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3 AXIS MULTIPURPOSE MACHINE

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ABSTRACT

In the globally competitive market it is quite important for the manufacturer to do some miracles to maintain and make others feel its presence in the market. The ultimate goal of every manufacturing firm is to earn profit and expand their business. Time is kind of money for a production unit. The more the company produces the product by utilising the available machining hours of the company the more is the profit earned by the company. The factors affecting the production of the unit depends upon the number of factors. One of the most important factors is production capacity and production time. Every unit wants to always increase their production capacity with minimum amount of production time. For this one should utilize their resources efficiently including machines, man, method, material handling of the material. One of main problem suffered by the manufacturer is the amount of time wasted behind the material handling of the material from one place to another for carrying out different operations to gain a desired output. To solve out their problem one of the way is to reorganise the plant layout. But it has a disadvantage that it cannot increase the output. The other option is to install a new machine but even with this there is a disadvantage that the space constraints would affect the productivity. For such problems affecting the output this machine is bliss for all such issues. Our 3 axis cnc machine has a lot of advantage in comparisons to other available machines in the market. One of the major advantages is its easy manufacturing interchangeability. One can use it for cnc operations, plotting operations, 3d printing operations and last but not the least for laser cutting operations. All this is done just by altering their heads according to the need to the operations. By using this machine one can definitely reduce their material handling time, over budget machines, space restrictions etc. This machine has a lot of features which are rare and new for the market. It can definitely be a great resource for the company who wants to increase their productivity with less amount of finance, less space utilization

I. INTRODUCTION

Modern machine tools are controlled by a computerized numerical control (CNC). For this reason, manufacturing processes, for example, drilling, turnings, and milling, are also referred to as CNC machining when the machine tool is controlled by a CNC. The main task of CNC is to provide the controlled relative motion to the tool and workpiece. All these tools involved in the machining operations perform different process by removing the material from workpiece in a particular pattern according to the code to achieve desired output product geometry. Therefore, these processes are also referred to as subtractive manufacturing. Further subtractive manufacturing processes are reaming, threading, or laser cutting, plasma cutting, and water cutting.

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Because of their commonalities, some processes are contained in one machine. For example, most milling machines allow a tool change so that a drill or reamer can be used. A milling machine with an automatic tool changer and an automatic workpiece changer is called a machining centre. A fourth axis offers further processes, for example, threading and turning. The machining centre described could carry out many manufacturing processes. The combination of different processes in one machine facilitates more economical manufacturing because, for example, the quantity of clamping can be reduced.

In contrast to the subtractive manufacturing processes, additive manufacturing processes add material to manufacture parts with the desired geometries. This enables waste reduction because unwanted material will not be added. Particular process steps, such as drilling, do not have to be applied; for example, a hole is formed by not adding material in the desired position.

This paper [3] focuses on energy consumption and indicates that accurate assessment and modelling of manufacturing processes are becoming increasingly important. The case study presented shows that additive manufacturing has greater advantages than conventional manufacturing processes when the number of parts was small. In addition, additive manufacturing offers new manufacturing strategies and makes customized solutions possible, even for small quantities. Furthermore, additive manufacturing makes production on demand and production on site possible [1, 2, and 4]. All these properties indicate that additive manufacturing is a key technology for economical manufacturing. Depending on the additive manufacturing processes, post processing is required for good results. The post processing can be done manually or automatically by CNC machining [1, 2]. The processes of additive manufacturing are completely different to subtractive manufacturing processes, although they have many commonalities, which are outlined later in this paper. Additionally, [5, 6] suggest that a combination of subtractive and additive manufacturing processes is recommended

Reason for development of 3axis multipurpose machine

A manually organized workpiece transport is flexible but not effective: each machine requires reclamping and its own setup, which takes time and reduces the achievable accuracy [2]. Therefore, a production strategy is required.

Subtractive machining process

Machining is any of various processes in which a piece of raw material is cut in to desired shape and size by a controlled material removal process. The processes that have this common theme, controlled material removal, are today collectively known as subtractive manufacturing. Machining is a part of the manufacture of many metal products, but it can also be used in materials such as wood, plastic, ceramic and composites. They include a wide variety of machining processed which include such as milling, boring, drilling. Subtractive manufacturing produces lower, more capable tolerances than additive manufacturing. Subtractive methods result in smoother surface than additive methods. Additive manufacturing creates micro-pores which can lead to infection in medical uses and also add fatigue points that can lead to stress fractures with heavy loads. Parts intended for long term use or high stress use is best made with subtractive manufacturing. Medical and aerospace industries prefer subtractive for parts required to stay in the body for long periods of time and for flight-critical aerospace functions.

