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New strategies for measuring and sorting shaped glass stones using image processing☆

Michal Kelnar*, **Radek Martinek, Petr Bilik, Filip Volny, Jan Vanus, Zdenek Machacek, Jan Zidek**

Department of Cybernetics and Biomedical Engineering, VSB — Technical University of Ostrava, 17. listopadu 2172/15, Ostrava-Poruba 708 00, Czech Republic

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Summary This article aims to propose progressive methods for objectively evaluating significant mechanical and geometrical characteristics of gemstones used for making fashion jewellery. These characteristics significantly affect the overall visual aesthetic look of the respective jewellery stones. Different image processing methods are used in industrial microscopy to design new products. The key aspects for having a successful design is thoroughly analysing the material for possible gem-stone defects and properly defining their behaviour when using different optical systems. Using a high-tech experimental laboratory, the authors carried out a control measurement. The main contribution of this paper is the design, implementation and verification of the functionality of new methods for evaluating the quality of machine cut jewellery stones. These progressive methods have the potential to succeed in industrial microscopy or defectoscopy.

Introduction

Machine cut jewellery stones and fashion jewellery stones (hereinafter SGS) are geometric spatial formations bordered by several ground surfaces. Their main function is primarily optical-aesthetic. The basic characteristics of aesthetic perception are brilliance, fire and sparkle; see Garcia-Ayuso et al. (2002), Jamal and Goode (2001).

Identifying and evaluating the parameters of a given SGS optical-aesthetic function is a subjective task and is difficult to quantify, thus it is very difficult for machines to perform this task. However, because assessments of brilliance, fire and sparkle are based on the translucency of the SGS, it is obvious that geometrical and mechanical characteristics of the given SGS significantly affect its resulting optical-aesthetic perception.

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* Corresponding author.
E-mail address: michal.kelnar@vsb.cz (M. Kelnar).

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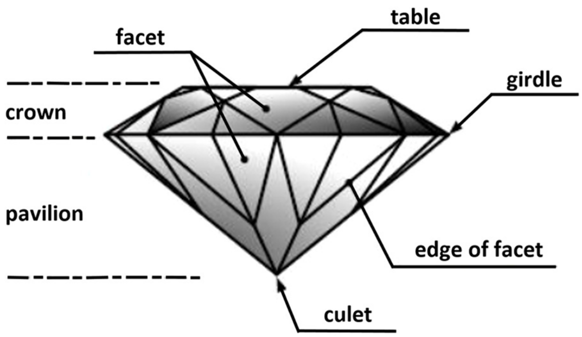

Figure 1 Parts of jewellery stone.

This article is focused on the use of modern defectoscopy methods, see Bovik (2010), Davies (2004), Rosenfeld (2013), Sonka et al. (2014) to detect and evaluate (see adaptive methods in Martinek et al., 2010; Martinek and Zidek, 2010, 2014; Pavlidis, 2012) SGS defects. This especially applies to defects in geometry, surface micro-reliefs, integrity defects and defects found in the chemical silvering layer.

Methods

Ground SGS surfaces can be generally divided into functional faces that actively influence its optic effect, while optically non-functional faces do not significantly affect the final optical effect. SGS is geometrically divided into two parts — the crown and the pavilion, see Fig. 1, Jamal and Goode (2001).

The crown is the part of the stone that can be seen during normal use of the stone. The pavilion, on the other hand, is the part that normally cannot be seen. Faces that create the crown and the pavilion are optically functional. These two geometrical parts of the stone meet at a point called the girdle.

The girdle is an optically non-functional surface that is located around the stone's greatest perimeter. The girdle is the primary structural element of the stone that most significantly affects its geometrical dimensions.

The crown of the stone consists of three different shapes: facets, tables and edges. The facet is a flat face that is optically functional. There are always some located on a stone and their number depends on how the stone is ground. The table is also a flat optically functional face, however, there is only one of the on each stone. The plane of the table is parallel to plane of the girdle. Last, but an equally significant part of the crown, is the edges. There are several types of edges, but generally in ground stones, they are the lines or curves at which the facets meet the table and the girdle. Edges are divided into facet edges, table edges and girdle edges. A facet edge is the meeting point of two facets. A table edge is the meeting point of the facet and the table and a girdle edge is the point at which the facet meets the girdle. The pavilion of the stone also consists of three shapes. Facets and edges are the same, but instead of a table, there is a tip. It is the point where three or more facets meet. It is also the functional end-point of the stone, see Jamal and Goode (2001).

Current evaluation methods

a) *Evaluation using a reflective sphere* — this is an indirect method of evaluation. This method is based upon shooting a beam of white or monochromatic light perpendicularly through the table of the respective SGS. Inside the stone, the light spreads into beams which exit the stone and are reflected on a hemi-spherical focusing screen. The resulting image provides information about the stone's geometric characteristics, facet macro relief and correct structure, see Garcia-Ayuso et al. (2002), Jamal and Goode (2001).
b) *A profile projector* — this is used to measure the product's basic geometric ratios. It is also an indirect method of evaluation. A profile projector is a device that reflects a highly magnified shadow on the focusing screen. This shadow is then used for taking general measurements of geometric characteristics (lengths, angles) that cannot be measured directly on the stones due to their small size, see Garcia-Ayuso et al. (2002), Jamal and Goode (2001).
c) *A contact profilometer* — this is a device used to measure facet relief up to a defect depth of 0.1 μm. The device operates as follows: A diamond tip moves across the surface of the facet. When the tip moves over a bump, it results in a vertical movement that is then recorded. The result is a parameter that represents the roughness of the respective surface. This measurement method is, however, not entirely accurate, see Garcia-Ayuso et al. (2002), Jamal and Goode (2001).
d) *Interference of light waves* — these waves are in a different phase due to their reflection from the different height of points in the surface of the stone. It is a very sensitive method used to measure the geometric characteristics of a surface at nanoscale. Due to the nature of the product, it is also necessary to perform a visual inspection. The first type of inspection is the ''visual evaluation by the human eye''. Such inspection is performed on products laid over screens or on products that are equally oriented. A comparison with a reference sample is often used. For such assessment, it is necessary to provide a light source which provides light which's spectral characteristic is as close as possible to natural daylight and more importantly to the eye of a trained and experienced evaluator. All optical-aesthetic characteristics and defects that can be identified by eye are visually evaluated. ''Visual evaluation by magnifying glass'' is performed at 4× to 20× magnification. This method is mostly used to inspect the surface of the product, the grinding quality and the inner purity of the stone. Commonly used are gem magnifying glasses, Brinnel magnifiers or table magnifiers, see Garcia-Ayuso et al. (2002), Jamal and Goode (2001).
e) *Visual evaluation by a microscope* — when a detailed assessment of presence of various artefacts inside a product is needed, the ''visual evaluation by a microscope'' is used. The microscope operates at 20× to 500× magnification and is used to identify and distinguish defects on the surface of the product or in-side it. The microscopic image can be digitalised and processed by a computer (Sanz, 2012; Snyder and Qi, 2010; Sonka et al., 2014;