

Application of Technology 4-Axis CNC Milling for Manufacturing Artistic Ring

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Abstract

This paper describes the efforts of writers to make use of technological artistic CAD-CAM in the manufacture of the products of artistic rings small medium industry. Methods used in this paper is Subtractive Prototyping namely manufacture of product master ring wax with the utilization of 4-axis CNC milling technology. Investment casting is used in this paper to form the silver ring with relief. Investment casting process is conducted in a department of Large Hall of Culture and Batik Yogyakarta. Product attributes and the selection of the artistic design of the ring will be made the object of research derived from the brainstorming process is conducted in conjunction with the creative team. The final results of this paper suggest that the method of investment casting and prototyping subtractive capable of producing 6 product artistic ring (Helmet Trail Ring, Iron Man Ring, Dart Vader Ring, Sansekerta Ring, Engineer Ring, and Harley Skull Ring) made from wax and silver. Quality product made from wax ring master recognized with greater precision, detail, cheap and accelerating stages of Investment casting compared to master products made from vero white.

Keywords: Jewellery; Artistic CAD-CAM; Subtractive pro-totyping; Investment casting; 4-axis machining; Rings of the artistic

Introduction

The world jewelry industry matured and developed, but in developing countries like Indonesia, especially in the cultural city of Yogyakarta as still retain the conventional technologies in the manufacture of jewelry products as well as souvenirs. The conventional technique is done by small metal souvenir industry in Yogyakarta has some constraints such as stained and casting technology that is still modest, the limitations of the gift and jewellery design variation because the industry can only do the duplication of existing products. This resulted in the production of time becomes longer, often occurs a process of trial and error, and product quality is not maintained. On the contrary in developed countries such as the UK, China and the USA began to develop the technology of CAD-CAM to resolve the issue. In 2008 technology CAD-CAM in Indonesia started to get one of these through PSTI-UAJY. PSTI shared local SME (Small Manufacturing Enterprise) UAJY teamed up to do a research on the application of artistic CAD-CAM to increase the quality of the product the typical souvenirs of Jogjakarta in order not to lose the gift of a foreign country. New in the year 2012 the research on the design of the product ring based CAD-CAM can be performed optimally. The design of the ring-based CAD-CAM beginning with the creation of the prototype as the master product and continued with the process of investment casting. The results of the observing about journals reference and research that has been done shows that to produce a good jewelry, detail, and quickly required creative technology CAD-CAM [1].

Methodology

The process of making the product ring using the method of investment casting, as are the risks of need requires a master product in the process. Manufacture of prototype-based CAD-CAM, better known as Rapid Prototyping [2]. Rapid Prototyping is a technique of making prototypes quickly and precisely, producing a quality product in a short time. The quality of the casting is determined from the master quality product made [3]. Development of Rapid Prototyping technology for Artistic CAD-CAM, developed by Deepa Saching Ghag and Jayesh J Dange in their journal, entitled "the Adoptability of CAD/

CAM for jewellery making industry using comparison technique", they introduce an alternative process of CAM in the manufacture of the prototype of the additive and subtractive prototyping prototyping. subtractive prototyping in this technique planned tool movements cut away extraneous material from the work piece to form the required design part. Processes include milling, turning, or drilling [4]. Additive prototyping in this technique a design part is built up by adding layers of material upon each other directly linked with a 3D model [4].

Stages of research (based on Figure 1)

