Optimization of the Toolpath Strategy for the Master Ceramic Jewelry Mold Pattern Using the Rhinoceros Software and Router CNC Machine

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ABSTRACT
The progress of the manufacturing industry is very dependent on the development of science and technology. The current industrial revolution 4.0 encourages people to think more creatively in developing their business units. The creative economy helps the government of the Republic of Indonesia to increase state revenue from the export of these manufactured industrial products to other countries. This is also supported by the habits of the Indonesian people who are consumptive to increase people's purchasing power of these products, one of which is ceramic products. The ceramic industry in Indonesia is currently growing rapidly and getting full support from the government to increase its competitive advantage so that it can compete with local and international ceramic products. Ceramic products, including textiles, tableware, and jewelry. One of the efforts to increase the added value of this product is the use of CAD / CAM artistic technology with a CNC machine. Ceramic designs by providing additional motifs with complex relief contours and distinctive cultural or regional characteristics can be added with the use of reliable artistic CAD software such as ArtCAM and Zbrush. The master prints of artistic patterned products with Indonesian batik reliefs are obtained using a CNC router machine with precise and accurate quality. Optimization of manufacturing so that the cutter trip on the CNC machine runs optimally is used Rhinoceros 4.0 software. Two optimal machining strategies, namely horizontal roughing and parallel engineering in the CAM software, are used by researchers to obtain the NC code and the optimal patterned jewelry ceramic product master. A CNC router machine with a capacity of 1.5 kWh with workbench 800 x 600 mm is used for the manufacturing process. The results showed that the application of this technology in the local ceramic industry was able to reduce the design and manufacturing time of jewelry ceramics about3-5 days faster. The total design work from the CAM simulation stage to the jewelry product master was 8.0 hours.

Keywords: *Ceramic Products, Artistic CAD, Rhinoceros 4.0, Horizontal Roughing, Parallel Finishing.*

1. INTRODUCTION

The creative industry can be defined as one of the sectors that are able to take advantage of creativity, individual talents, and skills that can create wealth and employment opportunities by empowering the ability to create and the abilities of the individual concerned. This industry can absorb labor up to an average of 2.3% of total workers in Indonesia or 2.2 million workers in 2000-2009 [1]. The ceramic industry in Indonesia is one of the main industries capable of meeting import and export needs. Currently, the production capacity of the Indonesian ceramic industry reaches 580 million m2 and is ranked the fourth largest in the world. However, Indonesia's ceramic production last year only reached 370-380 million m2 or around 65.51% of the total existing capacity, as stated by the Indonesian Minister of Industry [1]. Changes in ceramic manufacturing techniques that were previously carried out using conventional techniques are now starting to be changed using design technology based on Computer-Aided Design (CAD), and Reverse Engineering (RE) or often referred to as Computer-Aided Reverse Engineering System (CARESystem) [2-7] it aims to accelerate the production process at the design and manufacturing stages of the master mold product so that production

capacity can be met. This is done as part of the factory's effort to satisfy customer tastes for artistic ceramic products.

Ceramics or kramos are a form of product from clay that has undergone a combustion process [6, 8, 9]. The use of ceramic materials in everyday life is increasingly widespread because this material can produce unique products, can be combined with various colors, and is accompanied by the development of science and technology [10]. Jewelry ceramic is a type of jewelry product, and this is the result of the development of ceramic products which are then combined with precious metals [11] The selling value of Jewelry ceramic will be high if it is decorated in the form of ornaments with relief contours and unique colors and characteristics. Creative ceramic jewelry designs with precise textures and reliefs, have distinctive details and can be produced through the collaboration of modern advanced manufacturing technology based on Computer-Aided Manufacturing (CAM) and CNC machines as described by [6, 9]. The development of CAM and CNC technology for ceramics has enabled this industry to increase its production process to become a reliable manufacturing industry in Indonesia. Existing CAM and CNC technologies also offer advantages for the ceramic industry in reducing production costs, and speeding up the production process [6]. CNC machines are technological manufacturing machines that are widely used in the industry. CNC machines are used to speed up the production process. The CNC machine has a Spindle speed of up to 60,000 rpm. CNC machines are high-tech machines that are used to increase the efficiency, accuracy, and quality of workpieces compared to conventional machines [12]. Estimating machining time is an important step towards an optimal and practical production plan [13]. [9] in his research describes how the efforts of engineers to increase productivity and cost optimization through the use of CNC manufacturing technology with the achievement of working time results of 32.49% and can achieve an economic value of up to 10.33% for manufacturing costs. Setting the machining strategy toolpath parameters in the CAM software can also affect the machining time designed by engineers [4-6]. The machining toolpath strategy consists of speed, stepover percentage, feed rate, and tool path strategy [14]. However, the use of CAM software in the ceramic industry to the mass, precise, and accurate fabrication stage of ceramic products is rarely found in real production. This is because there are still many ceramic factories in Indonesia that use handmade technology and the lack of working capital owned by the factory owners.

