International Journal of Computer Applications (0975 – 8887)
Volume 17– No.7, March 2011

Rapid Tooling for Producing Stretch-formed Jewelry

Vishal Gulati
GJ-University of Science and
Technology, Hisar, India

ABSTRACT
In this paper, Computer Aided Designing (CAD) in conjunction with Rapid Tooling is applied to design and produce forming tools (punch and die) for stretch-formed jewelry (generated on thin sheet metal on top of which jewelry patterns are raised with forming tools by stretching the sheet metal beyond its elastic limit. The work presents a parametric voxel based CAD paradigm for modeling of such forming tools which contains English alphabets as jewelry patterns.

Keywords
Jewelry, CAD, Rapid Tooling

1. INTRODUCTION
Jewelry is an area where automation has been included through CAD and RP technologies. These technologies are being applied for designing and building jewelry prototypes [12-14]. In this paper, CAD in conjunction with Rapid Tooling (a much-anticipated application of RP that adopts RP techniques and applies them to tool making) is applied to design and produce forming tools (punch and die) for stretch-formed jewelry. The work presents a CAD paradigm for modeling of such forming tools which contains complex geometry of jewelry patterns. In order to produce accurate tooling, it has been created by using RP techniques that quickly translates the 3-D CAD models into tangible products.

Many commercial parametric feature based [1-4] CAD systems have been developed for the purpose of designing jewelry, which are very efficient and useful in designing different kinds of jewelry. All of these systems have the capability of exporting models to RP machines. But in majority of these systems, designing is performed manually using various tools and usually the design steps cannot be programmed to be executed automatically. This means that each different piece of jewelry would have to be created basically from the beginning. Some parametric systems [5-11] have also been developed where the jewelry design is expressed by a set of parameters and constraints and the user's participation in the design process is through the dentition of the parameter values. ByzantineCAD has been developed for the designing of pierced medieval Byzantine jewelry [5-6]. A unified jewelry modeler has been created for designing and creating carved jewelry [7].

2. STRETCH-FORMED JEWELRY
Stretch-formed jewelry is generated on thin sheet metal (gold or silver) on top of which jewelry patterns are raised with tooling (punch and die) by stretching the sheet metal. The raised surface is reflected by light imposed on it and helps in visualization of the jewelry pattern. The jewelry making process puts sheet metal under combined bending and tension by clamping around at edges and stretching over a die. The process strains the sheet metal beyond the elastic limit to set it permanently between tooling (shown in Figure 1).

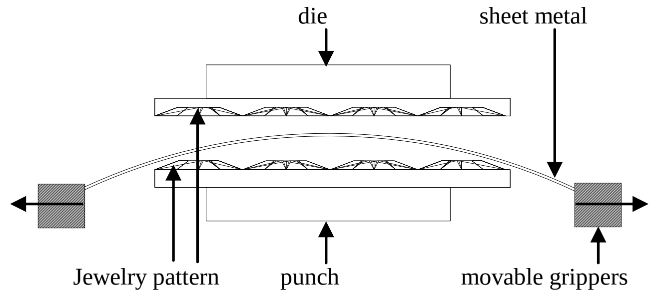


Figure 1: Stretch forming process

3. MODELING OF JEWELRY PATTERNS
The forming tools for producing stretch-formed jewelry contain jewelry patterns which are to be embossed on top of the sheet metal. This work is towards the modeling of such forming tools which have English alphabets as jewelry patterns. The reason for this preference is that the representation of initials or names on rings, pendants, bracelets, earrings, etc. gives a personnel touch to the jewelry.

3.1 Structural Element for Jewelry Pattern

Jewelry patterns are created by using very small structural elements said voxels. Voxel is small structural element that is used as building block in a pattern. It is generated by using the sketching approach which uses 2-D entities (line, arc etc.) to sketch a closed profile followed by extrusion perpendicular to the sketching plane of the profile (Figure 2). These voxels are placed side by side, either at top, bottom, right or left of each other, and joined into an alphabet as shown in Figure 3.

