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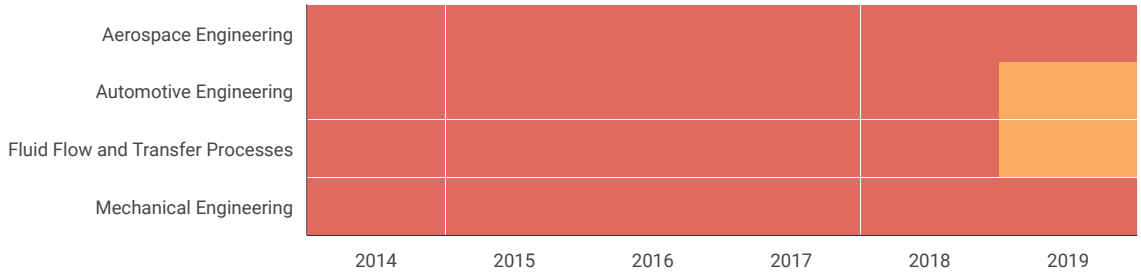

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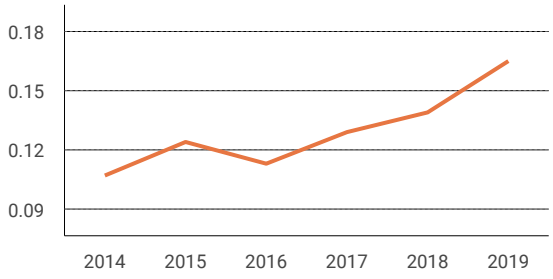

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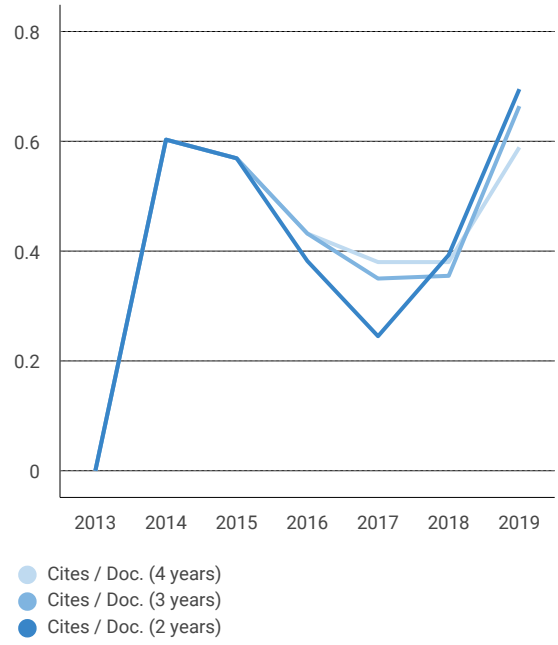

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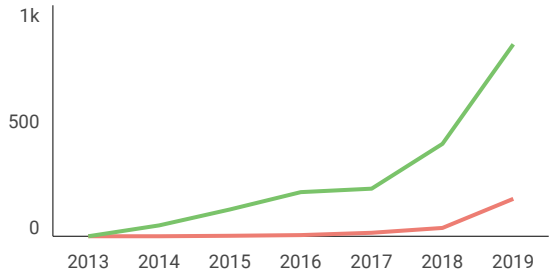

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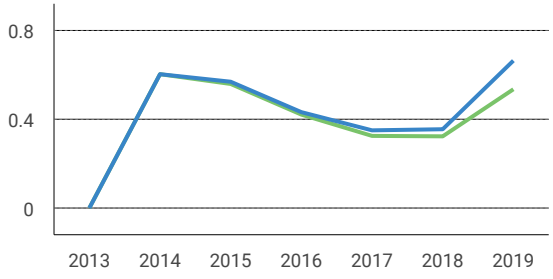

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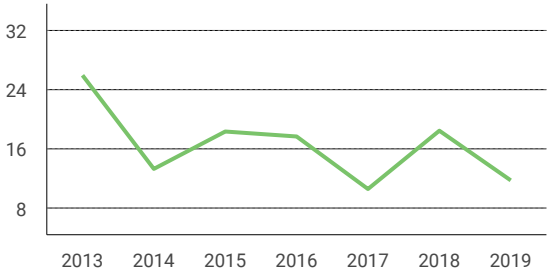