This paper will discuss comprehensively the application of CAM rhinoceros 4.0 technology and CNC router machines in the process of manufacturing optimization based on CAM on CNC router machines. This is done by researchers as a research effort to help the local industry of Naruna Ceramic Studio, Salatiga to innovate the development of ceramic products from handmade tableware ceramics to Indonesian batik-patterned jewelry products.

2. METHOD

In this paper, jewelry ceramic product design is obtained through a design process using CAD technology called Z-brush R7. The input-output from this Z-brush is in the form of a 2.5D CAD design model with the .stl format (see Figure 1). Two materials, namely: yellow gypsum and white gypsum are used in this paper to make a printed product master (Figure 2.a) and a printed pattern master (Figure 2.b.). Yellow gypsum material with a size of 350mm x 250mm x 15mm was used to make a master jewelry ceramic mold (Figure 2.c). White gypsum is used to make jewelry ceramic imprint patterns (Figure 2.d.).

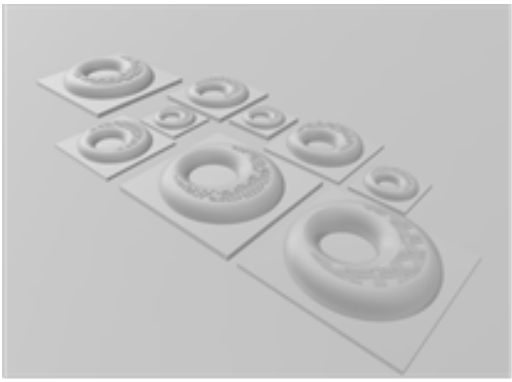


Figure 1 Design of Ceramic Jewelry Products

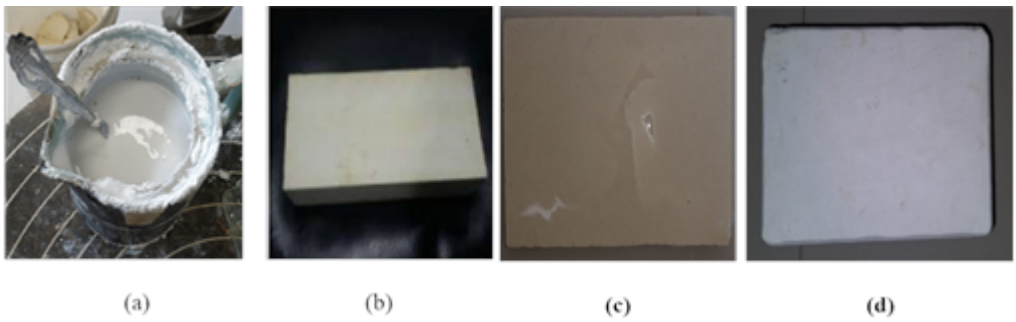


Figure 2 (a) White Gypsum, (b) Yellow Gypsum, (c) raw material master product; (d) the master raw material of the mold pattern