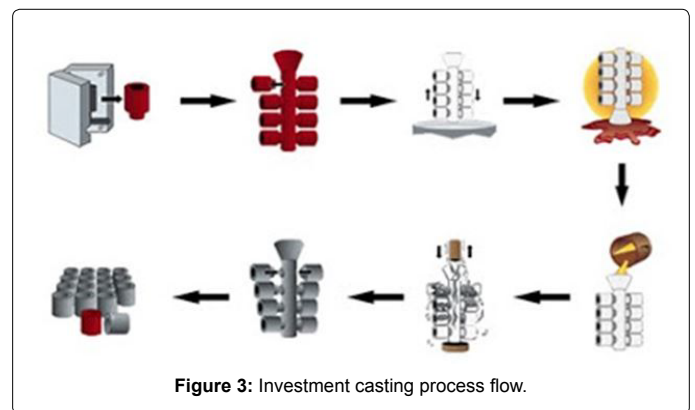
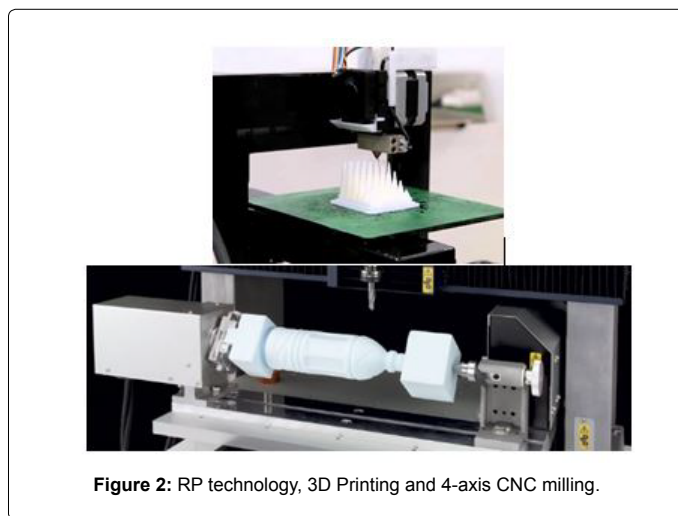
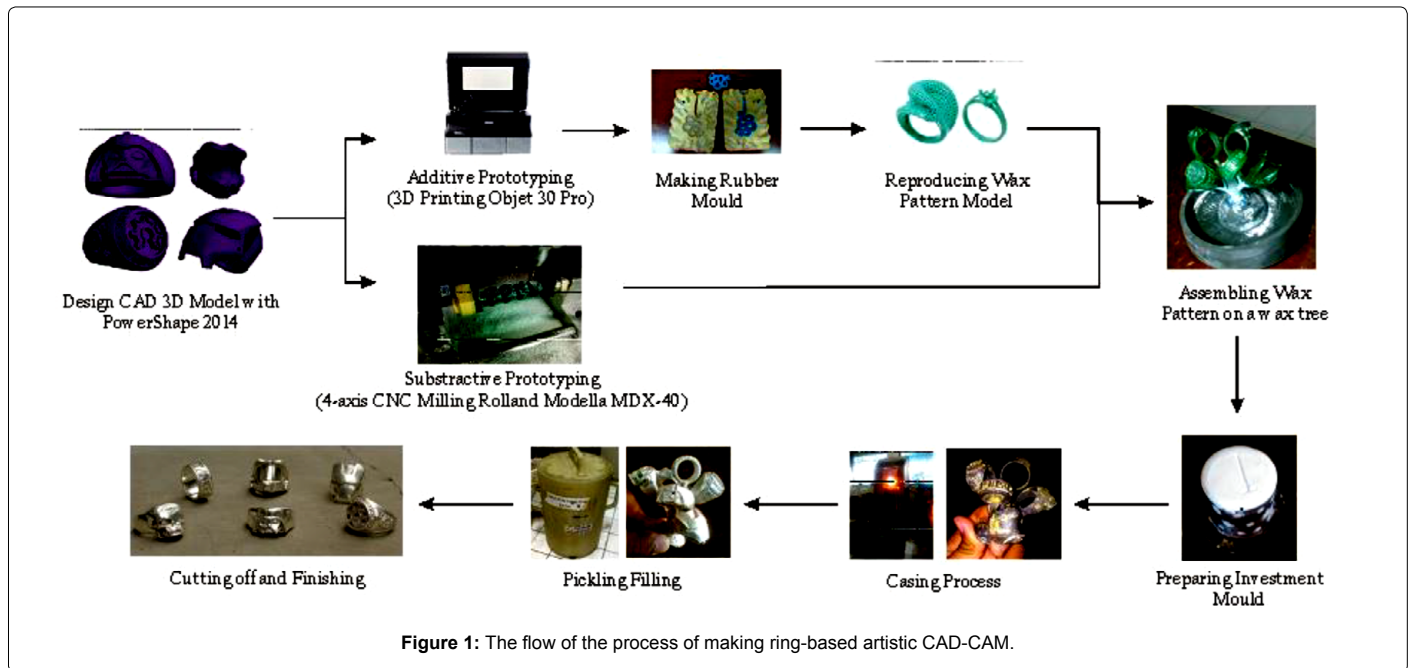
1. Creation of 3D models of artistic creation ring artistic ring using software power shape. Power shape can do the cutting operation, the establishment of the wireframe mesh, and the remodeling of the surface quickly.
2. The manufacture of master of products with rapid prototyping technology is the technology used to create the master product is a subtractive and additive prototyping prototyping. Subtractive prototyping using 4-axis cnc milling rolland modella MDX-40 to form the prototype ring while Additive prototyping using 3D printing object (Figure 2).
3. Manufacture of products of artistic creation, artistic ring ring using the method of investment casting or often called lost wax casting. The casting process is done with a pattern of planted in order to cast a mold, and then the pattern is removed by way of warming up so the obtained cavity, the casting is often also called lost wax casting. The advantage of the system is saving time and casting models that are created can be just as