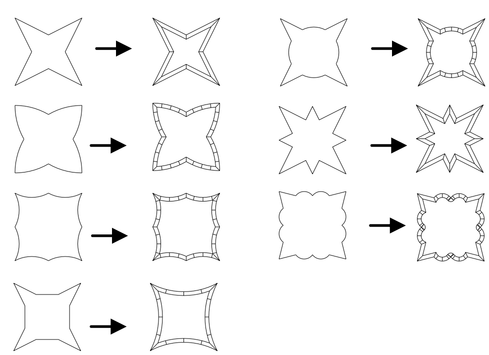


Figure 2: Sketching approach to create voxels

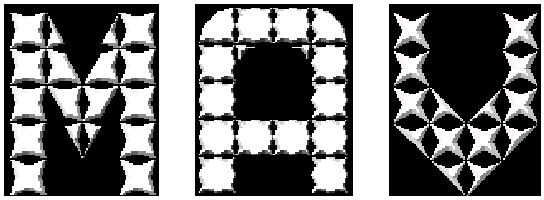


Figure 3: Alphabet jewelry patterns

3.2 Modeling Parameters

The geometry of voxels is parameterized with parameters. With the appropriate definitions of these parameters, a variety of alphabet jewelry patterns can be generated. A voxel is represented with following modeling parameters (Figure 4).

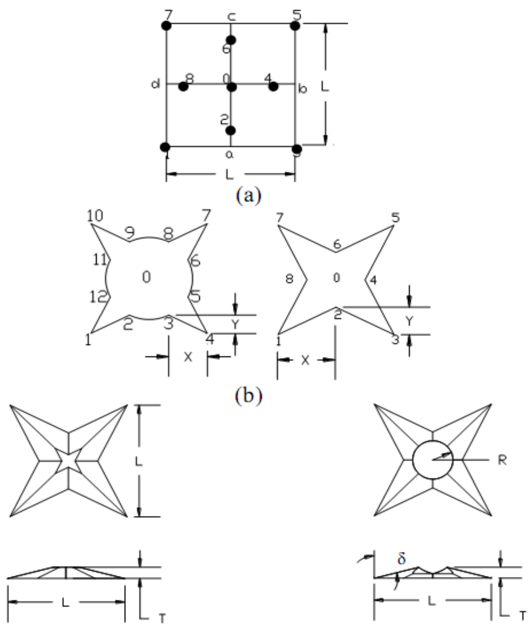


Figure 4: Modeling parameters (a) Valid points (b) Variants (d) Dimensions of voxel and inclination angle of side surface

1. **Valid points (P):** It represents maximum number of valid points from which a voxel is created. It may be nine, thirteen, or seventeen. The profile of voxel element is assumed to be inscribed in a square. The center and four corner valid points of the square are fixed. The rest of valid points are variable. Figure 5 shows a voxel with nine valid points i.e. from 0 to 8. Points 2, 4, 6, 8 are variable points and points 0, 1, 3, 5, 7 are fixed. Variable points 2, 4, 6, 8 can vary between points 0 to a, 0to b, 0 to c, and 0 to d respectively.

2. **Size of voxel (L):** It is equal to the size of square in which voxel profile is created.

3. **Thickness of voxel (T):** It is the height of extruded voxel. This parameter should be such that when metal sheet is stretched with forming tools; it would not be sheared off. The value of voxel height depends upon the percentage elongation of sheet metal.

4. **Inclination of side surface (δ)**: It represents the taper angle of extruded voxel. Voxel sides are tapered to make its side surfaces reflective. Reflective surface send back light giving optical effects. The value of δ needs to be carefully worked out. If the taper angle is too large, the profile terminates to a point before it reaches the specified depth. Practically, in stretch forming process with die and punch, larger taper angle of voxel element will shear off the sheet metal. If the taper angle is too small, side surface of voxel will be not reflective.

5. **Variant (X & Y):** These are defined as distances between fixed point and next/previous variable point in horizontal and vertical direction. Variants are used to get different profiles of a voxel class and hence variation in jewelry patterns. The relations $L/8 \leq X, Y \leq 3L/8$ and $R < L/2 - Y$ are used as constraints for the class of voxels having nine valid points.

