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Development of computer-aided design module for automatic gemstone setting on halo ring

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Abstract

This paper proposes computer-aided design modules for automatic setting and arranging of gemstones and diamonds on the head of a halo ring. These modules are able to automatically set the center stone, side stones, and accent stones by using a set of inputs from user. To develop the mentioned modules, the authors have studied several key parameters: sizes and cuts of center stones, side stones, and accent stones, distances between stones, sizes and shapes of prongs, including shrinkages and metal loss during production process. Those parameters were taken into account to derive their relationships in terms of mathematic models. These mathematic models were further used in the development of the computer-aided design modules based on RhinoScript Platform in the Computer-Aided Design (CAD) software named Rhinoceros. The module was developed for assisting CAD designers to automatically generate gemstone rings and to set and arrange center stone, side stones, and accent stones on parts of the rings. It was developed using data and information about jewelry ring design from jewelry designers and a manufacturer, as well as, collaborating with the manufacturer for testing the developed module. The proposed module can help CAD designer to reduce gem setting and arrangement time by about 67-70% in comparison to the manual method. The results and details of the development of the module and the development of the proposed generative design system were included in this paper.

Keywords: Geometry tolerance, Jewelry design, Automatic design, Computer-aided design, Volumetric shrinkage

1. Introduction

At present, gems and jewelry industry has to deal with high competition in the world market. It needs quick response to customer requirements with high flexibility in product design and price estimation before going to the production stage. Therefore, it is very important to develop computer-aided design (CAD) systems to assist in the jewelry design process. We found that bottleneck exists in placing, arranging, and setting gemstones and diamonds on the body of jewelry rings such as head, shoulder, and shank of the rings. Changing of the gemstone size and/or the ring size requires rearrangement of gemstones on the body of the ring, which is time-consuming. This commercial age is based on customized design. As a result of this work, we can provide various combinations of gemstone sizes and setting types to customers, based on just one original ring design.

This paper therefore proposes the development of a computer module, working on CAD system, in which changing the size of the center stone prompts the module to calculate the number of the surrounding stones, the distance between the stones, and position of the stones. It will also automatically arrange the stones based on the input data. Furthermore, the geometry tolerance is studied and incorporated into the mathematical model.

2. Materials and methods

2.1 Halo ring

Halo ring is a ring setting where a center gemstone is surrounded with a collection of round pave diamonds, micro pave diamonds, or faceted color gemstones. These pave stones glitter with light and bring attention to the center stone to create interest. The term "halo" is used because the center stone looks like it has a halo. The halo ring setting can be set with all sorts of gems such as diamonds, sapphire, ruby, etc. The parts of halo ring are illustrated in Figure 1.

2.2 Volumetric shrinkage tolerance in jewelry casting process

A mass of molten metal shrinks as its temperature decreases. When the mass solidifies, there is a sudden reduction in the volume which can be very significant in some metals. And even after a metal has solidified a certain

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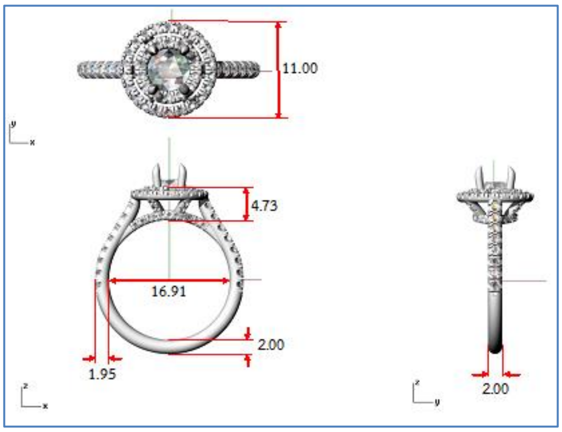
Figure 1 Anatomy of the halo ring

amount of shrinkage in volume can still take place [1-2]. Volumetric shrinkage in pure metals upon freezing is typically 5.03 % for gold, 5.00 for silver and 4.25 % for copper [1]. It is unpleasant for the casting to end up with smaller than the expected size. Therefore, preparing a wax model of a jewelry object needs to take into account the amount of volumetric shrinkage, which can be vary for different materials.

2.3 Methodology

The methodology used in this research is as follows.

