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THE APPLICATION OF CAD/CAM/CNC TECHNOLOGY FOR AUTOMATIC CERAMIC PRODUCT PROTOTYPING USED BY SMALL AND MEDIUM-SIZED CERAMIC MANUFACTURERS IN THAILAND

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ABSTRACT

The application of CAD/CAM/CNC technology for ceramic product prototyping can increase the ceramic products' added value and increase the competitiveness of small and medium-sized ceramic manufacturers in Thailand. This is the process of applying/using the Computer Aided Design (CAD) to help design the elements of the original products and simulate the molding conditions of the prototype products, also known as Computer Aided Manufacturing (CAM) and then convert the results of milling cutting path (Tool Path) to NC-Code and G-Code in order to be able to use it to control CNC milling machines (CNC Machine) for creating the prototypes of ceramic products.

However, in the application of CAD/CAM/CNC technology for automatic prototyping of ceramic products for small and medium-sized ceramic manufacturers in Thailand, it was found that necessities of readiness that each manufacturer should take into account are as follows: (1) Process of computer design, (2) Process of products molding simulation, and (3) Process of products prototyping by using CNC Machine. Therefore, the manufacturers need to get prepared for 2 main factors, which are: 1) specific manpower (1–2 workers) and 2) investment cost of providing or purchasing mini–CNC Machines for human labor's compensation. Also, the application of CAD/CAM/CNC technology in the manufacturing process will enable the entrepreneur to increase their competitiveness.

Keywords: CAD/CAM/CNC Technology, Automatic Prototyping of Ceramic Products, Small and Medium-sized Ceramic Entrepreneurs

INTRODUCTION

Nowadays, there are five (5) types of ceramic manufacturing in Thailand, including ceramic tiles, sanitary ware, tableware, souvenirs, and spool insulators. The ceramic industry is a business group that has currently been facing a variety of problems which are obstacles to business operations, especially related to the imports of (very) low-priced Chinese ceramics. Almost all types of ceramics enter Thailand's market at a price rate ranging from 30-50% cheaper, particularly the cheap ceramics imported along the country's borders. This causes serious consequences for the entrepreneurs with low investment budgets in the northern area. They finally needed to call a protest to convince the government to take care of their special privileges on fuel use and promote the use of ceramics in the country, but there were no serious actions taken. Moreover, previously, the entrepreneurs also demanded the government's support for using low-priced fuel—which is the main cost for both LPG and NG (natural gas). Similarly, financial institutions also help support only the entrepreneurs who are not at risk of financial liquidity— there isn't any help for other small and medium-sized ceramic industries. (Phithak, 2020).

The data of ceramic imports and exports from the Federal of Thai Industries showed that the export statistics of ceramic products, in 2017, the export value was 26,720 million baht and in 2018, the export value was 27,234 million baht. The comparison of export values between January to August 2018 was 18,341.91 million baht in total. In the comparison of the same period in 2019, the export value was 18,746.84 million baht in total. On the contrary, the export value was more than 30,000 million baht per year. (Federation of Thai Industries, 2022)

Another problem is from the entrepreneurs— most of them kept manufacturing the ceramic products with the same patterns for the market. Also, some entrepreneurs face other problems, including product copying and manufacturing expansion, which seriously lead to high market competition (Sahasomchoke, 2013). In addition, the problem of marketing found in ceramic industries in Lampang Province which they must have faced with the low-price competitors still exists today (Samuttharak, 2014). Due to the complexity of the products required by the customers, if using the traditional production process

which requires a large number of tools and equipment, small companies or manufacturers have to refuse the orders from customers, resulting in a loss of market opportunities. So, the entrepreneurs should consider modern production using advanced technology to help in production (Bukwan, Kongton & Rianthong, 2022). Therefore, the solution to this problem is that the manufacturers need to adjust the production management strategy by applying the application of CAD/CAM/CNC technology to help increase the efficiency of the production process to meet consumers' needs.

