Y, and Z axes of the reference system can be both commanded and measured by the data processing unit. There are also simpler 2.5-axis machines, in which the workpiece can be moved simultaneously along two axes, while the tool movement along the third axis is controlled separately.

More complex machine tools have additional numerically controlled axes. In these cases, in addition to movements along the X, Y, and Z axes, rotations around one or more of these axes can be controlled, and there may also be additional axes belonging to secondary carriages or traverses, which are likewise numerically controlled.

The Cartesian rectangular coordinate system consists of [1]:

- Z Axis - The Z motion axis is defined by its alignment with the spindle:
  o In drilling, milling, and boring machines, this spindle rotates the cutting tool while the workpiece remains stationary.
  o In parallel or turret lathes, the spindle rotates the workpiece. When multiple spindles are present, the Z axis is chosen as the one for which the rotational movement is perpendicular to the workpiece.
- X Axis - If possible (according to the machine's kinematics), the X motion axis is horizontal and usually has the longest linear travel. It is typically defined immediately after the Z axis:
  o In machines with exclusively linear movements (e.g., planers), the X axis is parallel to the main cutting direction.
  o In machines that rotate the workpiece (e.g., lathes and some grinding machines), the X axis is radial and aligned with the cross slide.
- In machines where the cutting tool rotates (milling, drilling, etc.):
  o If the Z axis is horizontal (e.g., horizontal spindle milling machine), the X axis lies in the horizontal plane and is oriented to the right relative to the spindle.
  o If the Z axis is vertical (e.g., vertical spindle milling machine), the X axis lies in the horizontal plane and is oriented to the right.
- Y Axis - The Y axis is always defined third, and its orientation must complete the definition of a right-handed Cartesian coordinate system.
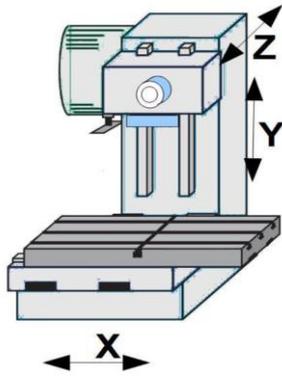
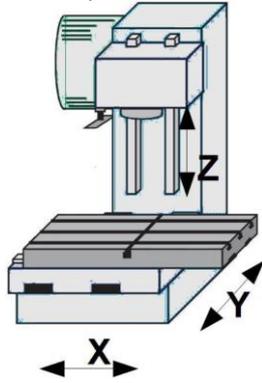**Fig. 2.** *Horizontal spindle machining center [1]*

Fig. 3. *Vertical spindle machining center [1]*

Numerically controlled machine tools enable machining with very high productivity and precision. One measure of machining productivity is the Material Removal Rate (MRR), which represents the rate at which material is removed and allows for the evaluation of machining efficiency. The material removal rate is defined as the volume of chips removed per unit of time, expressed in [mm³/min].

The volume of removed chips can vary depending on:
- The workpiece material: harder materials, such as titanium or steel, have a lower MRR compared to softer metals.
- The cutting conditions: a more intensive cutting regime will result in a higher material removal rate.

CNC machines are used in a wide range of fields, such as:
- Aerospace industry, for the precise machining of complex part geometries, such as turbine blades, aircraft fuselage components, and more.
- Automotive industry, for high-volume production of engine parts, gears, and interior components.
- Medical field, for machining implants, various surgical instruments, and medical devices.
- Tool and die manufacturing, for producing molds for plastic injection molding, die casting, and other manufacturing methods.

The future challenges and trends for CNC machines focus on energy efficiency, the skills and capabilities of operators and programmers, as well as the machining of new alloys, particularly those used in the aerospace industry.

In conclusion, CNC machines can be considered the cornerstone of modern manufacturing, providing high levels of precision, efficiency, and flexibility. As technology continues to advance, CNC systems are becoming increasingly automated.