1. Collecting gem's cuts and gem's sizes [3-4].
2. Studying and designing halo rings, as well as, analyzing the factors taken into consideration in designing halo rings.
3. Studying how to model halo rings using computer-aided-design (CAD) package such as Rhinoceros 5.0.
4. Studying how jewelry CAD package can automatically arrange gems on halo rings, as well as studying the conditions of the arrangement.
5. Studying jewelry casting process and analyzing the factors that affect shrinkage in volume.
6. Studying how to set geometric tolerance for volumetric shrinkage during casting process and for metal loss in polishing and finishing process.
   From the case study of jewelry production process we found that, for industrial work, the workers attempt to set the allowance of the 3-axes in millimeters rather than using percentage, because of ease of communication during production process. The silver casting is our case study. Therefore in wax modeling and casting, volumetric shrinkage of casts along the X-, Y-, and Z-Axes is about 0.10 mm, while in finishing and polishing, the toal metal loss is approximately 0.10 mm in all axes. The setting allowance of the 3-axes in millimeters on a ring model is shown in Figure 2.
   As a result, we should set the geometric tolerance in X-, Y-, and Z-Axes at 0.20 mm for volumetric shrinkage and metal loss. For the ring size, we should use the size, which is one step larger than the order size for Japan ring's size standard and half size a size larger for US standard. US ring sizes are determined by a numerical scale, with quarter and half sizes, which increases a full size by 0.032 inch or 0.8128 mm in diameter. Japan ring sizes are also determined by a numerical scale, but only has whole sizes, as well as does not have linear correlation with diameter [5].
   From the study of the approach and conditions for gem arrangement on the halo ring, we found the following details:
   - The center stone cuts in this study are round cut and cushion cut. The type of center stone cut dominates the pattern of halo gems and the calculations of number of halo gems and gap between the gems.
   - The acceptable patterns of gem arrangement are in the positions shown in Figure 3 and Figure 4. The concept of arrangement of gems on the head of halo ring is based on trying to fit the gems on the positions at quarters and angles as illustrated in Figure 3. This arrangement will result in the halo appearing to look round. Figure 4 compares an example of acceptable and unacceptable arrangement.
     The popular sizes of the center gemstones range from 0.15 carat to 4.0 carat, while the popular sizes of the halo gems range from 0.002 carat to 0.035 carat. The gap between halo gems is between 0.20-0.35 mm. Figure 5 illustrates the gap between halo gems.
7. Deriving mathematic model of relationships between the factors to calculate number of halo gems and gap between the gems. The results in the previous steps formed a basis for deriving the mathematic model. For halo gem arrangement for round cut center stone, illustrated in Figure 6, the relationship between parameters in one layer is as follows:



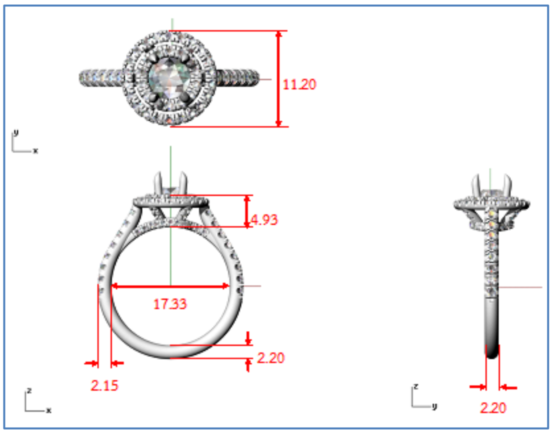


Figure 2 The target model is on the left and the compensate model is on the right