Additive manufacturing

Additive manufacturing, also referred to as 3d printing, is a technology that produces three dimensional parts layer by layer from a material, be it polymer or metal based. The method relies on a digital data file being transmitted to a machine that then builds the component. Examples of additive manufacturing

1) Stereo Lithography Apparatus
2) Fused Deposition Modelling
3) Multi Jet Modelling
4) Selective Laser Sintering

A part can be produced in much less time using additive manufacturing than using additive manufacturing than using traditional subtractive manufacturing methods. The mire complex (less solid) a part is, the faster and less expensive it is to produce. Anything that can be designed in a CAD program can be printed with additive manufacturing. Parts used for fit checks, presentation models and shot term use can best be made with additive manufacturing.

The Fused Deposition Modelling Process

This paper focuses on fused deposition modelling (FDM), a generic name for the fused deposition modelling (FDM) developed by S. Scott Crump and trademarked (http://www.trademarkia.com/fdm74133656.html) by Stratasys, Inc. In the context of the RepRap project (http://www.reprap.org/), an ongoing project that made and freely distributed a replicating rapid prototype, fused deposition modelling is also called fused filament fabrication (FFF). As described in [1], fused deposition modelling is an extrusion process in which thermoplastic material (filament) is continuously squeezed through a nozzle and deposited on a substrate. The material's energy suffices to fuse the substrate; after cooling down, a permanent connection is available. In contrast to other additive processes, the fused deposition modelling is suitable for both prototyping and production applications because parts with a high mechanical load capacity can be produced. Referring to the RepRap project, a wide range of users choose the fused layer modelling [1, 9, and 10].

Materials for Fused Deposition Modelling

Generally, plastics are used with fused layer modelling, for example, polylactide (PLA), acrylonitrile butadiene styrene (ABS), polycarbonates (PC), or combined plastics, for example, PC-ABS. There are also types of plastic that can be sterilized by gamma or by ethylene oxide for medical technologies. In addition, with small modifications, materials other than plastics can be processed, such as metals and ceramics [1].

Fast Hybrid Manufacturing for Higher Accuracy

As described previously, additive manufacturing can be done without subtractive manufacturing processes, for example, drilling. Generally, this also applies to fuse deposition modelling. The post processing was cited as a reason for combining both. This will now be explained with a focus on fused deposition modelling. The achievable accuracy depends on many parameters, for example, the layer height and nozzle diameter. If the layer height or the nozzle diameter is too large, the resulting staircase effect will reduce accuracy and surface quality of the part as well as the production time. Therefore, post processing is required. Improvement of surface finish by staircase machining in fused deposition modelling is outlined in [7]. Generally, a smaller nozzle diameter can increase the achievable accuracy (see Figure 1) but also increases manufacturing time, whereas a larger diameter can reduce manufacturing time but also reduces the achievable accuracy (see Figure 2). An approach will be explained for manufacturing a part with accurate holes for fit. Firstly, the part is manufactured with undersized holes using a large nozzle diameter (see Figure 2). Thereafter, the holes are re-bored. This strategy enables an optimal result with accurate holes and minimum production time .This concept is also applicable to threads and other fields requiring high accuracy.

Figure 1: Additive part manufactured by FLM with a small nozzle diameter and layer height. [8]

Figure 2: Additive part manufactured by FLM and subtractive post processed by drilling.[8]

Objective

As described above, there are good reasons to add the subtractive manufacturing processes to an additive manufacturing machine instead of using an FMS with different machines. Considering the mechanical load occurring with subtractive manufacturing, it is much better to equip a subtractive manufacturing machine with the additive manufacturing tool instead of equipping an additive manufacturing machine with the subtractive manufacturing tool. Therefore, to integrate the process of fused layer modelling into a CNC this is designated for subtractive manufacturing. This offers the development of machining centres combining both subtractive manufacturing and additive manufacturing**.**

Commonalities and Differences between FLM and CNC Machining

As described above, the processes of additive manufacturing are completely different than subtractive manufacturing processes, though they have many commonalities. These commonalities and differences are outlined in the following, with a focus on FDM and CNC machining.