Analysis framework of applying the CAD/CAM/CNC technology for prototyping of ceramic products for small and medium-sized ceramic manufacturers

It is important to get prepared for the application of CAD/CAM/CNC technology for the prototyping of ceramic products. Aside from the ability to apply CAD/CAM/CNC technology, it should also be taken into account that the ceramic manufacturing process consists of two major stages, including products design and prototyping. Then it will be approached to the manufacturing process in order to meet the consumers' needs and match the created product prototypes. Therefore, there are 4 elements of the analysis framework of applying the CAD/CAM/CNC technology for prototyping of ceramic products for small and medium-sized ceramic manufacturers, as portrayed in Figure 1 below.

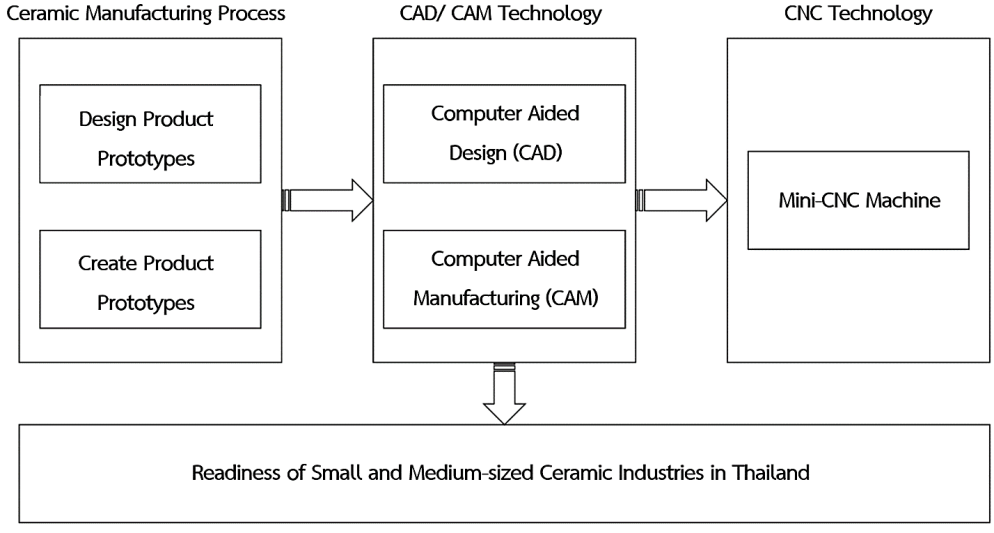

Figure 1 Analysis Framework of Applying the CAD/CAM/CNC Technology for ceramic product prototyping of small and medium-sized ceramic industries in Thailand

According to Figure 1, it was found that the important guideline for applying the CAD/CAM/CNC technology is to carefully study the manufacturing process of ceramic products and which stages they require the CAD/CAM/CNC technology for automatic ceramic product prototyping to increase the added value of the products and build competitiveness among ceramic entrepreneurs. This is consistent with the research result of Intarapadung (2021): Creating a mini-CNC machine for prototyping cups and bowls, and a research result of Bukwan et al. (2022): Developing and prototyping the ceramic products using layer-by-Layer method. This mini-CNC machine is capable of prototyping products in the ceramic production process of small and medium-sized industries in Thailand. It will increase market competitiveness and meet the needs of customers who have demands for products that require more complex production processes.

CONTENT

The process of designing and creating products in the ceramic manufacturing industry by using the Computer Aided Design (CAD), Computer Aided Manufacturing (CAM) and Computer Numerical Control (CNC) will save production lead time and have standardized models or prototypes to be more accepted by the customers.

Ceramic Manufacturing Process

The cycle or supply chain of the ceramic industry in Thailand consists of various relevant elements including raw material procurement, research, and design, manufacturing process, product quality inspection, marketing, and users (customers) as detailed in Figure 2 below.