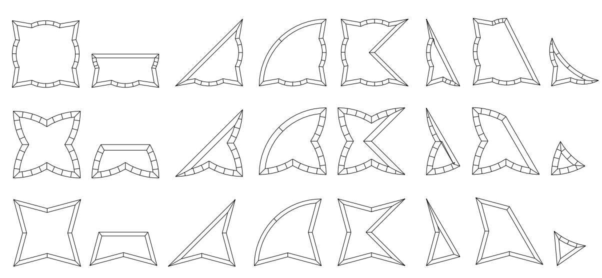
6. **Radius of center hole (R):** Voxel elements may be classified as with or without hole at the center with radius R.

3.3 Voxel Sets

In order to create any alphabet pattern, eight different shaped voxels (labled as V_1, V_2, V_3 .....V_8) have been created by using eight closed profiles described in Table 1, Seven voxels i.e. from V_2 to V_8 are derived from V_1, so therefore V_1 is said main voxel and V_2 to V_8 are said derivative voxels. The voxels with same geometrical and dimensional constraints are grouped in a voxel set. Such a type of voxel sets is shown in Figure 5. In an alphabet jewelry pattern, voxels that are to be joined in a pattern must be from the same set.

Table 1: Description of eight closed profiles for creating a voxel set

Voxel elements	Valid points used for creating closed profile
V_1	1-2-3-4-5-6-7-8-1
V_2	1-2-3-4-0-8-1
V_3	1-2-3-4-5-0-1
V_4	1-2-3-4-5-1
V_5	1-2-3-0-5-6-7-8-1
V_6	1-2-7-8-1
V_7	1-2-3-6-7-8-1
V_8	1-2-8-1



V_1 V_2 V_3 V_4 V_5 V_6 V_7 V_8

Figure 5: Voxel sets

3.4 Voxel Based Alphabet Patterns

Any alphabet pattern can be seen as combination of voxels placed in a 2-D matrix of size 5x4 (Figure 6). The size of pattern is 5L x 4L (where L is size of voxel). For example, modeling of an alphabet pattern 'V' is illustrated. It requires only two types of voxels (V_1 and V_3) from a voxel set as shown in Figure 7. These voxels are rotated in required orientation and then translated to the proper location in the matrix. Each time a voxel element is placed, it is concatenated with the previous ones. For alphabet 'V', positions of different voxels in 2-D matrix are shown in Table 2.

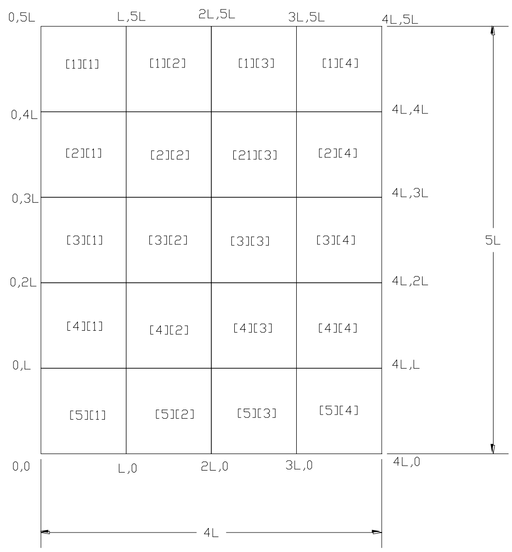


Figure 6: 2-D matrix for voxel placement

Figure 7: Alphabet pattern 'V'

4. MODELING OF FORMING TOOLS

Jewelry patterns are combined with a constructive solid (rectangular prism) using Boolean operations (Union and Subtraction) into forming tools (Figure 8). Die is created by subtracting the pattern from constructive solid and punch is created by attaching the pattern with constructive solid. These 3-D die and punch models are converted to STL format and transferred to RP machine that quickly translates the CAD models into tooling. Further, tooling is used to emboss patterns on thin sheet metal (gold or silver) by stretching the sheet metal (Figure 9).