2.1. Fundamental Types of CNC Machine Tools

2.1.1. Lathes [2]

Lathes are among the most widely used machine tools, allowing the machining of flat, rotational, or helical surfaces. Specialized CNC lathes have been developed to meet specific machining needs, such as turning centers for small-batch production or lathes designed for machining crankshafts, among others.
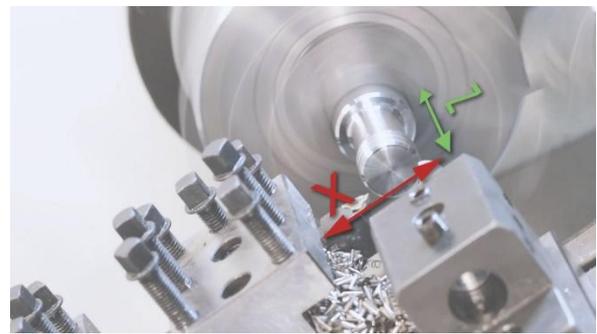

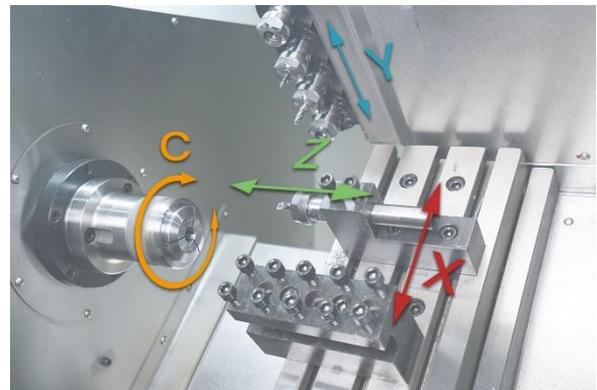**Fig. 4.** *Two-axis lathe; X and Z translational axes [3]*

Fig. 5. *Four-axis lathe; X, Y, and Z translational axes & C rotational axis [3]*

Fig. 6. *Vertical lathe VL-100CA [4]*

Fig. 7. *Horizontal lathe machining a camshaft [5]*

Fig. 8. *Precision machining of a complex part on a CNC lathe [6]*

One of the key characteristics of the turning process is that it provides high productivity [2]. Additional examples of CNC lathe configurations include:

Fig. 9. *Horizontal CNC lathe [2]*

Fig. 10. *Vertical CNC lathe [2]*

Fig. 11. *Single-axis CNC lathe [2]*

Fig. 12. *Double spindle CNC lathe [2]*

Fig. 13. *Multi-axis CNC lathe [2]*

2.1.2. Milling Machines

The milling process is characterized by a primary rotary motion performed by the cutting tool and a feed motion along a planar or spatial trajectory, generally perpendicular to the tool axis [8].

The cutting tool, called a milling cutter, is a multi-toothed cutting tool mounted on a rotating body, providing a primary cylindrical or profiled peripheral surface [9].

CNC machine tools can achieve precision and accuracy on the order of microns [μm] with high repeatability. This is ensured by feedback systems, such as encoders or probes, which are incorporated into many CNC machines, which detect deviations and inform the operator. CNC systems are continuously evolving to dynamically adjust parameters in real time, maintaining or correcting accuracy and precision throughout the machining process.

CNC machine tools are equipped with an automatic tool-changing system, allowing for continuous operation. The ongoing evolution of these machines has enabled the incorporation and use of advanced systems capable of detecting tool wear and adjusting parameters to compensate, ensuring consistent machining results.

One of the most important factors in evaluating a machine tool is its cost. CNC machine tools tend to have a high purchase price due to the complexity of the equipment and the technology involved. They require less highly skilled labor, as the operator primarily focuses on programming and process supervision, and setup times are reduced thanks to greater automation and fewer errors, resulting in overall cost savings in high-volume production.

Although the initial cost of CNC machine tools is higher than that of conventional machines, they are more cost-effective in the long term due to lower labor costs and increased efficiency.

For CNC machine tools, operators need skills in CNC programming (e.g., G-code), but their role is less focused on physical machining and more on ensuring correct programming and machine operation. Compared to manual machining, CNC operations have a shorter learning curve, particularly for entry-level operators, and CNC systems often provide diagnostic tools that alert operators to potential issues, eliminating the need for manual troubleshooting.

Comparing the training requirements and skills needed for conventional machine tool operators versus CNC operators, it can be concluded that while conventional machines require highly skilled operators with years of experience, CNC machines demand a simpler learning process, focused on programming and monitoring.

Another point of comparison between conventional and CNC machine tools is safety. Conventional machines carry a higher risk of accidents because the operator is physically close to the machine, and manual operation involves a greater risk of injury due to moving parts. Frequent direct interaction with the machine increases the likelihood of accidents.

The actual machining area is usually fully enclosed, limiting the operator's interaction with moving parts. Due to automated processes, the likelihood of workplace accidents is reduced, as most operations occur without human intervention.