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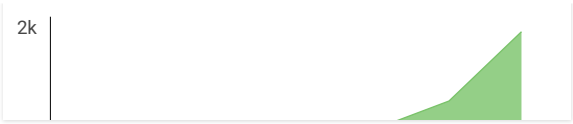

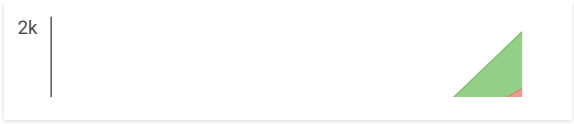

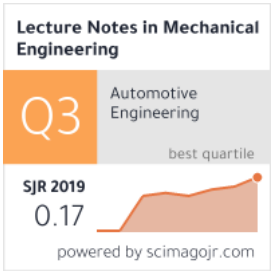

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Lecture Notes in Mechanical Engineering

Ubaidillah Sabino
Fitrian Imaduddin
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Proceedings of the 6th International Conference and Exhibition on Sustainable Energy and Advanced Materials

ICE-SEAM 2019, 16–17 October 2019, Surakarta, Indonesia

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Contents

Puzzle Islamic Floral Patterns Product Tiles for Wall and Ceiling to Decorate of Al Huda Mosque Indonesia—Design, Manufacturing, and Fabrication

P. W. Anggoro, A. T. Yuniarto, M. Tauviqirrahman, J. Jamari, A. P. Bayuseno, K. B. Purwanto, and O. K. W. Widyanarka

Abstract Ceramic wall ornaments that are commonly used as interior building and encountered in hotels, restaurants, residential elite, museums and places of worship. Ceramic is a decoration signifying strong characters or special characteristics of the building. This character is usually in the form of ornaments that adorn the walls and are designed according to the history of the development of the times. The basic characteristic of Islamic Ornament generally shaped floral such as leaves, stems, buds, flowers, and palms. Wall tiles with special needs with unique ornaments and precision are very unlikely produced by some industrial ceramics in Indonesia at this time which still depends on hand made. This study has introduced a range of novel applications that combine digital manufacturing technology and conventional fabrication in the ceramic industry. The input image with the nuances of Islamic motifs with the format. JPG successfully raised to 2.5 D CAD models using ArtCAM software. To get the master pattern prints that precision, accurate and appropriate use of technology additive manufacturing with 3D Objet 30Pro. Conventional ceramics Manufacturing process technology at PT. Nuanza Porcelain Indonesia used to get ceramic products with Islamic nuances of Pattern puzzle flora. The integration of two technologies of CAD and RP this managed to get the design ceramic wall ornamental Islamic precision and detail with the dimensional error of less than 2.00 mm. Ceramic design results in accordance with Islamic ornamentation and was already installed in the mosque of Al Huda in 2018.

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1 Introduction

Ceramic art is one branch of art that processes ceramic materials. This art is used to create a work that is traditional to contemporary. Ceramics are coverage for all objects made of clay, which undergo a process of heat or combustion so that it hardens. In everyday life, ceramics are often used as household appliances, displays, electronic devices, building ornaments.

From the classical world that encircled the Mediterannean to the boundaries of Scandinavia and to the New World, tiles have been used as architectural fixtures and for the embellishment of interior walls, floors, and ceilings. Monochromatic tiles were the main means by which tin-glazing techniques were disseminated throughout much of the Medieval world [1]. Tile is an enduringly popular choice because it can famously low maintenance, durable, and easy to clean, tile is an enduringly popular choice. But lately, tile has shed its reputation as just a sturdy and practical design solution. A tiled surface can be a piece of artistry. "Designing with the tile" explaining the fundamental principles of color, pattern and texture and their impact in this research. Tiles can bring color, pattern, and texture to a room where it is lacking, or they can enhance attributes that already exist as reported by Renzi [2]. In the context of modern manufacturing product design according to [3–6] the use of computer-aided design (CAD)—based design technology is an absolute requirement to get quality, precise, accurate and precise ceramic products. CAD in the ceramic design process, engineers are used to generating 2D sketch images or photo images in .jpg format quickly, precisely and precisely into 3D model surfaces or solid models as customers want. The use of 3D CAD (Computer-Aided Design) tools is an important factor in shortening time to market and reducing product development costs. By adopting broad 3D CAD technology as reported by Refs. [7, 8], product development has moved from physical to digital mockups, and from 2D to 3D designs in recent decades. 3D CAD has become part of a fully digital development process that includes design, modeling, simulation, and tooling [9, 10]. For new designs, if digital forms of similar product models are already available in databases, search techniques 3D like what has been explained by Refs. [11–13] can be used to search for product models with similar design shapes and objectives. In this case, the new design can be accelerated by reuse, in whole or in part, from the previous design. 3D search and reuse techniques have been widely studied [14, 15]. Although there are already several commercially available 3D search engines [12], the search and development of new 3D models remains a very active research topic in the field of product design and retrieval areas, especially in the ceramic tile industry.