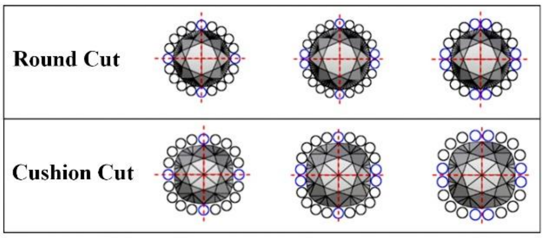


Figure 3 Acceptable patterns of halo gems setting

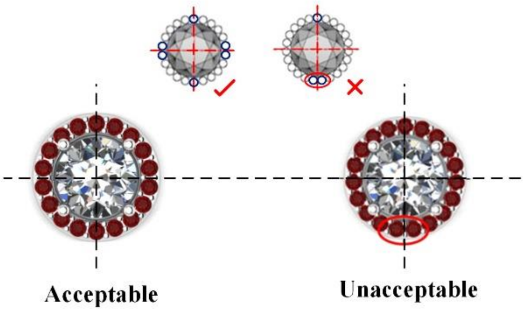


Figure 4 Example of acceptable (left) and unacceptable (right) arrangement

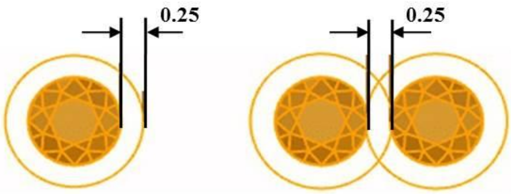


Figure 5 Gap between halo gems

$$N = C / (d + g) \quad (1)$$

$$C = 2\pi R_c \quad (2)$$

$$R_c = R_D + R_1 + R_2 + R_d \quad (3)$$

For two-layer halo arrangement, Eq.3 is transformed into Eq.4.

$$R_c = R_D + 2R_1 + 3R_2 + 3R_d \quad (4)$$

For halo gem arrangement for cushion cut center stone, illustrated in Figure 7, the relationship between parameters in one layer is as follows:

$$N = C_{(new)} / (d + g) \quad (5)$$

$$C_{(new)} = C_{(old)} a \quad (6)$$

$$a = \frac{D_{(new)}}{D_{(old)}} \quad (7)$$

$$D_{(new)} = R + R_1 + R_2 + R_d \quad (8)$$

For two-layer halo arrangement of cushion cut, Eq.8 is transformed into Eq.9.

$$D_{(new)} = R + 2R_1 + 3R_2 + 3R_d \quad (9)$$

Where N is the number of halo gems, g is gap between the halo gems, D is diameter or width of center stone, d is diameter or width of halo gems, C is the length of the curve for arranging halo gems, RD is radius of center stone, RC is radius of C, Rd is radius of halo gem, R1 is gap between the center stone and metal part, R2 is gap between metal part and halo gem, R is half-width of cushion shape, C(new) is the length of the curve for arranging halo gems surrounding cushion center stone, C(old) is the length of the curve of cushion center stone, a is ratio of width of cushion stone, D(new) is distance between center of cushion center stone to center of halo gem, and D(old) is half of width of cushion center stone.

8. Developing the computer module which can automatically arrange main gem, halo gems, and accent gems by considering the proper gaps between them. The flowchart of the proposed CAD module is shown in Figure 8.
9. Cooperating with jewelry manufacturer for testing the proposed module.

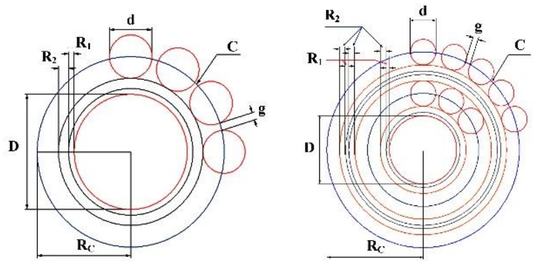


Figure 6 Relationship between parameters in halo gem arrangement for round cut center stone: one layer (left) and two layers (right)

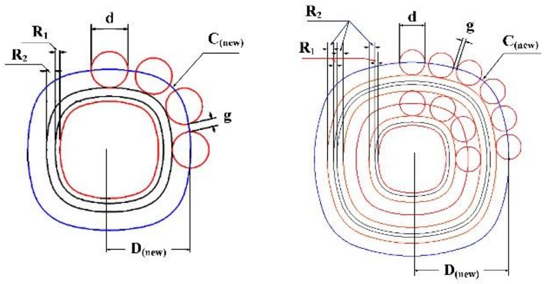


Figure 7 Relationship between parameters in halo gem arrangement for cushion cut center stone: one layer (left) and two layers (right)

3. Results

The proposed computer module was developed using Rhinoscript in Rhinoceros 5.0 platform on a computer workstation with Intel Xeon dual CPU Processor operating at 1.8GHz and 4.0 GB of RAM, working on a 64 bit system.