Based on safety considerations, CNC machine tools are generally safer than conventional machine tools, with automated processes and enhanced safety features that reduce the risk of operator injury.

The final comparison between conventional machine tools and CNC machine tools is summarized in Table 1.

Table 1. *Comparison between Conventional and CNC Machine Tools*

Criterion	Conventional Machine Tools	CNC Machine Tools
Precision	Limited, depends on operator skill	High precision and repeatability
Speed	Longer production times, manual adjustments required	Faster, continuous production with minimal downtime
Flexibility	Task-specific, limited adaptability	High versatility, capable of handling multiple tasks
Tool Changing	Changing	Automatic tool changers, larger tool storage capacity
Cost	Lower initial cost, higher labor costs	Higher initial cost, lower labor costs over time
Operator Training	Training	Easier to train operators, focus on programming and monitoring
Safety	Higher risk due to operator interaction	Workspace usually fully enclosed, automated processes enhance safety

2.2. Multiaxis machining centers – 3, 5, 7 and 9-axis

Multi-axis CNC machines, such as 5-axis, 7-axis, and even 9-axis machines, represent significant advancements over traditional 3-axis CNC machines. These machines offer enhanced capabilities for machining complex geometries, reducing setup time and improving part accuracy.

In theory, 5-axis CNC machining centers offer numerous advantages beyond those already provided by 3-axis CNC machine tools. These include faster material removal rates and higher-quality surface finishes [10].

Freeform surfaces, also known as sculpted surfaces, are widely used in various current engineering applications, often employed to enhance the aesthetics or functionality of parts [11].

Freeform surfaces are characterized by the inclusion of non-planar and non-quadratic surfaces, generally represented through parametric or polygonal models [11].

Multi-axis CNC machines are machines capable of moving the cutting tool or the workpiece along multiple axes simultaneously. Unlike 3-axis CNC machines (x, y, and z), multi-axis CNC machines provide additional degrees of freedom, enabling more complex part geometries and improved machining

efficiency. In the Cartesian coordinate system, six degrees of freedom can be defined: three translational along the axes and three rotational about the axes. Conventional CNC machines allow control of movements along the three linear axes.

In addition to these movements, numerically controlled multi-axis CNC machines enable a range of additional motions:

- 5-axis numerically controlled machines allow, in addition to the standard translations, rotations around two additional axes, A and B.
- 7-axis CNC machines add two more axes, often including a third rotational axis and additional linear axes.
- 9-axis CNC machines and those with an even higher number of axes involve highly complex multi-axis systems, often used for machining intricate parts.
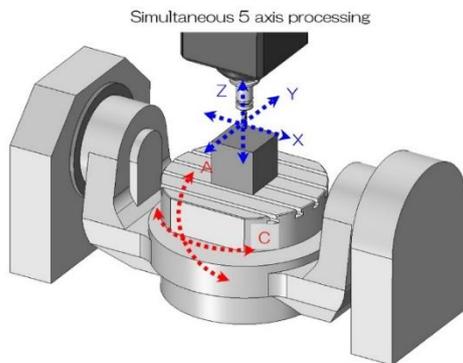
Fig. 14. *Configuration of a 5-Axis Vertical CNC Machine [12]*
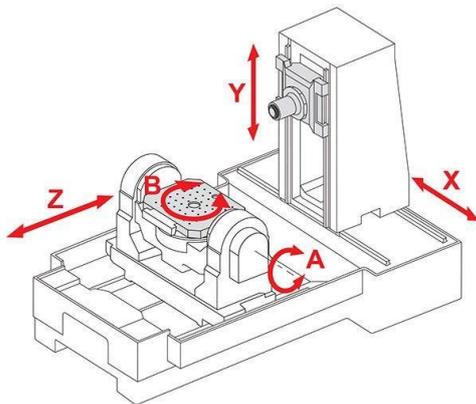
Fig. 15. *Configuration of a 5-Axis Horizontal CNC Machine [13]*

Fig. 16. *Machining Using a 5-Axis Vertical CNC Machine [14]*

The main advantages of 5-axis CNC machines are as follows:

- They can simultaneously move the cutting tool along five axes, which is ideal for creating complex shapes with intricate surfaces or profiles.
- When applicable, they can perform all necessary machining operations in a single workpiece setup, minimizing part handling and alignment errors, which results in reduced production times.
- Continuous control of the tool orientation allows for optimized cutting angles, reducing tool wear and improving surface finish.