Computer-Aided Design (CAD) is a computer program used to draw a product or component in the form of 2D vectors and 2.5D models. CAD models usually go through several design modifications, each time requiring simulation of physical properties and functions before finally being produced into engineering products

[16]. The application of CAD allows the optimization of product concepts before the manufacturing process.

Artistic Computer Aided Manufacture (ArtCAM) makes it easy to produce highly complex artistic designs quickly and effectively [6]. ArtCAM is used in various manufacturing industries such as the souvenir industry, ceramics, jewelry, spare parts, etc. for designing. ArtCAM is suitable for forming 2D and 2.5D models with a high degree of detail. However, until now rarely found any paper or research that discusses this software application as a tool to solve the problem of a real ceramic wall design with Islamic patterns in the ceramic industry in Indonesia.

Ceramic tiles are arranged in various shapes and sizes used on the floor or wall. Ordinary ceramic tiles for ornaments in mosques, hotels, historic buildings, resorts, and others. Mosques as places of worship are buildings and spaces that are believed by believers to be sacred and holy places [17]. For centuries, geometric patterns of Islam/Islamic Geometric Pattern (IGP) have been used as decorative elements on walls, ceilings, doors, domes, and towers [18]. Geometry in Islamic art and architecture creates a basic pattern in design [19]. Ceramics are widely used as building ornaments in places of worship, so they can add high artistic value. Ornaments on mosque buildings usually contain a philosophy/history of the development of the design. Some previous studies [3, 17–21] have only talked about the ceramic design patterns of cultural aspects, history, design concepts, up to prototype. While this paper, really applies modern technology CARESystem to accelerate the design time, manufacturing and fabrication of wall ceramics precision, accurate and able to disassembling rapidly on the building area to accelerate the time Installation of ceramics in the field. This kind of research is very rare and has a novelty on the process design and manufacturing techniques of a ceramic puzzle with CARESystem Technology.

Most of the best ceramic industries in Indonesia produce large quantities of tiles for the global market. In recent decades the progress of material science and production engineering has led to significant advances in quality and productivity [22]. The application of digital computer technology in terms of design and manufacturing has contributed greatly to this development [6, 20, 23–25]. Some ceramic companies such as PT. Doulton Indonesia, PT. Nuanza Indonesia has also implemented this technology. However, at present the regulation of production systems for tableware and ceramic tile ceramics with high production volumes has undergone changes, some or all of them no longer use hand made technology in the design process of master pattern prints but have gone through digital technology integration such as digital printing with in-jet [21], digital CARESystem on orthotic shoes and ceramic tableware [6, 23, 24] and digital CAM-CNC ceramic. Through this sophisticated system, it allows an attractive aesthetic opportunity to effect the detailed contours of the surface and glaze on artistic ceramic tile walls that can be fulfilled according to customer orders.

This paper explains the stages of design and fabrication of ceramic walls with IGP ornaments from flora patterned batik patterns where the initial input from customer NPI is only in the form of photo images in the .jpg format. The output of detail and precision ornamental motifs were chosen to be worked on in this paper are Islamic nuances for the buildings and walls of the Al Huda Mosque in Jakarta. The selection

and determination of Islamic tile ornaments by researchers are based on the results of tile designs by several previous researchers [1, 2, 17, 18].

2 Material and Method

Islamic tilework can be seen as a manifestation of cultural preoccupation with the covering of surfaces. The Islamic tile ornaments chosen for this paper are presented in Fig. 1 and have been installed on several walls of the Al Huda Mosque, Jakarta, Indonesia (see Fig. 7).