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all. Despite that the process end (finishing) process of silver prints are still using hand among them, sanding, or polishing (Figure 3).

4. Analysis of the results of the artistic ring product, different technology for the manufacturing master artistic rings will produce different quality of final ring product. This paper show the analysis and the results of artistic ring product with a different method of RP. The comparison factors that used is processing time, product's quality, and cost.

Machines, Tools, and Material

CNC Router milling MDX-40

Machine roland modella MDX-40 is a "desktop milling" a subtractive implementing systems Rapid Prototyping (SRP). This machine serves as a special CNC machines are used to make prototypes of products (Figures 4 and 5).

Rotary axis unit (ZCL-40A)

Optional rotary axis unit is an extra feature that is pinned to the roland MDX-40, with the rotary movement of the direction the cutter unit can not only gain 3-axis but can be up to 4-axis. This unit allows the rotary cutter milling to move reach all surfaces of the workpiece, so it is very suitable if applied on the creation of a prototype of the product ring that has a detailed and intricate relief [5].

3D Print object 30 Pro

3D Printing or Additive Layer Manufacturing is the process of making objects in 3 dimensions or any form of digital models. How it works almost the same as laser printers with techniques to make the object of a number of layers/layer, each printed above each layer (Figures 6 and 7).

Milling cutter used

In the process of making the prototype by using the 4-Axis CNC Milling cutter preparation requires so as to cut the workpiece. The product formed is the product of small-sized ring, then the selection of the cutter becomes important to produce prototype products quality is good. The cutter being used there are 4 types of cutter i.e. end mill cutter 6 mm, end mill 3 mm, ball nose 2 mm, and ball nose 0.5 mm (Table 1).



Figure 4: CNC router milling roland modella MDX-40.

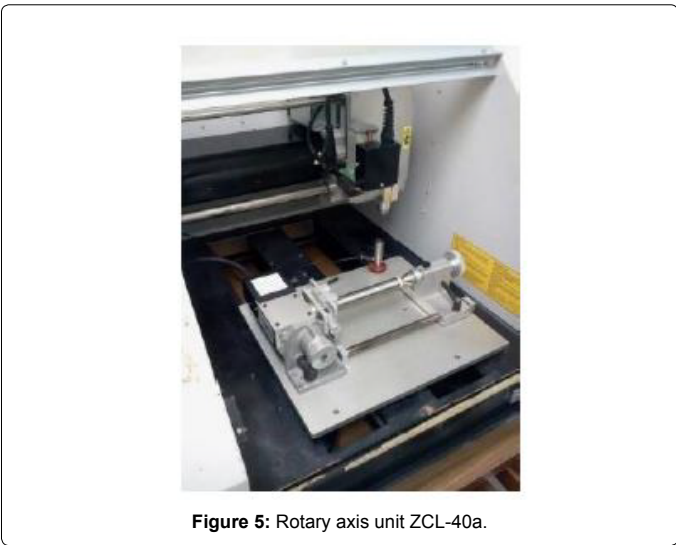


Figure 5: Rotary axis unit ZCL-40a.