Compared to 5-axis CNC machines, 7-axis CNC machines offer the following additional advantages:

- Increased flexibility provided by the addition of extra degrees of freedom, often in the form of rotational or translational axes. This further enhances the capability to machine complex parts, including intricate profiles and multi-faceted geometries.
- Improved tool access: with a 7-axis machine, the tool entry direction can be precisely controlled to machine the part from different angles, allowing access to hard-to-reach areas that would be impossible with fewer axes.
- Reduction in the number of cutting tools required: the high flexibility in tool repositioning allows the 7-axis machine to complete operations without changing the tool, thereby reducing downtime.

A 9-axis CNC machines represent the ideal solution for highly efficient and precise machining, offering the following specific advantages:

- Extremely high flexibility: with 9 axes, CNC machines can perform a wide range of highly complex operations.
- Multifunctionality: in addition to the standard movements (X, Y, Z, A, B, C), 9-axis machines often incorporate additional rotational or linear axes for compound motion, allowing them to machine multiple areas of a part simultaneously or in a single setup.
- High level of automation: at this level, CNC machines are often integrated with robotics or automated systems for tool changes, part handling, and even quality control.

To conclude this subsection on 5-axis, 7-axis, and 9-axis CNC machines, these represent the pinnacle of precision manufacturing technology. These machines are designed to meet the demands of industries requiring high precision, complex geometries, and

reduced setup times. The data obtained support the role of these machines in enhancing production efficiency, accuracy, and surface quality. At the same time, a reduction in material and tool consumption is also observed.

In essence, as the number of axes increases, so does the machine's capability to handle more complex parts, leading to significant improvements in manufacturing efficiency, product quality, and overall system performance.

However, it should be noted that as the number of axes increases, the complexity and difficulty of programming the part also increase proportionally.

2.3. Hybrid CNC machine

Hybrid CNC machines, which combine Additive Manufacturing (AM) and Subtractive Manufacturing (SM), represent a sophisticated class of machines designed to produce complex parts with high precision. These machines allow a part to be 3D-printed using additive processes, such as welding or deposition, and then employ traditional machining, such as milling, turning, or grinding, to finish the part's geometry and surface quality. This hybrid approach combines the benefits of both additive and subtractive processes, making it particularly useful for aerospace, automotive, and medical industries, where high precision and machining efficiency are critical. Key advantages of this approach include reduced material removal by machining, significant reduction in effective machining time, and a high level of accuracy.

It is designed as a potential upgrade for any existing CNC machine to produce metal parts without altering its original functionalities. The unique feature of this process is that the part is built close to its final shape, and finishing machining is carried out using the same CNC machine. Custom software generates the NC program for constructing the near-net shape [15].
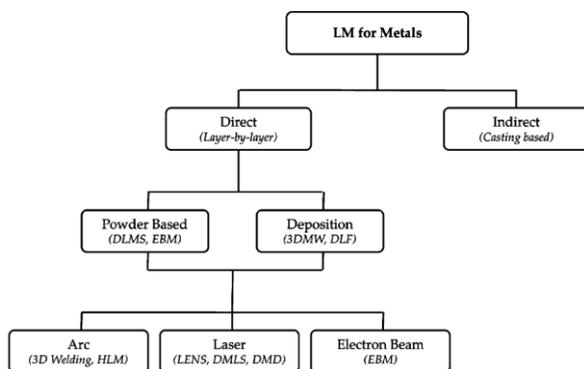
Fig. 17. *Layered Manufacturing for metallic tools and components [15]*

Table 3. *Abbreviations legend of Figure 17*

Abbreviation	Complete name
DMLS	Direct Metal Laser Sintering
EBM	Electron Beam Welding
3DMW	3D Micro Welding
DLF	Directed Light Fabrication
HLM	Hybrid Layered Manufacturing
LENS	Laser-Engineered Net Shaping
DMD	Direct Metal Deposition

Based on the manufacturing method, they can be classified as sintering and deposition technologies.

In powder bed technology, a layer of metal powder is first spread, and the required regions of the layer are selectively sintered. Deposition technology involves depositing material only in the required regions [15].

A common characteristic of all these approaches is that the base material is either in powder or wire form. Due to the complete melting of the material, the precision and surface quality of freeform manufactured parts are generally lower than those of machined parts [16].