Differences

The subtractive process needs a clamping device to withstand the mechanical load occurring during manufacturing. Such a clamping device is not intended for FDM. Experiments at the Institut für Maschinen und Anlagenbau in Emden and recommendations of the RepRap project indicate that a heating bed improves the FDM process. Therefore, a heated clamping device as a combination of both is needed. This could be achieved with a heated vacuum clamp. The challenge of engineering such a heated vacuum clamp is to prevent the additive manufactured parts from absorbing and deforming while clamping.

In addition, a special extrusion tool is required. In contrast to milling and threading, a further axis is needed inside the tool for accurately defined motions of the filament for predefined deposing. This tool has to be compatible with existing tool holder and tool changer systems.

Furthermore, the process-specific M-codes of additive manufacturing are completely different from M-codes for subtractive manufacturing. These M-codes have to be integrated into the CNC to make additive manufacturing possible. The challenge is to make a minimum of modifications and protect the integrity of existing M-codes.

Approach

This approach is based on a fully assembled CNC machine, or, more precisely, a three-axis CNC milling machine. The process of fused deposition modelling is integrated into the existing CNC architecture.

CNC Architecture for FDM

For this approach, a CNC with a customizable architecture is required. The CNC has to offer possibilities for the integration of new hardware, additional M-codes, and self-developed (sub) programs. Furthermore, a programmable logical controller (PLC) is required, because it is an essential component of the CNC architecture. For this approach, an internal PLC is used which is integrated into the CNC software.

Figure 3 shows CNC architecture for FDM. Several components are integrated into the previously existing CNC architecture for enabling FDM. All components are interconnected by a common interface: the hardware abstraction layer. The CNC core, the PLC, and the human machine interface (HMI) are standard components of a CNC [2]. Therefore, the previously existing CNC architecture offers these components although they are modified. The modifications are outlined later in this paper. Furthermore, the fully assembled CNC machine offers a motion controller with its sensors and actuators for three axes, which are used for positioning the FDM tool. A further axis is required for filament transport. Its integration is outlined later in this paper. But the temperature controller is not a

CNC standard component. The integration of the temperature controller with its sensors and

actuators is a major part of this approach. These hardware components of the temperature control are controlled by a software component called microcontroller interface (CI). The modification of the previously existing CNC components and the integration of the new components are outlined in this paper.

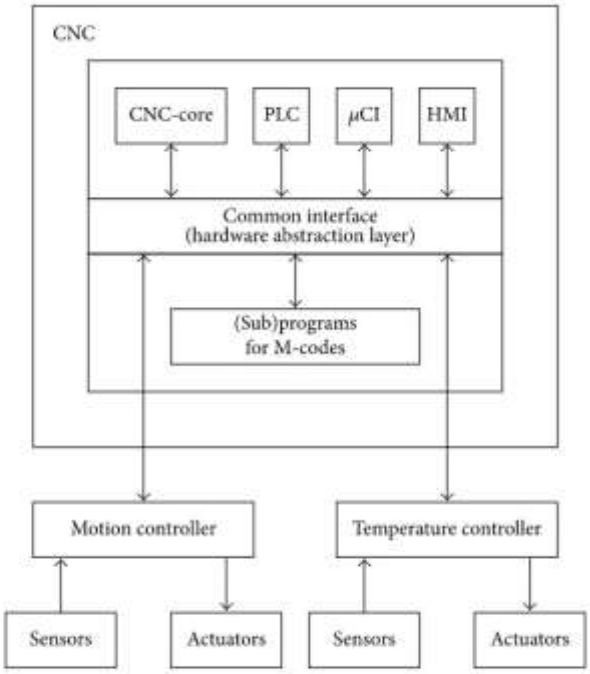

Figure 3: The extended CNC architecture for fused deposition modelling.

Temperature Control

A temperature control is required for the extrusion process at the hot-end (nozzle). A heating bed temperature control can optimize the process during manufacturing the first layers. Furthermore, a working space temperature control and a cooling fan can optimize the process. A distributed microcontroller-based closed-loop temperature control can offer the functionalities of temperature control. Therefore, the microcontroller (μC) controls three systems: hot-end temperature, working space temperature, and cooling fan speed. A heating bed is not considered because its effect is restricted to the first layers, while a whole working space temperature control offers also effects in further layers. The principle of the three temperature control systems is similar; therefore, only the hot-end temperature control is outlined.