Figure 6: 3D print objet 30 pro.

Roughing process using cutter End Mill 6 mm diameter and 3 mm in diameter it is the eating process early in order to be fast, eat a lot, as well as get into narrow crevices so that process more efficient. Semi-Finishing process using a 2 mm diameter Ball Nose cutter due so that the cutter can reach out to a smaller area of roughing stage and produce a more smooth surface. While the Finishing process uses a Ball Nose cutter diameter 0.5 mm due so that the resulting smoother surface, capable of reaching the entire product gaps so that the results are perfect [6].

Wax material used

The resulting prototype should be made of wax so that at this stage of the process of investment casting does not need to make a candle so

that the results of models machining directly arranged on tree candles. Material the used material wax Ferris Jewell waxed. This material is a material specific to the form of the product ring. There are 3 types of materials i.e. materials wax for weddings ring, wax for womens ring, and wax for mans ring with 15 mm diameter respectively. The determination of the material it is based on the shape of the wax ring and the required area. Products with a large volume of material will be better to use wax for mans ring (Figure 7).

This wax is ferris material also consists of a variety of types of products that are marked with a color code, such types of effect on the ability of the wax in the formed using 4-axis CNC machine Milling. The material used in this research is a good green materials for high speed machining CNC (Figure 8 and Table 2).

Master Product with Subtractive Prototyping

The establishment of subtractive product prototyping using technology 4-Axis CNC Milling toolpath strategy needs a cutter and machining parameters. Following toolpath strate-gies used with the parameters of machining. First stage is roughing process using raster toolpath strategy, second stage is semi-finishing using raster toolpath strategy, and third stage is finishing using raster toolpath strategy (Figure 9).



Figure 7: Jewell ferris material wax.

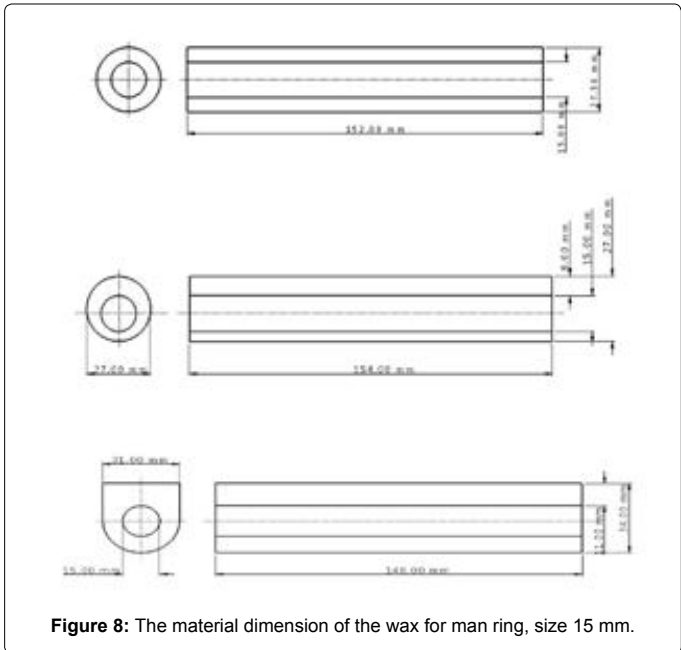


Figure 8: The material dimension of the wax for man ring, size 15 mm.

Cutter	Diameter (mm)	Flute	Character
End Mill	6	4	Roughing
End Mill	3	4	Roughing
Ball Nose	2	2	Semi Finishing
Ball Nose	0.5	2	Finishing

Table 1: Table of cutter.