Nine jewelry ceramic models with .stl format as shown in Figure 1, so that it can be simulated in the CAM software, a model variation process needs to be carried out so that there are still model defects from the images that have been generated from the artistic CAD application used in this paper, namely PowerSHAPE 2016. The main view and the results of the model drawing from CAD to CAM software can be seen in Figure 3.After making sure that the model design shown is safe (Figure 3), so that the design can be turned into a 3D product, it is necessary to optimize CAM-based manufacturing so that the movement of the milling cutter can be done. well-controlled and safe so that the output obtained can be optimal, precise, and accurate. The Rhinoceros 4.0 CAM technology was chosen in this paper because it is considered capable of collaborating well on the CNC router machine used (Figure 4). Two machining strategies are defined for the roughing and semi-finishing stages using horizontal roughing, while the final stage (finishing) uses the parallel finishing strategy (Figure 5). In general, the stage of the CAM simulation process from the 2.5D CAD input stage of the .stl format model to obtaining the NC code that is ready to be processed on the CNC router machine can be presented in Figure 6. The stages of the jewelry pendant product master manufacturing process on the CNC router machine can be presented in Figure 7. The stages of the master process of making jewelry pendant molding patterns using white gypsum material with manual technology are in Figure 8. The verification of the research results in this paper can then be presented in Figure 9.

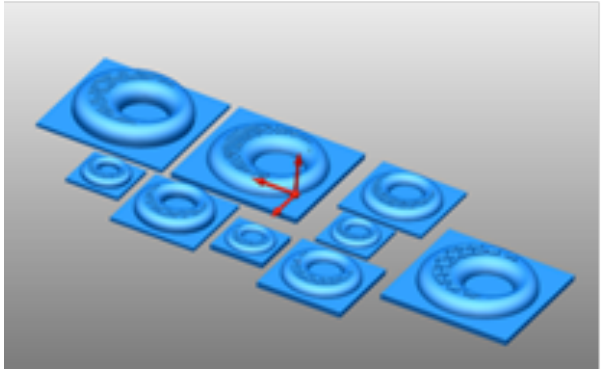
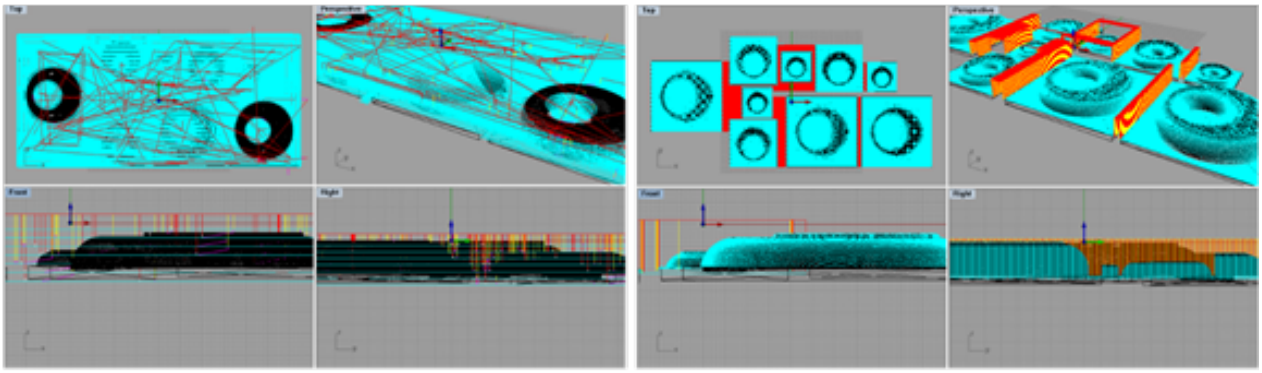


Figure 3 Display of design models from Software PowerSHAPE to Rhinoceros 4.0

Figure 4 CNC router machine



(a) (b)

Figure 5 Toolpath of the machining strategy in Rhinoceros 4.0 software: (a) roughing process with horizontal machining strategy; (b) semi finish and finish with parallel finishing machining strategy