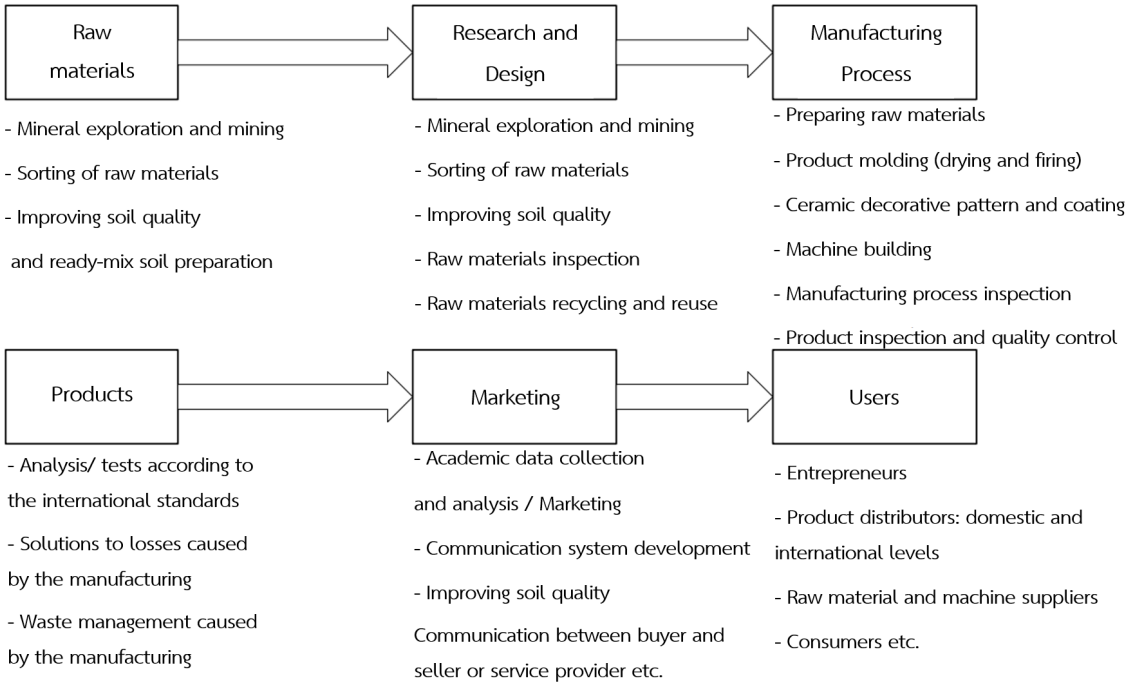

Figure 2 The cycle or supply chain of the ceramic industry
Source: Pottery Clay (2021)

It was found that most small and medium-sized ceramic entrepreneurs in Thailand are located in the northern region, such as Lampang, and Chiang Mai, and in the central region, such as Ratchaburi, Samut Sakhon, and Samut Prakan. Also, they mostly produce ceramic tableware and stoneware by using traditional human labor in every stage of production, including soil preparation, designing, and molding, or creating prototypes. Look at an example of creating a prototype by using human labor as portrayed in Figure 3 below.

Figure 3 Creating ceramic prototype by using human labor with a pottery wheel machine
Source: Intarapadung (2021)

According to Figure 3, using human labor can cause problems for the entrepreneurs in creating the prototypes in the long term. Since there are not many skillful specialists who are experienced in making ceramics by hand. The wages must also be increased. Moreover, the problems of copying products and very low-priced ceramic imports from China are very important and still need to be solved. Also, if the entrepreneurs have a large number of orders, it may cause a production delay when they have time constraints. The customers will not be pleased or may even consider different manufacturers. Therefore, applying the CAD/CAM/CNC technology will certainly solve the mentioned problems. However, small and medium-sized ceramic entrepreneurs may face a higher cost of investment. Because they are using CAD/CAM/CNC technology, the entrepreneurs must prepare a budget for skilled labor with computer design and CNC machines.

CAD technology for ceramic product design

Presently, there are many licensed and open-source software of CAD technology to apply for the product design process, such as AutoCAD, Solid Work, Unigraphics, and Rhinoceros. The program users must learn how to use the major program instructions, including, Sketch tools: straight lines, curves, circles, Mold-making tools for product

prototyping: Revolve instruction or Extrude instruction. Look at an example of revolve instruction as portrayed in Figure 4 below.