The generation of vector surface modeling from .jpg format photo files to 2.5D solid tiles component modeling in this paper using ArtCAMPro 2015 CAD software can be presented in Fig. 2.

This research originated from the problem of PT Nuanza Porcelain Indonesia in the manufacture of puzzle type wall ceramics which is still done manually (hand made) with the results not precise and incorrect when assembled. This technology also requires a design time of 10–12 months longer with the size of the wall ceramic image from the photo with the printed one not the same because it is not precise and accurate. The brainstorming results obtained the design of wall ceramics with the type of Islamic Geometrical Patterns (IGP) in the form of photos in the .jpg file format, as in Fig. 1. With the help of ArtCAM 2015R2, PowerSHAPE 2016 and Autodesk basic Netfaab, the vector format with.jpg format was 2.5D CAD model of IGP ornamental wall ceramics and designed based on puzzle patterns. The results

Fig. 1 Islamic geometric ornamen with floral patern with .jpg format

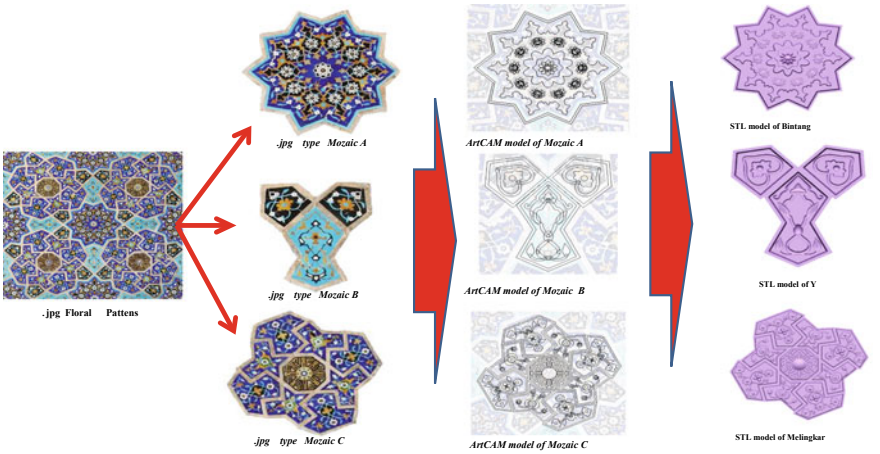

Fig. 2 Vector generation for geometric Islamic floral pattern using ArtCAM pro 2015

are presented in Fig. 3 the .STL format with 800–850 edge angles (see Fig. 8 at the bottom left). Giving edge angle is done so that when the pile ceramic is released from the core and the cavity can be released perfectly. The stages of vector generation of ceramic Tiles IGPs at ArtCAM 2015 are presented in Fig. 2. The 2.5D results of this ceramic model were then carried out by the verification process of geometry and solid surface modeling using basic Netfaab. The results are presented in Fig. 3 and are called master model prints of ceramic Tiles puzzle parts. This mold master finally fabricated the BOP (see Fig. 4) until the product was made into ceramic tiles as in Figs. 5, 6, and 7.

To get the results of part puzzle of ceramic tiles products with precision, accurate and precise IGP ornaments; Geometry measurements using a caliper dial with a tolerance of 0.01 mm until error deviations are obtained from the comparison of the dimensions between the dimensions of CAD drawings, prototypes of 3D printer results and pile prints before being burned with the final results (see Table 1 and Fig. 4).

In order for tile products designed with fabrication and fabrication to have perfect geometry and shape conformity [see Figs. 5 and 6] in terms of the deviation of errors that occur less than 2.00 mm then the procedure worked in this paper is to provide a magnification of a volume area of 15–20% on the 2.5D CAD ceramic model that