Table 2: Position of different voxels in the matrix for Alphabet pattern 'V'

Operation Number	Voxel	Position
1	V_1	[1][1]
2	V_1	[2][1]
3	V_1	[3][1]
4	V_3	[4][1]
5	V_3	[3][2]
6	V_1	[4][2]
7	V_3	[5][2]
8	V_3	[3][3]
9	V_1	[4][3]
10	V_3	[5][3]
11	V_1	[1][4]
12	V_1	[2][4]
13	V_1	[3][4]
14	V_4	[4][4]

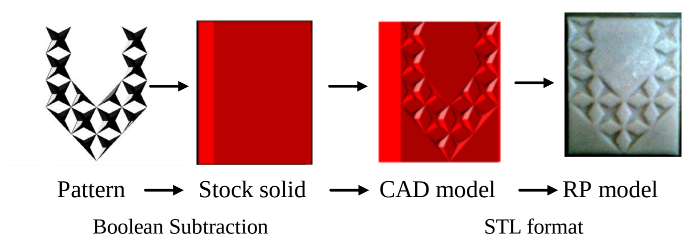


Figure 8: CAD and RP models of forming tool (die)

Figure 9: Embossed pattern on sheet metal

5. CONCLUDING REMARKS

This work proposed a parametric voxel based CAD paradigm to produce forming components (die and punch) for a class of medieval jewelry. The proposed paradigm unfolded good results for simple as well as moderately complex forms of jewelry patterns. The presented paradigm can provide the capability of designing custom-engineered jewelry items in an easy and efficient manner using parametric design concept. The paradigm has also been tested by creating STL models and sending them to RP machine for Rapid Tooling.

6. REFERENCES

[1] JewelCAD, http://www.jcadcam.com, Jewelry CAD/CAM Ltd.

[2] ArtCAM Jewel Smith, http://www.artcamjewelsmith.com, Delcam plc.

[3] TechGems 3.0, http://www.techjewel.com, TechJewel.

[4] JewelSpace, http://www.jewelspace.net, Caligory Software.

[5] Stamati V. and Fudas, I., 2005, A Parametric Feature Based CAD System for Reproducing Traditional Pierced Jewelry, Computer Aided Design, Vol. 4, No. 37, pp. 431-449.

[6] Stamati V., Fudas I., Theodoridou, S., Edipidi C. and Avramidis D., 2004, Using Poxels for Reproducing Traditional Byzantine Jewelry, Computer Graphics International 2004, Crete, Greece, June 16-19.

[7] Gulati V., Singh H. and Tandon P., 2008, A Parametric Voxel Based Unified Modeler for Creating Carved Jewelry, Computer Aided Design & Applications, Vol. 5, No. 6, pp. 811-821.

[8] Gulati Vishal, Singh Hari & Tandon Puneet, 2009, "Integrative Modeling to Produce Ornamental Products", Computer Aided Design & Applications, Vol. 6, pp. 27-42.

[9] Gulati V., Tandon P and Singh H., 2010, A Jewelry Modeler for the Fret-worked Bangles, International Journal of Computer Applications, Vol. 2, No. 2, pp. 76-80.

[10] Stamati V. and Fudas, I., 2005, A Feature-Based CAD Approach to Jewelry Re-Engineering, Computer-Aided Design & Applications, Vol. 2, Nos. 1-6, pp. 1-9.

[11] Wannarumon S., 2010, An Aesthetic Driven approach to Jewelry Design, Computer-Aided Design & Applications, Vol. 7, No. 4, pp. 489-503.

[12] Molinari L. C. and Megazanni M. C., 1998, The Role of CAD/CAM in the Modern Jewelry Business, Gold Technology, Vol. 23, pp. 3-7.

[13] Molinari L. C. and Megazanni M. C., 1996, Rapid Prototyping: Application to Gold Jewelry production, Gold Technology, Vol. 20, pp.10-17.

[14] Wannarumon S. and Bohez E. L. J., 2004, Rapid Prototyping and Tooling Technology in Jewelry CAD, Computer-Aided Design & Applications, Vol. 1, No. 1-4, pp. 569-575.