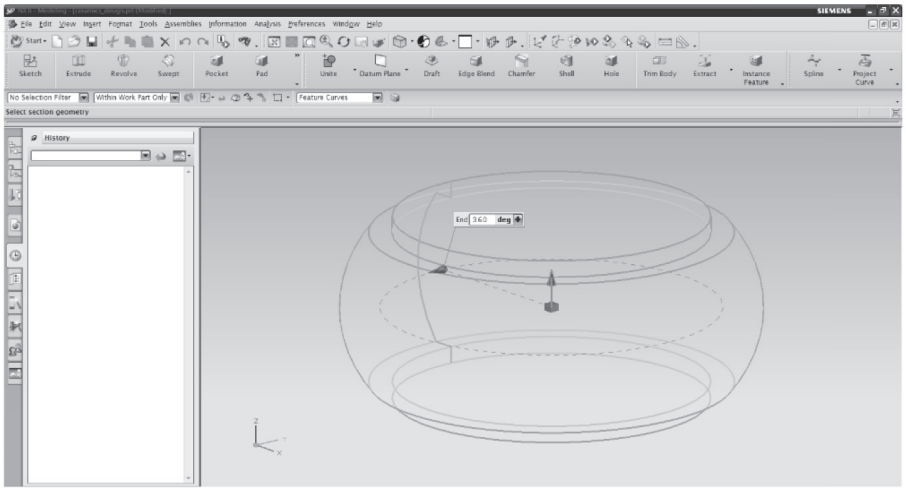

Figure 4 CAD Technology: Unigraphics NX6
Source: Intarapadung (2015)

CAM Technology for ceramic product manufacturing

Using the computer system will help increase the efficiency of prototyping and product manufacturing processes because it can analyze the weaknesses and strengths of the product shapes. It can also simulate the milling path (tool path) of the workpieces. Look at an example of simulating the milling path for product molding by using the Unigraphics NX6 Program as shown in Figure 5.

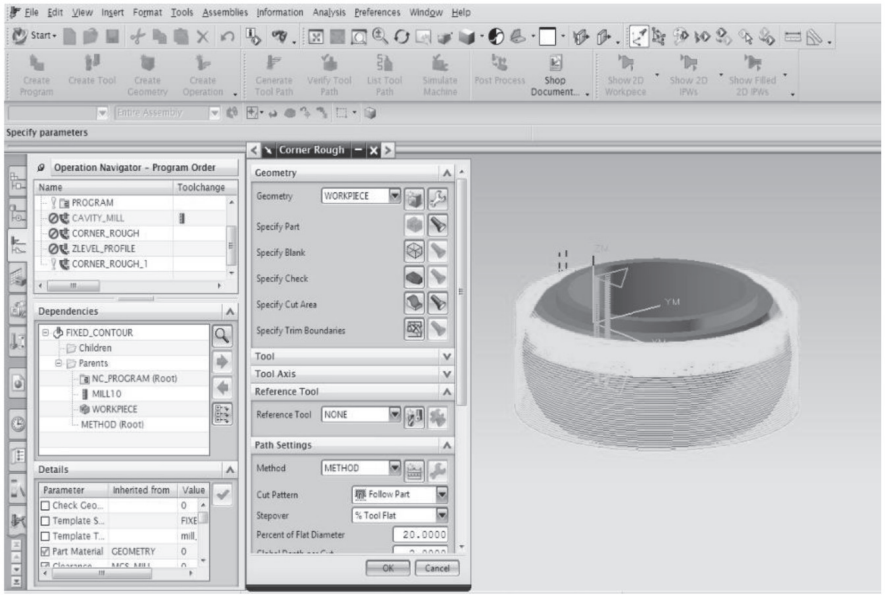

Figure 5 Simulation of the milling path (tool path) for product molding by using the Unigraphics NX6 Program
Source: Intarapadung (2015)

CNC Technology for automatic ceramic product prototyping

Computer Numerical Control, or CNC, is a technology to help create product shapes with common 3D modelling software. The most popular ones are: SolidWork, AutoCAD, Rhino, Aspire, and Unigraphics. These programs have basic geometric designs. It can also support the converting results of milling path simulation, product turning, and drilling to work automatically. This CNC technology works under G-Code and NC-Code instructions and the milling tool (CNC cutting tool) is controlled by specific computer software, such as Mach3 and Unigraphics NX as depicted in Figure 6 below.