	Blue	Purple	Green	Gold	Orange
Flexibility	Excellent	Good	Fair	Good	Poor
Hand Carvability	Good	Excelent	Fair	Good	Fair
Hardness (Shore D)	52 (Softes)	55	55	58	63 (Hardtes)
High-Speed CNC	Poor	Fair	Good	Excelent	Excelent
Viscosity@300F (cPs)	3850	3350	1560	2030	3550

Table 2: Jewell ferris wax type material.

The results of the master product is generated by the method of prototyping is a subtractive candle wax are formed using a CNC Milling Machine. This method of producing products also produces waste in the form of wax's chip, the chip but if collected in the back can recycle and recreated by means of heated and reprinted. The results of the master product to an artistic ring can be seen in the picture below (Figure 10).

Master Product with Additive Prototyping

The Master Product created by additive prototyping methods using 3D printing objet 30 pro technology. This technology created step by step and layer by layer. 3D printing objet 30 pro divided the material become 2 parts, there are vero white material as the main material and support material as supported the main material. vero white material is photopolymer (Rigid Opaque Materials) like plastics composite (Figure 11).

Machining Time

There are 6 design artistic rings that created, helmet trail ring, iron man ring, dart vader ring, sansekerta ring, engineer ring, and harley skull ring (Figures 12 and 13).

Machining time to created 6 model artistic rings with additive prototyping is more quick than subtractive pro totyping because with 3D printing objet 30 pro can build 6 model all at once, this is the possitive side of additive prototyping. Machining time 6 vero whites rings needs 4.82 hours. Machining time to created 6 model artistic rings with subtractive prototyping method needs 46.97 hours (Table 3).

Cost Calculation

Calculation cost of artistic ring with Wax's Master

Cost calculation for created Artistic Ring with Waxes master product:

Cost Calculation Created Master Product=Materials Cost+MachinesUsageCost

= (Quantityof MaterialxMaterialsPrice)+(Machining Timex Rent Rolland MDX - 40 Price)

= (2 × Rp150.000,-)+(46.97 × Rp20.000,-)

= Rp300.000, - + Rp939.400,-

= Rp1.239.400,-

Cost Calculation for Production Process=Silvers Material Cost+Investment Casting Cost

= (Calculation of Silvers Usage × Silvers Price)+Casting Services Price

= (150gramxRp9.000,-) + Rp150.000, -

= Rp1.350.000, - + Rp150.000, -

= Rp1.500.000, -

Total Production Cost =Master Product Cost+Production Process Cost

= Rp1.239.400, - +Rp1.500.000, -

= Rp2.739.400, -

Calculation cost of artistic ring with vero white's master

Cost calculation for created Artistic Ring with Vero Whites master product below: (USD 1=Rp 13.000,-) (Table 4).

Cost Calculation for Production Process=Master Rubbers Cost + Silvers Material Cost + Investment Casting Cost = (Quantity of product × Master Rubbers Price) + (Calculation of Silver Usage × Silvers Price) + Casting Services Price

= (6 × Rp200.000, -) + (150 gram × Rp9.000, -) + Rp150:000, -

= Rp900.000, - + Rp1.350.000, - + Rp150:000, -

= Rp2.400.400, -

Total Production Cost = Master Product Cost + Production Process Cost

= Rp660.550, - + Rp2.400.000, -

= Rp3.360.550, -

Analysis and Comparison

Two comparison factor to analysis the capability of rapid prototyping technology for created artistic rings. First factor is surface quality, second factor is machining time and third factor is cost.

Surface quality

Rings quality define in 2 aspect, first is rings size and rings surface. Master Product with subtractive prototyping (4-axis CNC Milling), the output more accurate because no different size between 3D model and prototype. Surfaces wax ring looked smooth and detail. Master product is very well created [7,8].