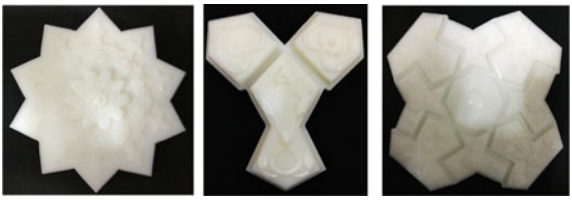

Fig. 3 The ceramic tile mold pattern master output from 3D print objet 30 Pro

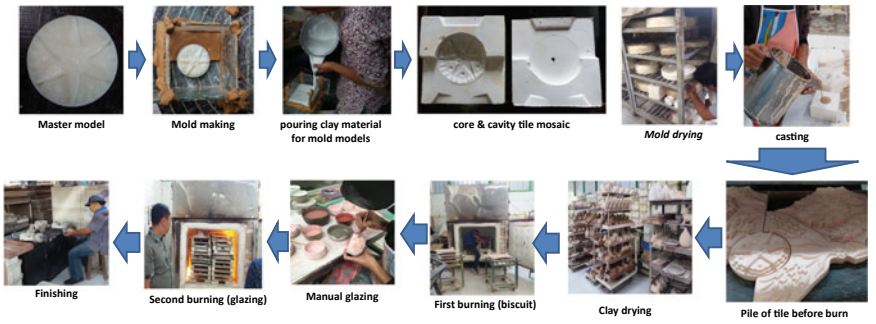

Fig. 4 Mold making and fabrication process ceramics tile at PT Nuanza Porcelain Indonesia (NPI)

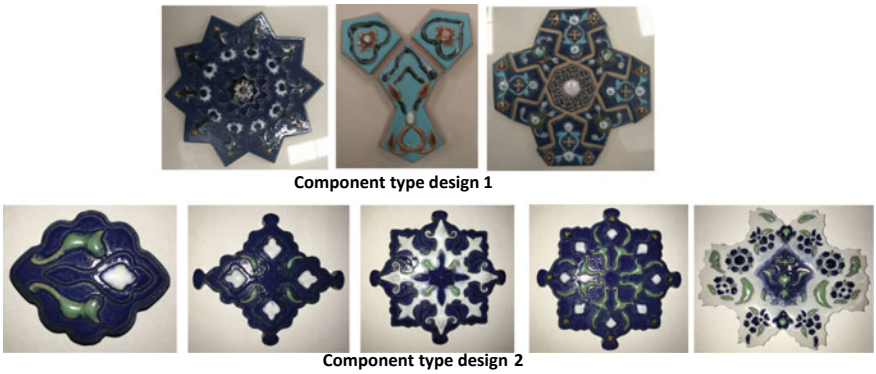

Fig. 5 Component tiles with floral patterns and geometric ornament

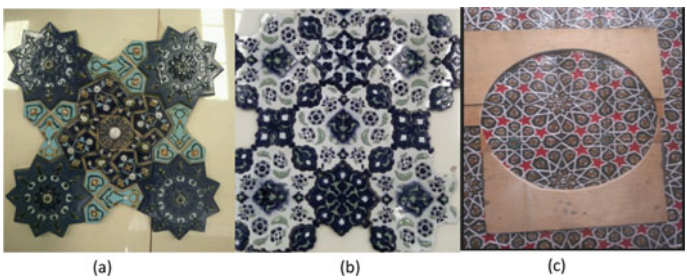

Fig. 6 Produk assembling Islamic tiles **a** Combination geometric ornament and floral patterns. **b** Syrian and Egyptian tiles. **c** Geometric ornament tiles

has been made at ArtCAM. This is done because based on the results of research conducted by researchers after the kiln process in the NPI oven generally the volume

Fig. 7 Some Islamic tiles from research have been installed on the walls of the Al Huda Mosque in Jakarta, Indonesia

of the final ceramic product will shrink by about 15% with the size present on CAD drawings. The final results of ceramics can be presented in Figs. 6 and 7.

Figure 5, if assembled into a single unit will form a wall decoration with Islamic ornamental ceramics as shown in Fig. 6 and after pairing it in the building of the Jakarta Al Huda mosque looks like in 7.