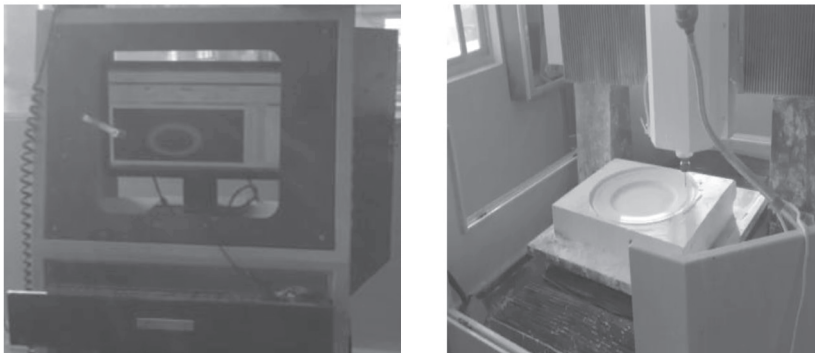

Figure 6 The control of automatic ceramic product prototyping by using the Unigraphics NX Program
Source: Intarapadung (2015)

After simulating the milling path by using computer software, it will be converted to NC-Code program instructions in order to control the path of the milling tool and product turning and drilling. There are 4 major elements of CN-Code or G-Code which are (1) the software functions/ instructions— starting with the letter G, (2) X, Y, and Z-axis coordinates, and (3) arc/curve coordinates— starting with the letter I, J and K, and (4) machine control—starting with letter F, S, T, and M as detailed in Figure 7 below.

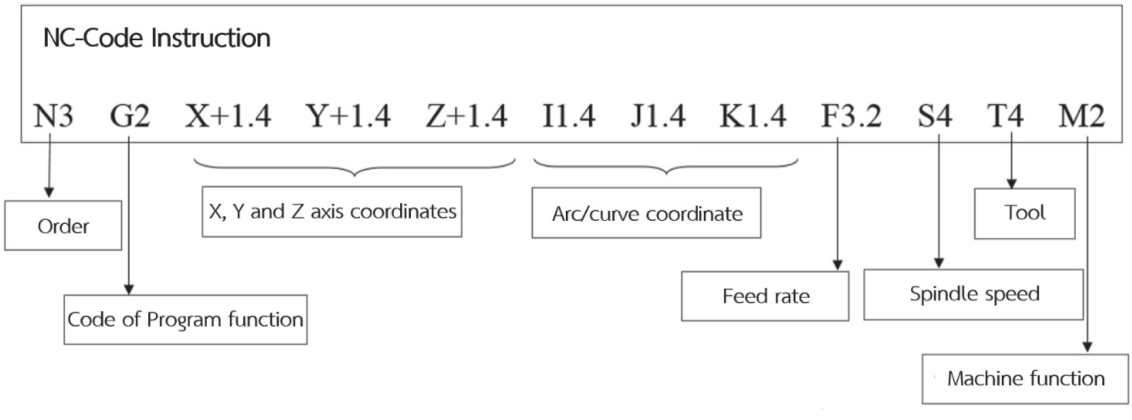

Figure 7 Elements of NC-Code Instructions
Source: Intarapadung (2015)

Look at an example of converting a milling simulation model with a CAM program into NC-code instructions in order to create a workpiece of Helical Interpolation by using Mach3 Program as shown in Figure 8 below.