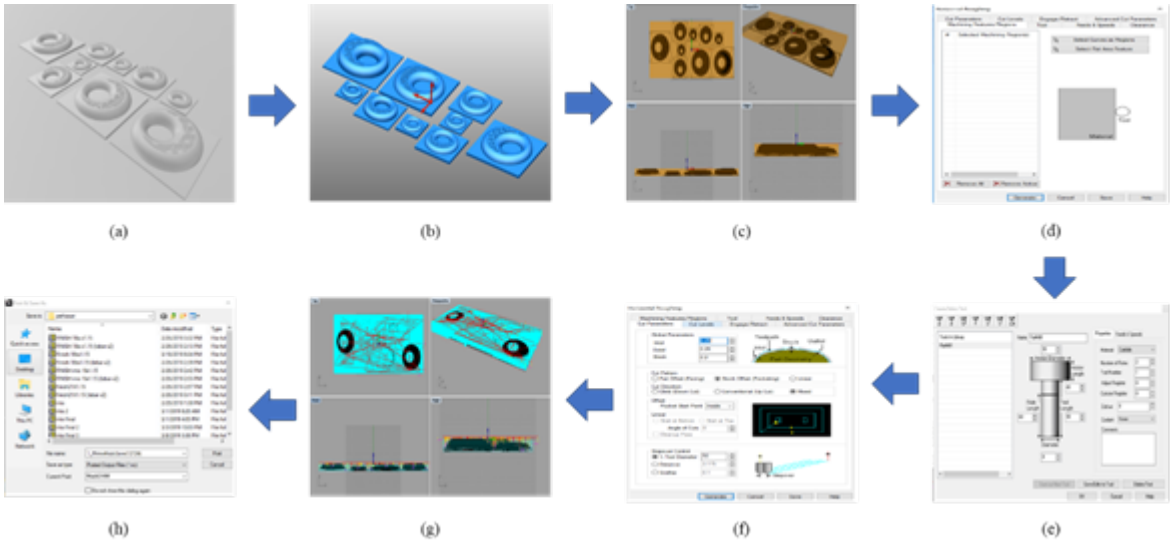


Figure 6 Stages of manufacturing optimization for jewelry pendant products on the rhinoceros CAM 4.0: (a). 3D CAD model liontin with .stl format; (b) 2.5D CAD model liontin with IGES format; (c) liontin model CAD in rhinoceros 4.0; (d) toolpath parameter on rhinoceros; (e) cutter setting; (f) input parameter machining; (g) simulation of toolpath strategy machining; (h) create NC code

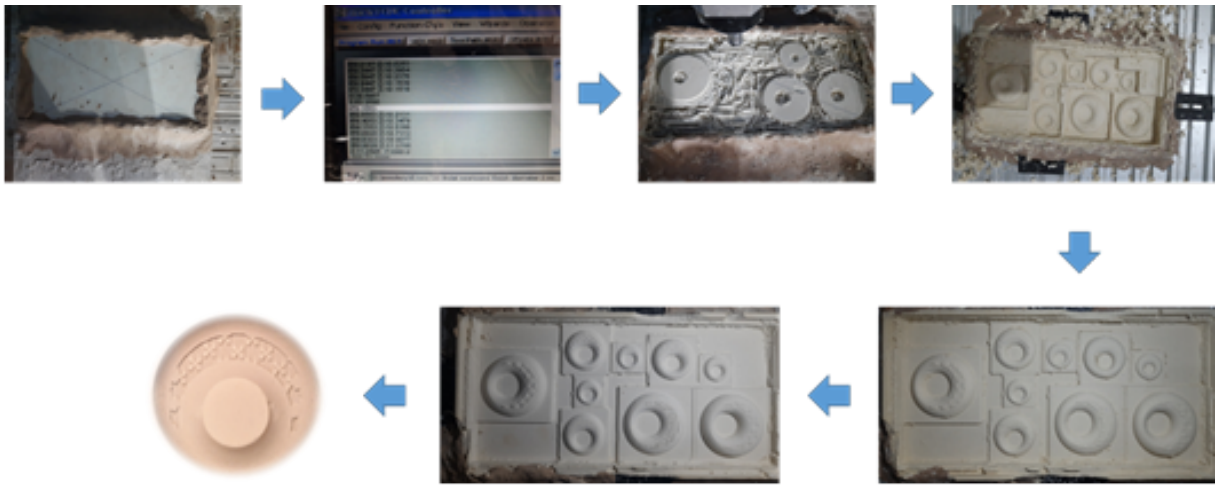


Figure 7 The manufacturing stage of the master pendant jewelry product in a CNC router machine