3 Result and Discussion

By the eighth century, the Islamic civilization had spread over a vast area that extended from India to North Arica and reaches up to Spain. Nourished by the cultural traditions of the conquered countries, it developed an astonishingly rich and varied aesthetic identify. The hot climate of the Islamic region and the extensive use of brick in the architecture made ceramic tiles a congenial and convenient form of embellishment for the inner and outer walls of both religious and secular building: glazed surfaces are cooling, and can be kept clean easily in a dusty environment [1, 2]. Geometric ornament, Floral patterns, calligraphic tiles, Persian monochrome tile, Seljuk or Abbasid tiles, Tile shape and styles, Il-Khnaid tile, Timurid Tiles, Safavid tiles, Syrian and Egyptian Tiles, and Iznik Tiles, is a variety of tiles that have been discussed in general by Refs. [1, 17, 18]. Base on Fig. 1, the images are included in the geometric ornament and Floral pattern categories and are an ornamental type of tiles so that they can be further processed to be vectored into a 2.5D solid ceramic wall model puzzle form using ArtCAM CAD. These two images will later be designed and fabricated into tiles that are arranged in the puzzle and mounted on the walls of the Al Huda Mosque, Jakarta Indonesia.

Table 1 Dimensional accuracy verification between 2.5D models, STL and RP of part safavid tiles

Part of cloudpart												
Point	2.5 Model on ArtCAM (mm)		2.5 D model with file STL (mm)		RP model (mm)		0,132Ceramic tiles (mm)		Error deviation of RP compare with ArtCAM (mm)		Error deviation RP to .STL (mm)	
	80°	85°	80°	85°	80°	85°	80°	85°	80°	85°	80°	85°
A	42.589	42.589	42.580	42.580	42.570	42.570	36.185	36.185	−0.020	−0.019	−0.010	−0.010
B	52.315	52.315	52.310	52.300	51.540	51.540	43.809	43.809	−0.770	−0.775	−0.770	−0.760
C	17.466	17.466	17.340	17.340	17.220	17.220	14.637	14.637	−0.250	−0.246	−0.120	−0.120
D	36.945	36.945	36.860	36.860	36.610	36.610	31.119	31.119	−0.340	−0.335	−0.250	−0.250
High	15.289	15.289	15.288	15.287	15.000	15.000	12.750	12.750	−0.290	−0.289	−0.290	−0.287
Part of sidepart												
A	110.815	110.815	110.610	110.700	110.550	110.570	93.968	93.985	−0.265	−0.245	−0.060	−0.130
B	95.801	95.801	95.750	95.790	95.690	95.710	81.337	81.354	−0.111	−0.091	−0.060	−0.080
C	78.534	78.534	78.500	78.510	78.320	78.330	66.572	66.581	−0.214	−0.204	−0.180	−0.180
D	92.243	92.243	92.210	92.240	92.190	92.230	78.362	78.396	−0.053	−0.013	−0.020	−0.010
E	64.333	64.333	64.310	64.320	64.240	64.260	54.604	54.621	−0.093	−0.073	−0.070	−0.060
F	72.100	72.100	72.000	72.000	71.870	71.890	61.090	61.107	−0.230	−0.210	−0.130	−0.110
High	17.246	17.246	17.245	17.245	17.170	17.170	14.595	14.595	−0.076	−0.076	−0.075	−0.075
Sidepart of corner												
A	16.240	16.240	16.190	16.220	16.030	16.180	13.626	13.753	−0.210	−0.060	−0.160	−0.040
B	135.753	135.753	135.270	135.490	135.040	135.220	114.784	114.937	−0.710	−0.533	−0.230	−0.270
C	17.252	17.252	17.110	17.100	16.730	16.720	14.221	14.212	−0.520	−0.532	−0.380	−0.380
D	117.115	117.115	117.050	117.000	116.750	116.680	99.238	99.178	−0.360	−0.435	−0.300	−0.320

(continued)

Table 1 (continued)