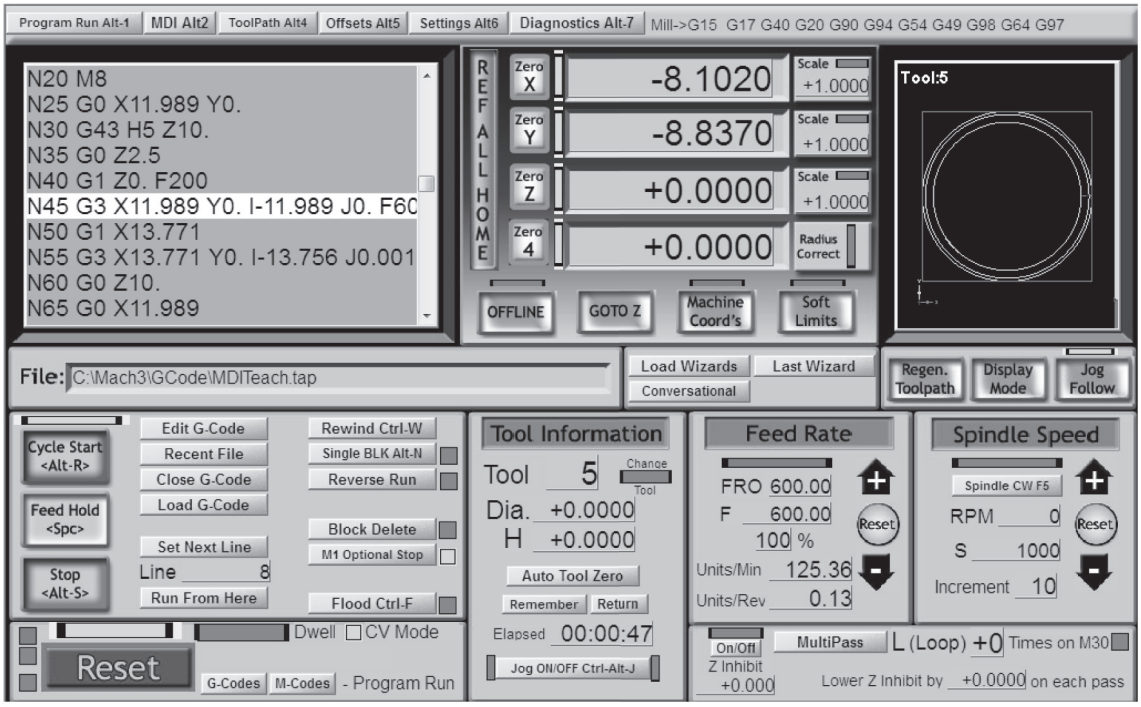

Figure 8 The control of automatic ceramic product prototyping by using Mach3 Program
Source: Intarapadung (2015)

According to Figure 8, this is an example of NC-code by converting with the Unigraphics NX Program. Practically, loading a set of instructions into a program of milling, turning, or drilling, like Mach3 or Unigraphics NX program, may require the operators to modify the initial instructions in order to be compatible with each type and version of CNC machine, like 2, 3, or 4 axes. This is significant for any entrepreneur to provide the specialized operators for applying this kind of technology. This technology allows any ceramic industry to create its own products and prototypes and avoid copying or imitation from other entrepreneurs. It assists in meeting customer needs. However, applying the mentioned technology requires good understanding and preparation of the entrepreneurs for more effective use.

Applying CAD/CAM/CNC Technology for Ceramic Product Prototyping

The stages of applying the computer aid for product analysis and prototyping are detailed in Figure 9 below.

