Design opportunities through production technology

PROF. DR. W. BÖHM
Schmucktechnologisches Institut, Pforzheim, Germany

Introduction

Ever since it began, the design of jewellery has been a synthesis of artistic creativity and production technology. Over the ages, artisans, with their overwhelming imagination and creativity, have been looking for new materials and techniques and have been supported in their work by new materials and technologies. The need for improved weapons is said to have driven production technology, but the decoration of arms followed on immediately. These newly learned and adopted techniques then influenced the work of the designers in all other decorative areas and created fashions. The combination of precious materials, innovative production technology and excellent handicraft led to jewellery which is so specific for a particular period of time that the date of origin of relics can be determined.

This early beginning demonstrates that pleasing jewellery is not bound to archaic production technologies because it never has been. Today, the variety of available technologies is much broader and the speed of development is much faster and even accelerating. Also, fashions change faster and faster. The time frame to renew a jewellery collection gets shorter and severe competition forces manufacturers to present updated jewellery items, for example, two times a year. Also, the number of producers and the design competition in a global market continues to increase. Short innovation and production times become a leading edge in competitiveness. So innovative production technologies are both an opportunity and a necessity.

Lasers

An example of a successful technology, introduced during the last few years, is the application of lasers in jewellery production. Modern Nd:YAG lasers, with a wavelength which is suited for precious metals, apply heat to the workpiece with a high energy density. No other energy source except an electron beam, which is not applicable for cost reasons, can be focused to such small areas. Heating by gas or micro plasma burners are not as efficient as a laser spot. Because of the high heat conductivity and the high reflectivity of precious metals, this is important for the welding of small parts or hollow ware. Accurate positioning of the parts in order to bring the gap to almost zero is a strict requirement. Otherwise, heat cannot be introduced into the material and the laser beam passes without energy absorption through the gap. In order to fulfil these requirements and to improve economy, automated handling and positioning systems for laser welding of hollow ware have been developed. For this group of products, this welding process has substituted brazing (soldering) procedures to a large extent and lowered costs significantly. This has opened, for given designs, new price and market segments and contributed to the success of such designs. In addition, lasers are commonly used to repair casting pores and wear defects.

Laser sources are available in a wide power range and can be used for welding, cutting and engraving. Laser spots with a focussed diameter of below 0.5mm allow the cutting and engraving of fine structures. Continuous wave lasers produce smooth edges and perfect engravings. The grooves produced by a focused laser are finer in width compared to turning, so decorations and images show a superior resolution. Since laser beams can scan a surface by computer control, complex patterns, images and characters can be achieved. This can be either a digitalized picture or a 2 dimensional CAD sketch with, for example, modern geometrical design with symmetric, straight and rectangular lines. The possibilities are only limited by the imagination of the designer. With the spread of lasers in the jewellery industry, more of these typical designs appear on the market.

However, 3-dimensional geometries are complex to work with. The laser has to be focussed on the surface within a limited range. This increases the requirements for programming and handling and, therefore, is only used for simple geometries like, for example, rings or tubes.

Due to the highly intense laser beam, heat dissipation is small and, therefore, welding procedures can be performed very close to gemstones. The design of such combinations, especially of larger gems and precious metals, can look lighter and more pleasant and have the gratifying effect of minimizing the risk of damaging the stone. Several companies have developed designs which could not be produced with standard brazing (soldering) techniques but only with laser welding.

The joining of different colours and materials is also an option of laser welding. As far as different absorption properties of the materials can be balanced, interesting combinations for new designs are possible. Also, ornaments and surface decoration effects with different materials can be achieved. With a laser it was possible to melt platinum into the surface of a gold substrate. The cross section, Figure 1, shows how the platinum penetrates the substrate. After grinding and polishing or sandblasting the surface, the ornaments appear with sharp contours. Platinum powder was placed on top of the surface of the substrate. Powder density and laser beam intensity had a major influence on the performance of the process.

If the parameters of the process are not properly adjusted, grooves are produced with a thin layer of Platinum in them, as shown in Figure 2. Many other materials can be combined in order to create colourful jewellery. Since the motion of a laser beam can be easily changed to any direction, complex ornaments can be achieved. New laser process technologies for optimized gold jewellery manufacture, including an innovative approach to granulation by laser technique, were presented at last year's Vicenza Symposium and published in reference (1).