Part of cloudpart												
Point	2.5 Model on ArtCAM (mm)		2.5 D model with file STL (mm)		RP model (mm)		0,132Ceramic tiles (mm)		Error deviation of RP compare with ArtCAM (mm)		Error deviation RP to .STL (mm)	
	80°	85°	80°	85°	80°	85°	80°	85°	80°	85°	80°	85°
High	17.136	17.136	17.135	17.135	17.050	17.050	14.493	14.493	−0.090	−0.086	−0.090	−0.085
Part of center												
A	120.750	120.750	120.460	120.410	120.380	120.170	102.323	102.145	−0.370	−0.580	−0.080	−0.240
B	109.498	109.498	109.440	109.440	109.260	109.260	92.871	92.871	−0.240	−0.238	−0.180	−0.180
C	14.452	14.452	14.420	14.400	14.390	14.270	12.232	12.130	−0.060	−0.182	−0.030	−0.130
D	101.097	101.097	101.030	101.060	100.940	100.970	85.799	85.825	−0.160	−0.127	−0.090	−0.090
E	22.385	22.385	22.320	22.360	22.200	22.260	18.870	18.921	−0.190	−0.125	−0.120	−0.100
High	21.793	21.793	21.792	21.792	21.500	21.500	18.275	18.275	−0.290	−0.293	−0.290	−0.292
Part of white ornament												
A	56.713	56.713	56.700	56.690	56.680	56.690	48.178	48.187	−0.030	−0.023	−0.020	0.000
B	22.450	22.450	22.400	22.430	21.930	21.960	18.641	18.666	−0.520	−0.490	−0.470	−0.470
C	66.804	66.804	66.370	66.410	66.260	66.310	56.321	56.364	−0.540	−0.494	−0.110	−0.100
D	67.560	67.560	66.620	66.530	65.860	65.370	55.981	55.565	−1.700	−2.190	−0.760	−1.160
E	118.950	118.950	118.920	118.940	118.850	118.900	101.023	101.065	−0.100	−0.050	−0.070	−0.040
High	17.533	17.533	17.532	17.532	17.400	17.400	14.790	14.790	−0.130	−0.133	−0.130	−0.132

Figure 1 explains that the secret of Islamic art lies in the power of ornament. Geometry, floral patterns make up the decorative principles in market contrast to western art, which focus on nature and the human body. Ornament dissolves mass, forge space, engages, excites and surprises the human eye. Geometry is fundamental to Islamic ornament, just nature is organized on symmetrical principles and geometric patterning envolved to a degree of complexity and sophistication that had never before been seen (see Fig. 6). Two previous researchers [1, 18, 26] also noted that Islamic engineers or Islamic artists reproduced nature with a great deal of accuracy. Flowers and trees were often used as decorative motifs (see Fig. 1), but in the arabesque pattern, lines of vegetal ornamentation define space, playing a masterful game with colors and creating a three-dimensional effect (see Figs. 1 and 2). Figure 1 is the type of Iznik Tile. This is an exceptional example of the tiler's art in terms of quality and brilliance of color, demonstrating the sophistication of design attained during the third quarter of the sixteenth century [1, 2].

In decorative and architectural arts, ornaments are decorations that are used to beautify parts of a building or object. Ornaments can be carved from stone, wood or metal and can also be formed with clay. Ornaments found in mosque buildings usually form a certain pattern with Islamic designs. Islamic art uses many natural motifs such as flowers and trees with accurate designs. The strength of Islamic art lies in the ornaments that form geometry, flowers, patterns, and calligraphy. For centuries, the Islamic Geometric Patterns (IGP) have been used as decorative elements on walls, ceilings, doors, domes, and towers [18] and in this paper it has been shown that ornamental motifs in Fig. 1 can be developed become a form of ceramic wall with the characteristics of IGPs. Ornaments formed in general are in the form of Zillij motifs with recurring features and flipping through their basic shapes. Zillij is an Islamic ornamental art that repeats geometric shapes so that intertwined shapes and lines are intertwined (see Fig. 1). Plant motifs and flowers as shown in Fig. 1 have also long been the basis for decorating Islamic buildings [18, 26].

Figure 2, is the stage of the IGPs vector generation process with geometric ornament and Floral Pattern types from photo files in the .jpg format which are divided into several puzzles into 2.5D Artistic CAD with .STL format. This vector generation process is carried out using ArtCAMPro 2015 which has a very good ability to build an artistic 3D model according to the wishes of the engineer with a physical model or initial photo. This stage of vector development, in general, first divides photo files into puzzle parts that are ready to be raised into a 2.5D model (see Fig. 2).