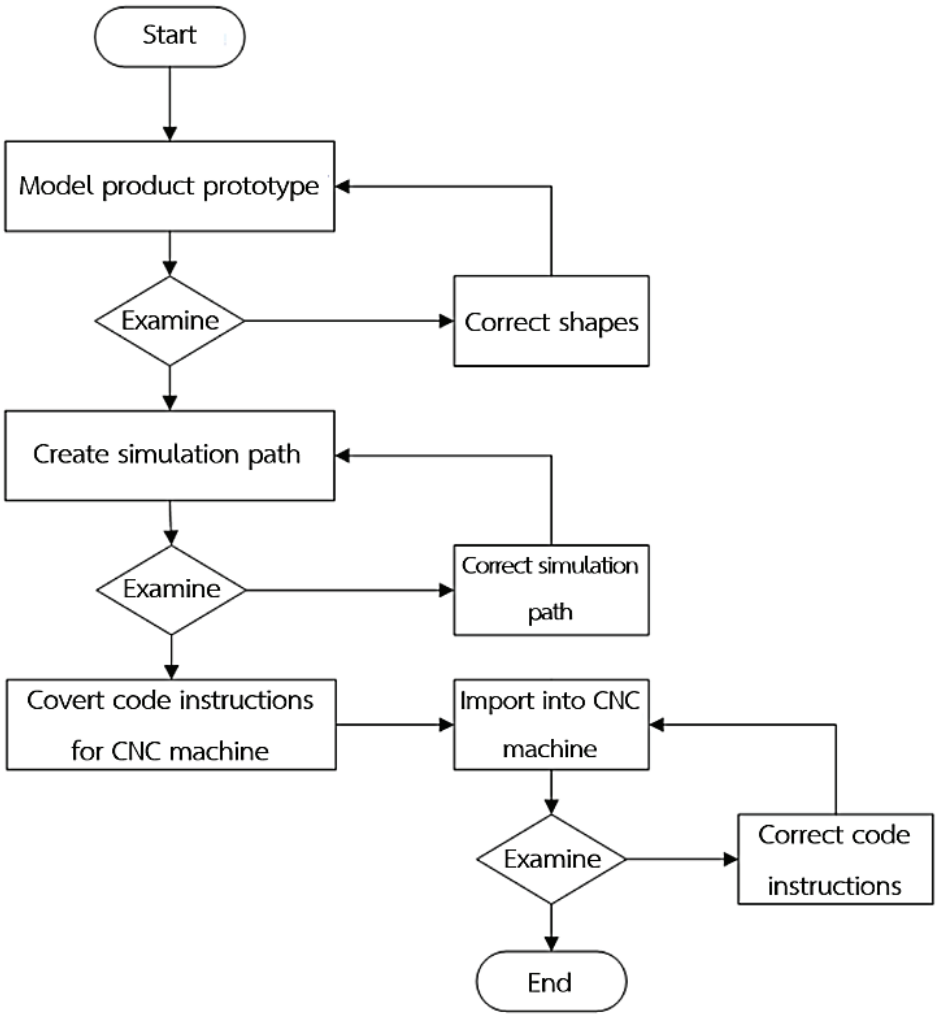

Figure 9 Stages of applying the computer aid for product analysis and prototyping

According to Figure 9, the application of the CAD/CAM/CNC technology for product analysis and prototyping of small and medium-sized ceramic industries consists of 3 major stages as follows: 1) Stage of product design 2) Stage of simulation path, and 3) Stage of importing code instructions into CNC machine. Also, each requires specialized operators in order to be able to modify or improve the results in each step. This certainly affects higher-cost investments in skilled labor or specialists and machine purchases. However,

small and medium-sized ceramic entrepreneurs can comfortably invest in mini or small CNC machines to help with their ceramic manufacturing process (Intarapadung, 2021).

The CNC machine which was designed and created in this research is a small CNC milling machine with 45 cm width, 45 cm length, and 45 cm height. The X and Y axes are controlled by using a stepper motor for the movement of the workpiece. The Z-axis is also controlled by using the stepper motor for the cutting/spindle path. The structure and components of a small 3-axis CNC milling machine are mainly composed of a tool that supports the cutting path on the X and Y axes and a tool that supports the cutting spindle on the vertical or Z-axis which is a metal structure providing an area for holding or placing the workpiece, as depicted in Figure 10 below.