The mathematic models explained in the previous section are used in the development of computer-aided design module for automatic gemstone setting on the head of the halo ring; some of the results are explained below.

The first example: designing a halo ring with the following details:

- Ring's size: US standard size 6 (diameter 16.51 mm.),

- A center stone with its size 1.039 carat (6.60 mm) with round cut,
- Halo gems: size 0.008 carat (1.3 mm), number of gems is even with the gap between them in the range from 0.20 mm. to 0.35 mm.
- Arranging the halo gems in one layer around the center stone.

In this example, number of halo gems is unknown, but it is requested to be even.

The requirements mentioned above are input into the module via the user interface shown in Figure 9.

Then the module calculates the number of halo gems required for this arrangement according to the conditions and then automatically sets and arranges the center stone and 18 halo gems with the gap 0.23 mm. as shown in Figure 10.

The second example: designing a halo ring with the following details:

- Ring's size: US standard size 14 (diameter 17.34 mm.),
- A center stone with a size of 0.330 carat (4.40 mm) with cushion cut,
- Halo gems: size 0.004 carat (1.0 mm), number of gems is even with the gap between them in the range from 0.20 mm. to 0.35 mm.
- Arranging the halo gems in two layers around the center stone.

Number of halo gems is unknown, but it is requested to be even.