Computer-aided Design

Another new and fast developing technology that boosts design opportunities is the tool of 3D-CAD in combination with Rapid Prototyping. Until today, designs have been limited by the structures and details that can be drawn by pencil and colour. Also, the 3-dimensionality of a design was restricted by the limitations of 2-dimensional graphics and the imaginative faculty of the human mind. 3-dimensional computer aided design produces objects in virtual reality which can be contemplated and modified in all 3 axes of space. Support structures on the inner side of a workpiece can be applied to strengthen a lightweight jewellery piece by the known methods of mechanical engineering. A CAD-workshop at the Fachhochschule, Pforzheim, has proven the enrichment of design opportunities afforded to design students. Complex objects with either organic or geometric structures can be created with reasonable efforts. The surfaces of a jewellery item can be affected easily in so many variations that this is similar to adding a new dimension to jewellery design. Figures 3 and 4 shows such an example for complex surface structures that can be created and varied easily with the help of a computer and an appropriate software. Also, the decoration of the inner side of a ring pattern or an increase in the strength or stiffness of an object can be performed. These examples have been designed by Jürgen Marquardt (3). One of the outstanding advantages of CAD is the ability of a computer to multiply objects easily and to combine them into a larger object in a wide variety of possibilities. Examples of such design work are given in Figure 5 (a-d). Designing such bracelets or rings in the traditional way would be very ineffective. Also, the production of these wax models manually is very time-consuming and, in some cases, impossible. Rapid Prototyping of models is not limited by the skills and cost of an artisan and enables the production of such jewellery in an economic way. These complicated models can be produced economically. A high resolution prototyping device can build a model with all the tiny details and complex spatial structures a designer developed

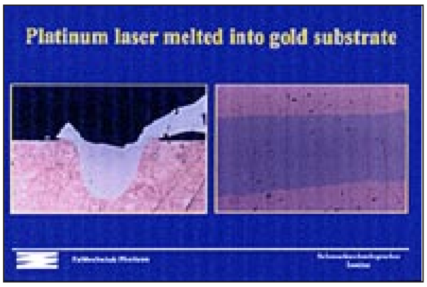

Figure 1 - Platinum powder melted into a gold substrate by a Nd:YAG-laser

Figure 2 - Platinum powder melted into a gold substrate with too high a laser intensity

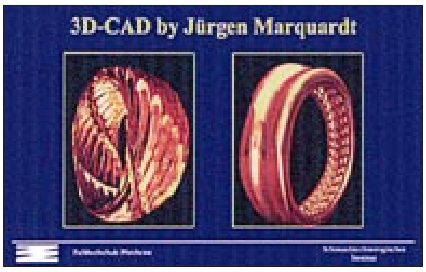

Figure 3 - 3D-CAD in photo realistic print-out, designed by J. Marquardt

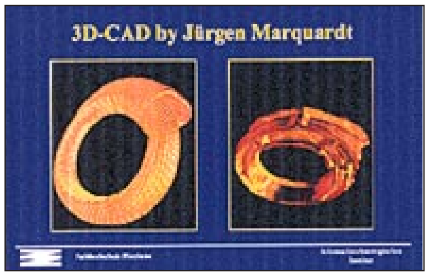

Figure 4 - 3D-CAD in photo realistic print-out with geometric and organic surface structures. Design by J. Marquardt