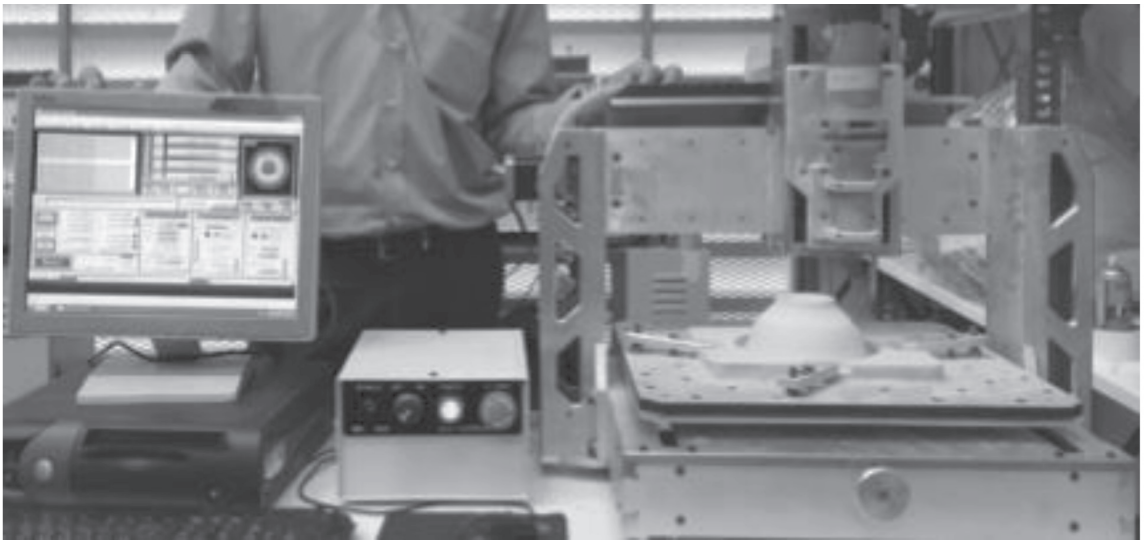

Figure 10 Example of a 3-axis CNC machine for molding ceramic cups/ bowls
Source: Intarapadung (2021)

The readiness of the entrepreneurs for applying CAD/CAM/CNC technology

The readiness of the entrepreneurs is an important factor in applying CAD/CAM/CNC technology for ceramic product manufacturing which includes 3 major stages as mentioned above. The process requires skilled labor or specialists on the computer for these activities: simulation of cutting path and CNC machine control for manufacturing. In order to prepare for effective ceramic manufacturing by applying CNC machines the following 2 steps have to be taken: (1) Recruiting the employees who graduated

in the field of product design or computerized production control; and (2) Supporting and Promoting the employees' skills by having them join training sessions, which are related to creating and controlling CNC machines. Besides, the information on CNC machines can be found in the Department of Intellectual Property's sites or by contacting the existing domestic and international manufacturers. Today, the number of CNC machine manufacturers keeps growing, so, they can be found more easily. However, these CNC machines still need some adjustments for compatible use in each ceramic enterprise.

SUMMARY

CAD/CAM/CNC technology has played an important role in the highly competitive businesses in the digital era. The application of CAD/CAM/CNC technology for automatic ceramic product prototyping for small and medium-sized ceramic entrepreneurs consists of 3 stages: (1) Stage of applying CAD technology for product design as per customer needs, (2) Stage of applying CAM technology for simulating the milling path or modelling the product prototypes and (3) Stage of applying CNC technology for importing the NC-Code or G-Code to control the CNC machines for automatic product prototyping. In the application of CAD/CAM/CNC technology as mentioned above, aside from taking into account the hardware and software that are parts of the computer system, the entrepreneurs also need to take into account the abilities of the workers who will be able to use the computer system as well. These workers are the key for manufacturing process results, which they will be able to improve at each step. Especially, if the entrepreneurs can find the workers who can complete in all 3 steps within just one person, it will affect a short-time payback period.

In addition, if small and medium-sized ceramic manufacturers want to try using the CAD/CAM CNC technology to develop their product prototypes, they can use this technology service provided by the following government sectors: 1) Ceramic Industries Development Center, Department of Industrial Promotion, Ministry of Industry–located at 424, Moo 2, Phahonyothin Road, Sala Sub-district, Ko Kha District, Lampang Province, 2) Products Prototyping and Ceramic Industry Raw Materials Center, Ceramics Building, Ratchaburi Technological College–in Ratchaburi Province, and 3) National Metal and Materials Technology Center (MTEC)– located at 114 Thailand Research Park, Paholyothin Road, Klong 1, Klong Luang, Pathumthani 12120.

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