Master product with additive prototyping (3D Print Objet 30 Pro), the output less accurate because vero whites ring had shrinkage about 10 percent at 3D Printing Objet 30 pros process. Surfaces vero white ring looked bad and rough. The prototype had horizontals marking line, that the effect of adding layer process in 3D Printing.

Machining time

Master Product with subtractive prototyping (4-axis CNC Milling), needed long time to created waxes prototype. 46 hours 58 minutes needed to created 6 rings.

Master product with additive prototyping (3D Print Objet 30 Pro), more efficient process, because rings can created all at once. Needed 4 hours 49 minutes to created 6 prototypes ring.

Cost

Master product with subtractive prototyping (4-axis CNC

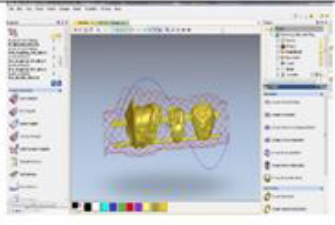

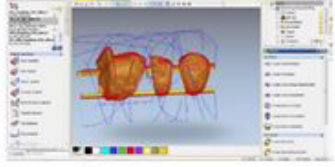

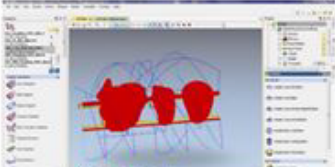

No.	Stage	Toolpath Animation in CAM Software	Cutter and Toolpath Strategy	Real Machining Condition
1.	Roughing Toolpath Strategy		<ul style="list-style-type: none"> • Cutter: Cutter End mill Ø6mm and End mill Ø3mm. • Toolpath Strategy: Raster Classic with angle 45°. • Spindle Speed: 8000 RPM • Feed Rate: 8 mm/ sec • Plunge Rate: 1 mm/ sec • Step Over: 3,6 mm and 2 mm • Step Down: 0,5 mm 	
2.	Semi-Finishing Toolpath Strategy		<ul style="list-style-type: none"> • Cutter: Cutter Ball nose Ø2mm • Toolpath Strategy: Raster Classic dengan angle 45°. • Spindle Speed: 10.000 RPM • Feed Rate: 7 mm/ sec • Plunge Rate: 0,75 mm/ sec • Step Over: 0,2 mm • Step Down: 0,2mm 	
3.	Finishing Toolpath Strategy		<ul style="list-style-type: none"> • Cutter: Cutter Ball nose Ø0,5mm • Toolpath Strategy: Raster Classic dengan angle 45°. • Spindle Speed: 10.000 RPM • Feed Rate: 6 mm/ sec • Plunge Rate: 0,35 mm/ sec • Step Over: 0,025 mm • Step Down: 0,05mm 	

Figure 9: The machining toolpath strategies.



Figure 10: Waxes master product.



Figure 11: Vero whites master product.

Milling), the cost more expensive, because need more processing time. Cost to created 6 waxes ring about Rp1.239.400,-.

Master product with additive prototyping (3D Print Objet 30 Pro), the cost more cheap because 3D Printing process is more fast. Cost to created 6 vero whites ring about Rp660.550,-.

Conclusions

Created artistic rings based CAD-CAM using investment casting for manufacturing process. Casting process is duplicating process, to created the well product needed the well master product too. To get well master product we need CAD-CAM technology, because created master product by conventional technology need more time and

Artistics Ring Product	Machining Time (hours)
Sansekertas Ring	6.43
Trail Helmets Ring	8.72
Iron Mans Ring	8.72
Harley Skulls Ring	7.7
Dart Vaders Ring	7.7
Engineers Ring	7.7
Total Machining Time	46.97

Table 3: Machining time with subtractive prototyping.

Issue	Quantity	Price	Total
Vero White	26 gr	USD525/kg	Rp 177.450,-
Support	30 gr	USD250/kg	Rp 97.500,-
Machine Usage Cost	4.82 hour	Rp 80.000/ hour	Rp 385.600,-
Total Cost			660.55

Table 4: Vero white's master product calculation cost.