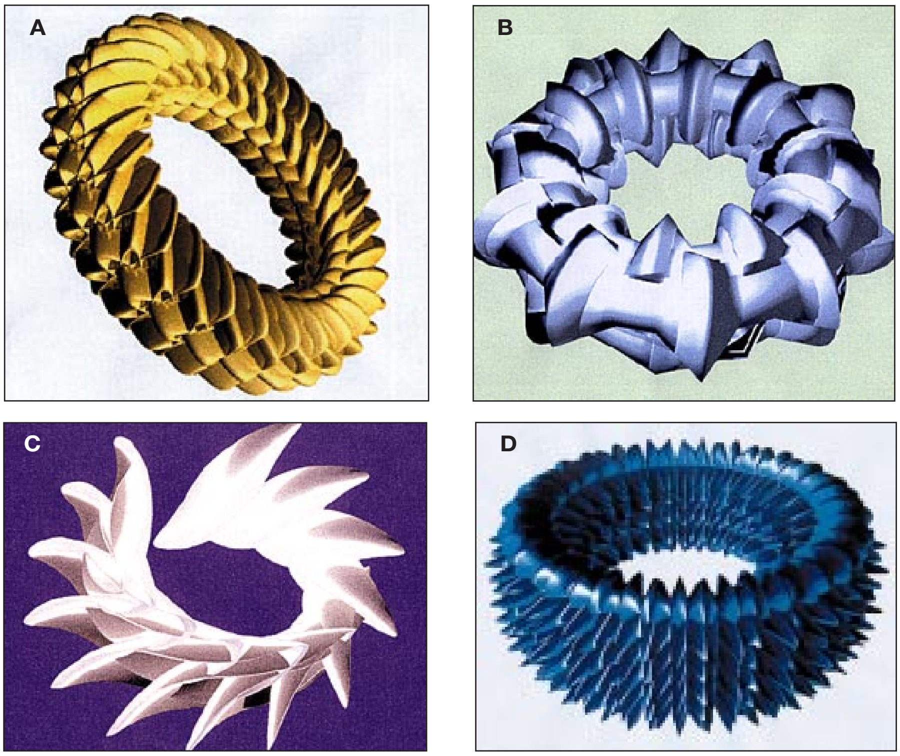

Figure 5 (a-d) - 3D-CAD of jewellery with a high degree of structural repetition. Designs by S. Nikulski, C. Gehring, T.Werner and B. Trebe (8).

with the aid of a computer and corresponding software.

The filigree and the spatiality with difficult undercuts of a model no longer ends at the limits of the skills and costs of an artisan. Investment casting is capable of reproducing all details of a wax model.

Rapid prototyping methods are developing fast and research work is done with probably a dozen different approaches. An introductory survey is presented in reference (2). The principle always is to slice a computerized model and to build it up slice by slice in wax, plastic material or metal. The contour of each slice varies according to the master model. In practical use for jewellery applications are automated wax modelers by multi-jet technology and stereolithography. The advantage of the automated wax modeling is the minimum slice thickness of 0.02 mm which produces a very smooth surface. Unavoidable steps can be flattened manually, as necessary. The wax is suitable for direct investment casting. Stereolithography, with its 0.3 mm slices and resulting steps, is commonly used for prototypes in mechanical engineering. The accuracy of the laser sintering processes is limited by the plastic or metallic powder which is sintered by a laser with minimum 0.5 mm focus-diameter. Nevertheless the results of such rapid prototyping are impressive. Figure 6 shows a model which was produced by laser sintering. The surface is still rough but in some cases satisfactory. The holes show over the bent surface a regular and reproducible structure. Figure 7 shows a test model built in wax by a 3D-modelling system. This example was produced with a medium resolution and demonstrates the accuracy of edges and contours and the surface structure. Metallic models have to be infiltrated by a low melting point metal after laser sintering. This process seems to be more relevant for rapid tooling which also can be of benefit for the production of stamped jewellery parts.

Electroforming

Another production technology that makes new and typical designs available to consumers is electroforming (4-6). By electroplating gold and carat gold alloys onto the surface of a shaped mandrel or mould which is removed afterwards, lightweight and round-shaped jewellery with great volume can be produced. Investment casting would not be able to deliver the desired low wall thickness and stamping could not process that volume and produce such detail as, for example, grooves. Designers have grasped the opportunities afforded by this technology and formed a specific class of hollow products. In the beginning, cost savings have been the driving force for this technology these are no longer to the fore. Companies, who recognized the design opportunities, succeeded with lightweight and eye-catching earrings and brooches which are of gold that can be hallmarked.

Since the process starts with a wax or zamak metal model or mould, the designer can work with conventional design tools with which he is very familiar.

Over the years the technology has become more reliable by use of computer control with better outputs. Thus, designers have dared to create more difficult geometries and widened the range of electroformed gold jewellery.