This image was then continued by the researcher to verify the dimensions, surface and solid model with netffab software before the printing process was carried out with additive manufacturing technology on the 30Pro object 3D machine. This printout, then determined as the master model of ceramic Tiles made from verowhite which has been enlarged in volume by about 15% and can be presented in Fig. 3. Figure 4 explains the stages of fabrication of each master puzzle mold pattern of Islamic Ceramic tiles that is done by casting operators, glaze, burning at PT. Nuanza Porcelen Indonesia. After finishing the finishing process for each puzzle on the ceramic tile forming components, an Islamic ornamental puzzle wall ceramic product will be obtained (see Fig. 5) and after assembling it into one size 100 $\times$ 100 cm it will look

like in Fig. 6. Installation results of all ceramic puzzles this ornament Islamic wall was successfully installed with great precision, good and accurate on the walls of the Al Huda Mosque in Jakarta, Indonesia (see Fig. 7). It can be seen that the results of the ceramics production and fabrication are following the results of the research that has been produced and developed by Refs. [3, 17, 18, 26–28].

Precision product results must have precise dimensional accuracy. The accuracy of dimensions in the design of wall ceramics is very important to compare from the initial dimensions to the results of the prints. This measurement aims to see and prove the success of the application of the reverse engineering method from the initial standard 2D to 2.5D (RP model) with the standards given by the PT. NPI of 2.00 mm. Dimension measurement is done by brainstorming with the creative team in the form of points, where each selected dimension is considered to represent several other dimensions. The measurement results with the caliper dial 0.01 mm produce several dimensions on the point of measurement as specified in Fig. 5 and are presented in Table 1.

The results showed that the deviation occurred below 1.00 mm for both design variations of 80° and 85°, while the standard given by the NPI was a maximum of 2.00 mm. Thus, the deviation between the 2.5D model and RP model meets the standard so that the model RP can be used as a master pattern template and can proceed to the ceramic tile fabrication stage (see Fig. 4) and the assembly process at PT. NPI until installation on all walls of Al Huda Mosque (see Fig. 7).

In summary, the stages of design—manufacturing—the fabrication of the distinctive Islamic floral wall tiles on this paper can be presented at Fig. 8. This stage proved to be able to bring the company to be able to compete in fighting overseas consumers will need artistic ceramic products with high selling value. Figure 8 next can be used as the basis for all local ceramic industry in Indonesia to be able to compete globally.

Ceramic tile produced at this research in an economical value is cheaper when compared with the manual technique that has been used by PT. NPI. According to information from the owner and Department of R&D PT NPI, it requires about 1–2 years for one type of precision and accurate ceramic mold pattern design. However, with CARESystem technology application in this paper for cases like in this paper, this can be produced in a month at least 10 variations of ceramic mold pattern design with Islamic pattern flora. This technology proved to accelerate the fabrication process of ceramic to the assembly stage on the production floor and installation in the mosque for less than 6 months.

4 Conclusion

Artistic 3D CAD-CAM such as ArtCAM2015 was applied to provide customized special ceramic tiles products that are specifically designed and manufactured for the Assembly of the Al Huda Mosque, Jakarta Indonesia. Ceramic Tiles products with ornament geometric and floral patterns exhibited precise surface contours and

Fig. 8 General stages of CARESystem application in the phase of design, manufacturing, and fabrication of ceramic wall in the local Indonesian ceramic industry

dimensional fit of the 2.5D CAD and 3D master pattern prints. All products provide good satisfaction for customers and PT NPI.

The Artistic CAD/CAM technology application with additive manufacturing on 3D printer machines to produce a master pattern of ceramic tile prints with IGP ornaments can provide precise, accurate ceramic end products with errors less than 1.00 mm and have been very well developed by researchers and PT NPI. Consumers also provide a very high appreciation for the results of ceramic tiles.

In the future, research on the usability of modern technology based on artistic CAD (Artcam, Vertec, brush), CAM (Powermill and Rhinoceros), and reliable CNC Milling machine as presented in this paper is able to complete practical solutions for local ceramic industry in Indonesia in order to compete with other competitors. The use of this modern technology will be able to produce ceramic products (tableware, tile wall, jewelry) containing the texture and ornaments with the characteristic of Indonesian native cultures such as batik, Islamic patterns, Java, Sumatra, animals, and plants. The result is in the form of good quality ceramic products, precision, accurate and truly presenting the characteristics of Indonesian culture and cultures.

The results of this research are also able to make PT NPI become the only local company in Central Java Indonesia that can compete at the Global level, especially in preparation to confront the industry 4.0.

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