Types of Hybrid CNC Machines:
- Hybrid Additive Manufacturing and CNC Milling: These machines can 3D print a part using metal wire or powder deposition and then employ CNC milling to machine the part. They are often used in the aerospace and automotive sectors to produce extremely complex and lightweight components.
- Hybrid Additive Manufacturing and CNC Turning: These machines integrate a 3D printing head with a lathe axis. The additive process is typically used to build features on cylindrical parts, while the lathe removes material for precision finishing.
- Hybrid Additive Manufacturing and EDM (Electrical Discharge Machining) - Hybrid EDM machines can add material through an additive process, after which EDM technology is used to precisely refine details on hard metals.

Advantages of Hybrid CNC Machines:
- Hybrid CNC machines enable the construction of complex geometries with minimal material waste. The additive process helps create the basic shape of the part, while the subtractive process finishes it, often eliminating the need for traditional methods of producing semi-finished parts.
- Hybrid CNC machines allow for the creation of parts that are difficult or impossible to produce using purely traditional subtractive manufacturing. This includes complex internal features, lightweight structures, and topology-optimized designs.
- Hybrid processes can reduce the number of steps required to produce a finished part by combining production and finishing in a single setup. This can lead to significant time savings and reduced lead times.
- Multiple parts or assemblies can sometimes be consolidated into a single part using hybrid

manufacturing, reducing the need for assembly and simplifying supply chain logistics.

Types of Materials That Can Be Processed Using Hybrid CNC Machines:

- Metals:

o Common materials used for hybrid manufacturing include titanium alloys, stainless steel, and aluminum alloys. These materials are suitable for applications requiring high strength-to-weight ratios and resistance to extreme temperatures.

o Additive processes are generally optimized for metallic alloys that can be welded or deposited using concentrated energy sources.

- Composites:

o In some hybrid systems, composite materials, including carbon fiber or glass fiber-reinforced polymers, can be used in the additive process, with subsequent machining performed to achieve the final shape.

The selected material must be compatible with both additive and subtractive processes, exhibiting suitable properties in terms of thermal behavior, hardness, and machinability.

Hybrid CNC machines provide high precision. The additive process generally has lower dimensional accuracy compared to subtractive methods, but once the part is printed, machining can achieve tight tolerances for features that require high precision.

The tolerance of additive processes can reach values around ±0.1 mm, although this may vary depending on the deposition method and material.

CNC milling or turning can achieve tight machining tolerances of ±0.005 mm, depending on the machine and tools used. Hybrid machines offer the advantage of adjusting the part geometry for precision during the subtractive machining process.

The limitations of hybrid CNC machines lie in material and process compatibility, machine complexity, and part post-processing. Integrating additive and subtractive processes requires careful analysis of material behavior and thermal effects. Process parameters must be finely tuned to avoid issues such as warping, cracking, or delamination. Hybrid CNC machines are more complex than traditional CNC machines, requiring advanced control systems, specialized software, and skilled operators to manage both additive and subtractive processes. Post-processing is often necessary, potentially including heat treatment, surface finishing, or stress-relief procedures.
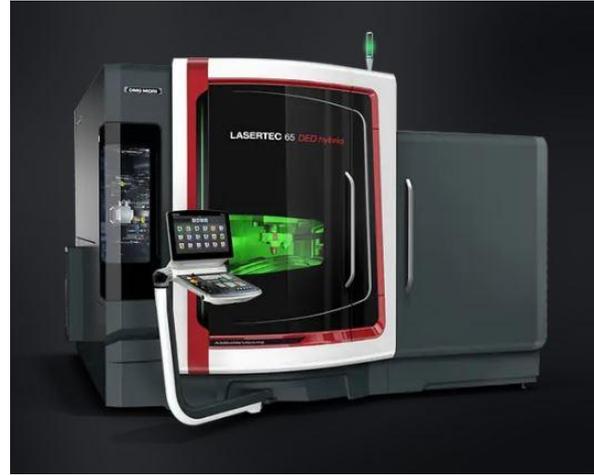
Fig. 18. *DMG Mori LASERTEC 65 3D [17]*

Following the review of hybrid CNC machines, the following types of machines have been identified:

DMG Mori LASERTEC 65 3D - This hybrid machine combines laser metal deposition (LMD) additive manufacturing with subtractive CNC machining. It is capable of producing high-precision parts.