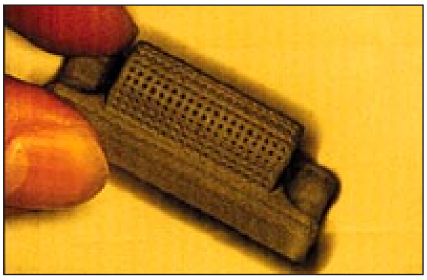

Figure 6 - Rapid Prototyping by laser sintering

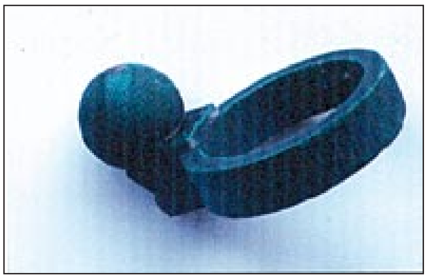

Figure 7 - Rapid Prototyping by wax-plotting

Powder Metallurgy

Powder metallurgy is another innovative technology that adds new design variations to the traditional products. This technology still has much potential for the jewellery industry. Today, for example, it has found application in the production of wedding rings and products which combine several colours. For contrast reasons, these products have mostly dull, matt surfaces. The main advantage of powder metallurgy is the possibility to combine materials that would either be dissolved in a molten phase or segregate. By blending, pressing, and sintering metallic powders, all desired gold colours and even platinum can be mixed in an appealing way. Continuous transitions from one colour to another can be made. Adding extremely hard components increases wear resistance. Metal Injection Moulding (MIM) technology is also a very interesting production method for jewellery as long as the lot size is big enough to pay for the high tooling costs. J.T. Strauss has discussed in detail the benefits and limitations of this process (7).

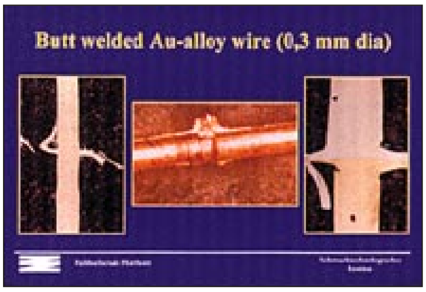

Figure 8 - Butt-welded gold alloy wire, diameter 0.3 mm, joining white and yellow golds

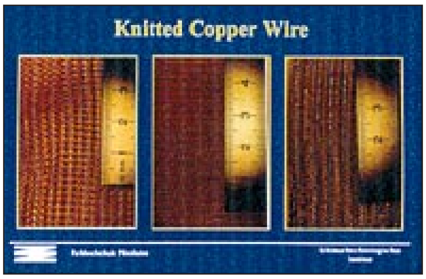

Figure 9 - Different stitch patterns of mechanically knitted metallic copper wire

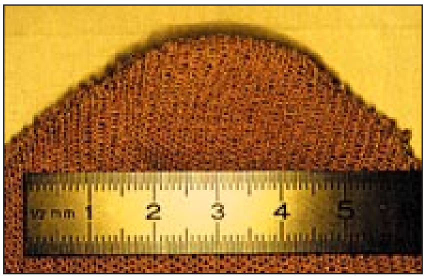

Figure 10 - Example of 3-dimensional metallic fabric

Knitting

Knitting of metallic wires was originally developed to protect flexible electrical connections or high pressure tubes in severe environment. The results of these products in copper or stainless steel were so good-looking that it soon inspired jewellery designers. Round shaped knitted collars and necklaces made from gold wire were offered to the consumers who readily accepted this new design and made it a success. Machines had to be developed to fulfil the specific needs of the jewellery industry for these products. Engineers in the knitting machine industry, who suffered from the depression of the textile industry, voluntarily adapted their machines to the new requirements. Today these collars are an important segment of jewellery. Welding technology of wires should be able to enlarge the design possibilities by creating multicoloured items. By cold-press butt welding, gold alloy wires with different colours have been joined together, Figure 8. Even the combination with platinum is possible. Also, the variety of structures can be increased, because with modern knitting machines, every single stitch is computer controlled and programmable. Flat sheets with almost unlimited stitch patterns can be imagined. Figures 9 and 10 show examples of different patterns and densities as well as contours. It is one of the research topics of the Schmucktechnologisches Institut to evaluate the opportunities and limits of this technology for new jewellery designs.

Concluding Remarks

These few examples of production technologies that offer increased design opportunities demonstrate the necessity of the cooperation between designers and technologists. Especially in those countries which suffer high labour costs, with highly developed technologies this is a key issue for economic success in the jewellery business. This philosophy has lead to the foundation of the Institute for Jewellery Technology (Schmucktechnologisches Institut) in Pforzheim and defines the tasks to be done. New technologies which arise in other fast developing industries can be adapted to the needs of the jewellery manufacturing industry. The interaction of production technology and design has not only offered opportunities to innovative jewellery production in the past but will also do so in the future.

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8 Project von Studiengang “Schmuck und Gerät” und “Maschinenbau” der Fachhochschule, Pforzheim, Project leader: J. Marquardt, SS97.