PROTOTYPE TOOLS FOR MACHINING THE ELEMENTS OF THE INSTRUMENTAL OPTICS

The article presents results of the survey in the area of manufacturing single elements, as well as, short batches of optical lenses machined with prototype tools based on a granite. These kinds of tools are built of a granite part, which is used for spherical surface projection of machined optical lenses, and a metal part, which is used for holding a tool to the machine. Both parts are connected together with an adhesive. Manufacturing a spherical surface in a granite area is possible on machines used for glass machining. The application of a granite as a construction material allows also for significant cost reduction in comparison to the traditional materials, such as alloys of aluminium, copper, and cast iron.

Key words: optical elements, granite tools, spherical surfaces

1. INTRODUCTION

An optical glass is manufactured within glass-works shaped as glass plates, blocks, and glass compacts. Semi-finished products are a subject of an appropriate treatment to obtain suitable dimensions, shape and quality of treated surfaces [1, 2]. Mechanical working (milling, grinding, polishing) is a part of a basic working in a manufacturing process of optical lenses.

Metal tools for grinding and polishing ball-shaped elements are manufactured on special machines for spherical surface machining or CNC machines. Metal tools are durable and suitable for long production batches. The disadvantage of these kinds of tools is their high price caused by application of expensive materials and complicated, time-consuming mechanical working [3]. In case of prototype optical elements, the application of tools made of metal alloys is particularly unprofitable. Cost decrease of manufacturing prototypes of optical lenses is possible thanks to application of hybrid tools. The surveys on prototypes of these kinds of tools are run in B&M Optik Sp. z o.o. company in Rzeszow in cooperation with

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Tools for optical lenses machining, made of cast iron, alloys of copper and aluminium are presented in the Figure 1.

![Tools for lenses machining](image)

Fig. 1. Tools for lenses machining: a) from brass, b) from cast iron, c) from aluminium alloy
Rys. 1. Narzędzia do obróbki soczewek: a) z brązu, b) z żeliwa, c) ze stopu aluminium

2. PROTOTYPE TOOLS FOR OPTICAL LENSES MACHINING

Prototype tools for glass machining consist of:

− metal part, cylindrically shaped, ended with a machine clamping on one side, and a flat surface on the other,
− cylindrical part made of granite, ended with a spherical surface on one side, and a flat surface on the other,
− an adhesive layer for metal and granite parts connection.

A spherical surface of a tool can be glued with abrasive pastilles or polishing material (Fig. 2).

![Tools for lenses machining](image)

Fig. 2. Tools for lenses machining: a) metal, b) with diamonds pastille, c), d) hybrid: 1 – metal part, 2 – layer of glue, 3 – granite part, 4 – diamond pastille
Rys. 2. Narzędzia do obróbki soczewek: a) metalowe, b) z pastylkami diamentowymi, c), d) hybrydowe: 1 – część metalowa, 2 – warstwa kleju, 3 – część granitowa, 4 – pastylki diamentowe
Metal part is being connected with a granite one with a special adhesive called Technikoll 8266. Granite part is replaced by disconnecting an adhesive connection by heating tool up to the temperature of 160 °C to 200°C, where an adhesive loses its adhesive properties. Afterwards, the replacement of a granite part for a new one, with the same or similar value of sphere radius is possible. The same adhesive is used for sticking diamond pastilles to the spherical surface.

3. MAKING A GRANITE PART

A granite part is made in following order:
- making a granite cylindrical bar (Fig. 3) by rounding,
- cutting a cylindrical bar on slices with appropriate thickness,
- milling a spherical surface.

Manufacturing process of making is possible to execute using milling machines for glass machining, because of similar properties of materials, which are granite and optical glass. A spherical surface can be machined with three milling methods [4]:

![Fig. 3. Cylindrical part of granite](image)

Rys. 3. Walcowy pręt z granitu
– profile machining – a radius of the obtain curvature is equal to the cutter radius,
– disk cutter milling – a cutter circles an arc with required curvature radius,
– cylindrical cutter milling – an axis of rotation is set up at an angle of $\varphi$ to the machined surface axis of rotation (Fig. 4). The radius $R$ of the curvature, obtained in this case, is a function of a cutter $D$ diameter and $\varphi$ angle (formula 1)

$$R = \frac{D}{2\sin \varphi} \quad \text{where} \quad \sin \varphi = \frac{D}{2R}. \quad (1)$$

Fig. 4. Schema of spherical surface machining with cylindrical cutter
Rys. 4. Schemat obróbki powierzchni sferycznej frezem cylindrycznym

If a cutting edge of a cylindrical cutter has a rounding with $r$ radius, then calculation formula of $\varphi$ angle has a following form:

$$\sin \varphi = \frac{D}{2(R - r)} \quad \text{– for concave surfaces}, \quad (2)$$

$$\sin \varphi = \frac{D}{(R + r)} \quad \text{– for convex surfaces}. \quad (3)$$

Precision of a tool spherical surface manufacturing is the same as a surface of a machined optic element. After a preparation of a granite part of a tool we can start working on a process of gluing a clamping part (metallic) with a machining
part (granite). Spherical surface of the granite part can be glued with diamond pastilles of a different diameter or with veneer for lenses polishing (Fig. 5).

Fig. 5. Prototype tools for lenses machining
Rys. 5. Prototypowe narzędzia do obróbki soczewek

Figure 6 presents a way of clamping a prototype tool and machined optical lens on a machine.

Fig. 6. Prototype tool on machining surface: 1 – metal part, 2 – granite part, 3 – diamond pastilles, 4 – lens, 5 – chuck of lens
4. CONCLUSIONS

Machining the optical elements with tools, where a spherical part is made of granite, allows to manufacture lenses with the same precision as in case of metal tools. The application of hybrid tools for machining unit optical elements brings very similar effects, such as:

- short manufacturing time of hybrid tools lasts around 2 days (manufacturing time of traditional tools lasts around 5 days),
- high precision of curvature manufacturing on hybrid tools is 0.002 mm (precision of curvature manufacturing on traditional tools is 0.1 mm)
- no necessity of tool running-in (metal tool requires additional running-in),
- surface roughness is $Ra = 0.006 \div 0.02 \mu m$. 

REFERENCES