- Mazak INTEGREX i-400AM - The Mazak hybrid solution integrates additive and subtractive technologies, enabling multi-tasking operations on a single machine.

Fig. 19. *Mazak INTEGREX i-400AM [18]*

- Hybrid Manufacturing Technologies (HMT) HBOT - This hybrid system integrates a robotic arm for additive welding or deposition and a CNC milling machine for subtractive finishing.

Fig. 20. *HMT HBOT AMBIT™ MULTI [19]*

Fig. 21. *HMT HBOT AMBIT™ FLEX [20]*

3. PROGRAMMING CNC MACHINES

Programming a CNC machine involves creating a set of instructions that tell the machine how to perform specific tasks to machine a part. These instructions are usually written in G-code, which is the language the machine uses.

Before creating the program, it is essential to know the type of machine, including its physical construction, as well as its software and capabilities.

The main step is to create a CAD model of the part containing the geometry and details necessary to later generate the toolpath, or to import a CAD model of the part into CAM software such as ESPRIT, Fusion 360, Mastercam, or others.

The next step is to define the sequence of machining operations according to the type of CNC machine, the part geometry, the workholding system, and the cutting tool or tools to be used.

To select the cutting tool and establish the optimal machining parameters, the following procedure is carried out:
- Selection of the cutting tool according to the machining process.
- Selection of the cutting parameters.

- Selection of the workpiece clamping setup.

After completing the steps described above, this data is converted into a language understood by the machine software, namely G-code. G-code is the standard language for CNC machines, with each line corresponding to a specific movement or action. Some typical G-code commands include:
- G0: Rapid positioning - moves the tool quickly to a location without cutting.
- G1: Linear interpolation - moves the tool along a straight line while cutting.
- G2/G3: Circular interpolation - moves the tool along a circular arc, clockwise or counterclockwise.
- M3/M4: Spindle rotation clockwise (M3) or counterclockwise (M4).
- M05: Stops the rotation of the main spindle.

After the G-code is generated by the CAM software, it may require processing through a post-processor, which adapts it for the specific machine model, taking into account machine-specific settings, cutting tool compensations, and other technical requirements.

Before running the program on the CNC machine, it is important to verify the generated G-code through simulation to check the toolpaths and ensure there are no errors, such as tool collisions or incorrect movements. Additionally, a dry run (without material or at a specified height above the part) can be performed on the CNC machine to verify that it behaves as expected.

Once the program simulation is complete, the G-code is loaded into the CNC machine software using various methods, such as Wi-Fi, direct cable connection (LAN, USB, etc.) from the computer to the machine, or via data transfer devices (memory stick, memory card, etc.). Next, the machine settings are configured, including verifying that the cutting tools are physically present in the tool magazine and correctly positioned. If they are not present or incorrectly positioned, corrective measures must be taken. The part to be machined is then placed in the machine workspace and clamped according to the part setup and the machining strategy considered optimal for the part, while also following the created program.

Physical measurements are taken using a probe (touch sensor) to indicate the part's origin point.

The steps described above represent the general programming algorithm for CNC machines. After completing all verification steps, the program can be executed. The operator must closely monitor the process to ensure the part is machined according to the intended specifications. If any issues are observed, such as poor surface finish or excessive tool wear, corrective actions must be taken.

After the machining operations are completed, final inspections of the machined part are performed through measurements and checks to ensure that the part meets the required specifications. If the operator

identifies any necessary adjustments to optimize or ensure proper machining, corrections can be applied.

The CNC programming workflow algorithm:
1. Create or import the CAD model.
2. Define the machining operations.
3. Select the cutting tools and machining parameters (feed rate, cutting speed, and depth of cut).
4. Generate the G-code.
5. Post-process the program to ensure compatibility with the actual capabilities of the CNC machine.
6. Verify the program using virtual simulations and dry-run tests.
7. Load the program and prepare the machine.
8. Run the program, monitor the process, and intervene if necessary to ensure smooth machining operations.
9. Inspect the parts for quality control.

4. CONCLUSIONS

The evolution from classic machines to CNC machines has brought a transformative leap in the field of mechanical processing, revolutionizing the way complex surfaces are manufactured.

Some of the key reasons why CNC machines are superior for processing complex surfaces:
- Increased precision and accuracy.
- Ability to process complex geometries.
- Automation and efficiency.
- Reduced setup time and cost.
- Minimized human intervention and error.

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