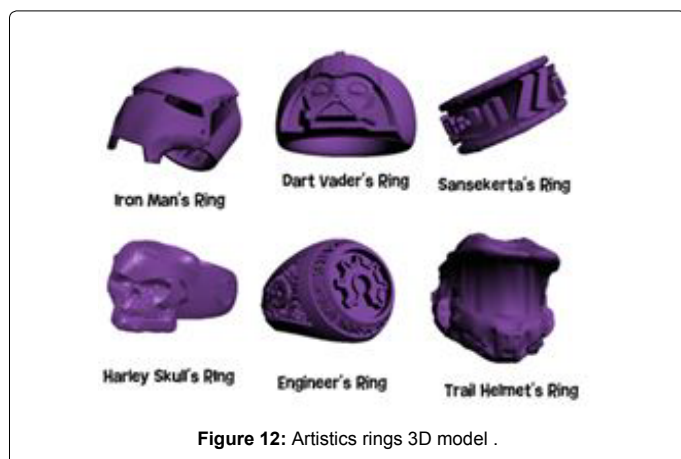


Figure 12: Artistics rings 3D model .

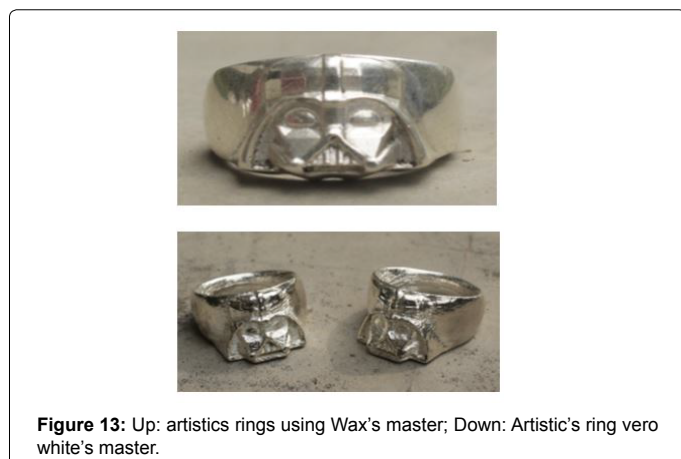


Figure 13: Up: artistics rings using Wax's master; Down: Artistic's ring vero white's master.

inconsistency. Rapid Prototyping is the answer of the problem. There are 2 kind of rapid prototyping first is subtractive prototyping and additive prototyping, subtractive prototyping using 4-Axis CNC milling with waxes materials and additive prototyping using 3D printing objet 30 pro with vero whites materials. Based on the researchs, the quality of waxes master product is more fine than vero whites master product. To created artistic ring with detail relief is recomended to using 4-Axis CNC milling although need more processing time.

References are important to the reader; therefore, each citation must be complete and correct. If at all possible, references should be commonly available publications.

References

1. CAD (2010) Technology and Training Department CAD for jewelers and silversmiths The Goldsmiths Company (Bulletin).
2. Wannarumon S (2013) Rapid Prototyping and Tooling Technology in Jewelry CAD. Computer-Aided Design and Applications 1: 569-575.
3. Wannarumon S (2011) Reviews of Computer-Aided Technologies for Jewelry Design and Casting. Department of Industrial Engineering, Naresuan University, Phitsanulok, Thailand.
4. Ghag DS, Dange JJ (2013) Adoptability of CAD/CAM for jewellery Making Industry Using Comparison Technique India.
5. Ratna Sari S (2012) Analysis of Designs Ring Variance with Art CAM Jewellsmith Technology and 3D Printing in Muntlans Jewellery Indonesia.
6. Stefani G (2013) Design Golden Ring using Investment Technology Methods for Surabayas Golden Jewellery, Indonesia.
7. Stefani Y (2014) Design of Name Cards Stand with Yogyakartas Cultural Theme (case study in Tins Art Jewellsmith), Indonesia.
8. Wannarumon S (2013) An Aesthetics Driven Approach to Jewelry Design. Computer-Aided Design and Applications 7: 489-503.