Figure 8 Stages of the master manufacturing process for ceramic product mold patterns with white gypsum material

Figure 9 Verification of research products

3. RESULT AND DISCUSSION

This paper describes the optimization of the process of manufacturing jewelry ceramic products based on the care system. The use of z-brush software in making 3D CAD models from jewelry ceramic produces 3D CAD models that have high artistic value or touch. And the design process time is faster than ArtCAM, and AutoCAD. This software has advantages in terms of the fast, precise, and artistic sculpting process compared to other CAD software: artcam, Autodesk fusion 360, solid work, master cam. According to [9], Z Brush is artistic CAD software that can support users to draw illustrations in 2.5 or 3 dimensional forms where the technique applied in this software is the sculpting technique. With this technique, CAD artistic engineers can produce designs in the form of 2.5d or 3D artistic models with detailed and complex relief contours based on input in the form of photo files with .jpg format.

The manufacturing optimization process of the master jewelry ceramic mold pattern uses a combination of the toolpath from the CAM software, namely Rhinoceros 4.0. This software is used by researchers to carry out the Roughing, semi-finishing, and finishing processes in a computer simulation until the optimal NC code is obtained. This is because the processing time is faster compared to other CAMs such as PowerMILL 2016. The movement of the cutter in the Rhinoceros 4.0 Toolpath is simpler and following the objectives of the research carried out by researchers and this has been successfully done by [9] and [6]. The horizontal roughing toolpath was chosen by researchers for the initial work process in this paper because it is about 25% -50% faster than other toolpath strategies (plunge roughing, horizontal re-roughing, plunge re-roughing). Meanwhile, a parallel finishing toolpath was chosen because, in addition to producing a faster processing time, the surface quality of the machining results for products with detailed relief contours is better than products with flat surfaces. This has also been done with maximum results [9], and [6].

The next stage is the jewelry ceramic machining process. This process uses a CNC Milling Router machine (Figure.7) owned by CV Sibad Engineering with a maximum machine speed that can be used is 25,000 rpm. The use of a CNC router machine in this paper is included in the high-speed machining that has been discussed by [9]. In his paper [9] discusses the application of machining process techniques using CNC technology in producing models and molds for tableware and sanitary ware in the ceramic industry. Covers different processes like high-speed machining, multi-axis machining, etc. which aim to improve the cutting process. In this research, the application of machining process techniques using CNC technology is not only intended to improve the cutting process but to produce detailed contours, textures, and ornaments on the master jewelry ceramic mold patterns. The machining process with a CNC router machine can produce several master jewelry ceramic molding patterns with different results.

The master of the jewelry ceramic mold pattern that has been finished is cut using a sawing machine according to the jewelry ceramic model that will be produced. The process of tracing the master pattern of the mold that has been cut using manual techniques with the material in the form of clay to form a tracing pattern from the master of the mold pattern, angled glass is arranged around the clay as a container for making molds (Picture.9). The research output from the design stage to the printed pattern product as shown in the picture. 9 produces a product that is quick and precise, both visually and physically.

4. CONCLUSION

The most optimal toolpath strategy for mastering the product master and the master pattern of jewelry ceramic prints with the Indonesian batik motif is horizontal roughing for the roughing process, parallel finishing for the semi-finishing and finishing processes. The total time for the simulation of the machining process using the rhinoceros CAM software is 6 hours 24 minutes, while the total time for real processing on the router machine is 8.0 hours. The application of artistic CAD / CAM technology with a CNC router machine in this paper is able to produce 9 product masters and a master pattern for ceramic jewelry pendants with Indonesian Batik motifs. In the future, this technology can also be applied to the work of tableware ceramic products, and tile wall with complex and precise contour relief motifs so as to increase the local ceramic industry's competitive advantage in order to compete with the overseas ceramic industry

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