Hot-End Temperature Control

The microcontroller receives the set temperature T_{set} from the CNC and controls the temperature independently from the CNC with a proportional-plus-integral-plus-derivative (PID) controller algorithm. Any other control algorithm is also applicable but the PID controller algorithm is well documented in literature and easily adaptable to occurring system changes. The temperature controller needs feedback; therefore, a temperature sensor converts the actual hot-end temperature T_{act} to the feedback signal T_{act}^{*}. This can be done, for example, using a thermistor with negative temperature coefficient (NTC), or PT100. The control loop (see Figure 4) focuses on hot-end temperature control.

During manufacturing, the cold filament is melted inside the hot-end.

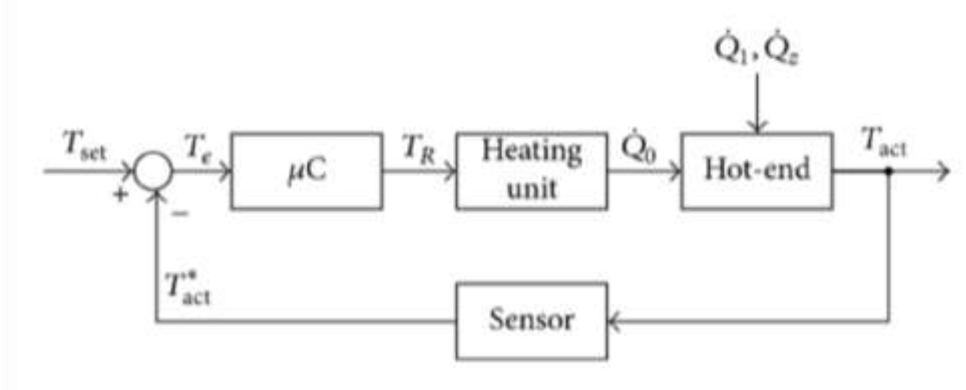

Figure 4: Hot-end closed-loop temperature control

Operation Principle

All required components are described for extending the CNC architecture for FLM, which is technically designated for subtractive manufacturing. This section describes the line of action to set the hot-end temperature for manufacturing.

1) The NC program is parsed and the NC program codes (G-codes and M-codes) are executed.
2) When the M-code M109 (see Table 1) is reached, the interpreter calls up the appropriate program called M109. The NC program parsing pause during M109 is executed.
3) The program M109 gets the set temperature by command call (M109 P<valve>) and commits the value to the PLC.
4) The PLC commits the value to the microcontroller interface (μCI).
5) The µCI commits the value from the PLC to the temperature controller () and frequently requests the actual temperature from µC. The µCI commits the actual temperature from µC to the PLC.
6) The PLC checks the comparing conditions while the temperature controller controls the temperature.
7) The PLC sets the enable signal when the comparing condition becomes true and the temperature is settled.
8) When the program M109 gets the enable signal, M109 is terminated and the NC program parsing is continuous.

This line of action is similarly applicable for M190 and M191. The programs M104, M140, and M141 are immediately terminated after setting the new set temperature. The NC program parsing is not paused.

II. CONCLUSION

The approach presented describes the integration of the fused deposition modelling process into a CNC architecture which is designated for subtractive manufacturing (milling) but without referring to any specific CNC. This permits engineering of hybrid manufacturing centres which offer FDM with post processing in one machine. The benefits are a minimum quantity of clamping, more accurate parts, and less production time. Furthermore, the integration offers another significant advantage over previous approaches because only one hybrid CNC architecture is needed for offering many processes. The same CNC can be used for additive manufacturing with subtractive manufacturing, only additive manufacturing, and only subtractive manufacturing. This prevents customers from assembling individual CNC systems for FDM and milling

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machines. Machine customers and machine operators do not need knowledge in different CNC systems because the new process (FDM) is integral in the familiar CNC system. This is economical for developers, customers, and users, regardless of whether they need hybrid manufacturing or not.

The approach presented focuses only on fused deposition modelling (FDM). Other additive manufacturing processes need also post processing. Therefore, the idea of hybrid manufacturing is also applicable to processes other than fused layer modelling.

As described in Section 7.1, further work is necessary for using the CNC architecture for hybrid manufacturing. Firstly, a clamping device is required which supports additive and subtractive manufacturing. Secondly, an extrusion tool is required which is compatible with the existing tool changer of the CNC machine. Thirdly, an extended CAM system is required which supports additive and subtractive manufacturing at the same time. Therefore, at the time of submitting this paper, the CNC architecture presented was not applied to a real hybrid manufacturing process, but it has been successfully implemented.

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