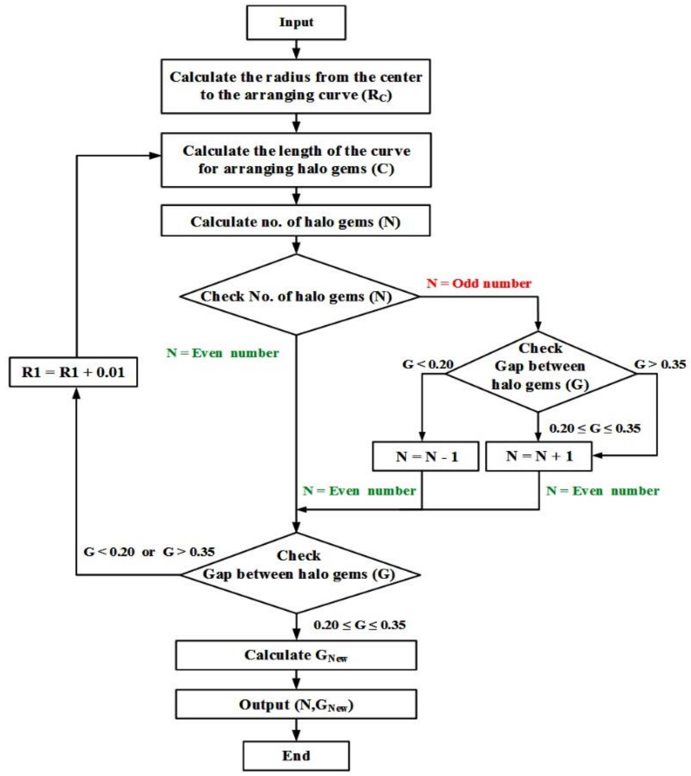


Figure 8 Flowchart of the proposed CAD module

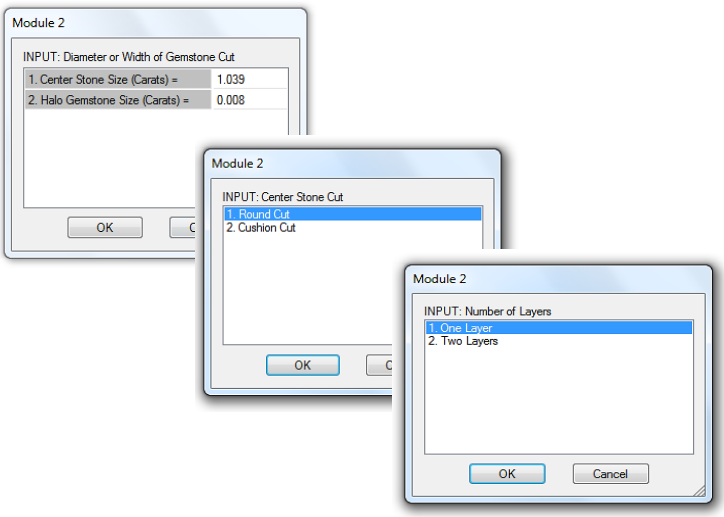


Figure 9 Input parameters of the first example

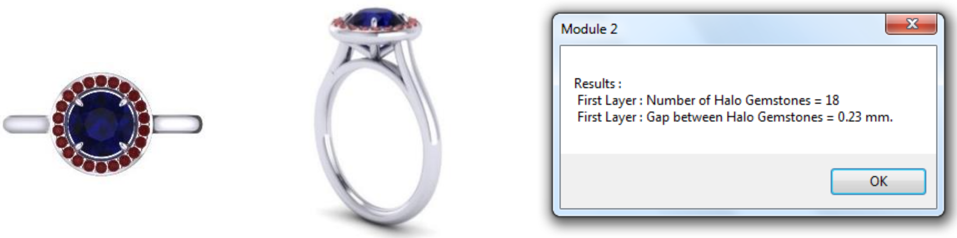


Figure 10 The resulting halo gems of the first example generated using the proposed module

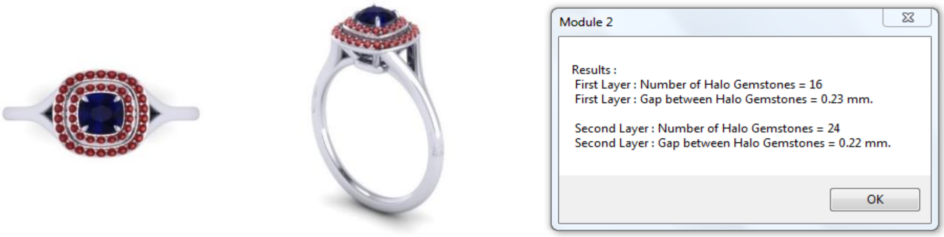


Figure 11 The resulting halo gems of the second example generated using the proposed module

The mentioned requirements above are input to the module via the user interface in the same way shown in the first example. Then the module performs the calculation of the number of halo gems required for this arrangement and then automatically sets and arranges the center stone, 16 halo gems with the gap size 0.23 mm in the first layer and 24 halo gems with the gap size 0.22 mm. in the second layer. The resulting halo gem is shown in Figure 11.

4. Discussion

The comparison of the proposed CAD module used for designing the halo ring examples and automatically setting gemstones on the halo ring and the manual approach with CAD was assessed by assigning the design of the two halo rings as explained in the previous section. The process starts from the participants (CAD designers) drawing the ring models, and then arranging the center stone and the halo gems onto the models. They typically arrange the halo gems by trying (trial-and-error) with different number of halo gems until obtaining the gap size between the halo gems within the requested range of 0.20 and 0.35 mm. They follow this with the preparation of the cutters to cut the channels for the settings. These tasks are quite time consuming. For the first example, the setting of the round cut center stone with halo gems in one layer, the designers spent on average 55 minutes to complete the task. In comparison the proposed CAD module it spent only about 18 minutes on the task, which is reduced production time by about 67.3%. For the second example, the setting of the cushion cut center stone with halo gems in two layers, the designers spent on average 87 minutes to complete the task. In comparison the proposed CAD module it spent only about 27 minutes to complete the task, which reduces production time by about 70%.

5. Conclusions

A computer-aided design module for automatic setting and arranging gemstones and diamonds on the head of halo ring is proposed and prepared. It is able to automatically set the center stone, side stones, and accent stones by using a set of inputs from user. We have studied the roles of sizes and cuts of center stones, side stones, and accent stones, distances between stones, sizes and shapes of prongs, as well as shrinkages and metal loss during production process. Those parameters were taken into account to derive their relationships in terms of mathematical models. These mathematical models were further used in the development of the computer-aided design modules. The module was developed for assisting CAD designers to automatically generate halo gemstone rings and to set and arrange center stone, side stones, and accent stones on parts of the rings. It was developed using data and information about jewelry ring design from jewelry designers and manufacturers. A collaboration with the manufacturer was used for testing the developed module. The proposed module can help CAD designers to reduce gem setting and arrangement time by about 67-70% in comparison with the manual method.

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