Research on Cam Channels for Zoom Riflescopes

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Abstract: *A modern riflescope is a complex device which incorporates some of the latest technologies for processing optical, mechanical and electronic components. Most of mechanical parts are manufactured using CNC technologies. A key optomechanical sub-assembly is the zoom system. In this paper are presented some aspects regarding the calculation and execution techniques of the riflescope zoom system, in particular focusing on cam channels.*

Keywords*: cam, zoom system, riflescope*

1. Introduction

A telescopic sight or riflescope (Fig.1) is an optical device with fixed or continuously variable magnification. The main assemblies are the objective lens, the central tube and the eyepiece.

Fig. 1. Zoom riflescope: main optomechanical parts

The central tube is made out of steel or high quality aluminum alloy and contains important subassemblies such as the zoom/erector system (including also a field lens), the reticle, the elevation and windage adjustment mechanisms and the illumination system. In addition the central tube is the place to attach the mounting rings.

2. The zoom system

Zoom means *continuously variable magnification*. The magnification value depends on objective focal length, eyepiece focal length and erecting system magnification. The technical solution to achieve a variable magnification in a riflescope is to design a special erecting system with magnification values in a specific range. Ratio between the maximum and the minimum magnification is called *zoom factor*. The erecting system has also the role to change the magnification and is called *zoom system*.

Usually the optical system for this zoom erector consists of a lens pair moving inside a tube. The motion low is controlled by a cam mechanism ([2]). Figure 2 shows a zoom optical system of a riflescope in two positions: for maximum and minimum magnification. It is very important to keep a constant distance between the two image planes, namely the front focal plane (FFP) and the second focal plane (SFP). The basic principle in a „two lens” zoom is to move one part to change the image size (magnification) and another part to keep the image plane in a constant position. The zoom system must correct the optical aberation for an entire magnification range, to have a sharp image during zooming.

The two lens groups must move along very precise curves calculated based on the laws of optics and materialized by the cam channels.

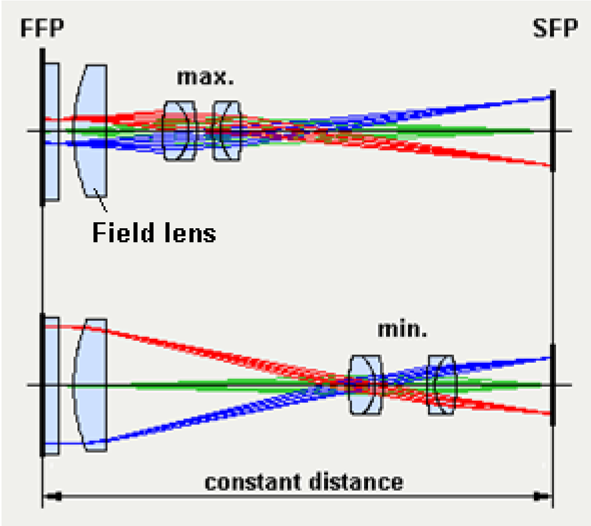


Fig. 2. Zoom optical system of a riflescope

In the present time ([1]) the industrial manufacturing of zoom riflescopes is inconceivable without the help of modern CNC technologies. A large part of the mechanical sub-assemblies such as the main tube, the zoom system, the eyepiece, are processed on machine tools of this type. By far the zoom system has the highest degree of complexity.
Figure 3 shows an example of a cam barrel with the moving lens groups inside, in two different positions. The motion of the two lenses is controlled by the barrel cam mechanism. There is an inner barrel with a linear cam and an outer barrel with the two curved cam channels. When the outer cam barrel is turned, the lenses move along the curved cam grooves.

Fig. 3. Zoom system sub-assembly: cam barrel

The system requires a great precision and the cams must be machined by computer controlled machining tools (CNC) to micron tolerances.

3. Design

The design of a zoom system for a riflescope starts with the optical computing for the erecting system. The next step is to study the motion low and to establish the cam grooves profile. It is a very complex process and involves the development of special software programs that combine automatic optical correction with mathematics calculations to find the best cam profile, based also on technical and technological considerations.
Based on these first design data it is important to check the cam profile by computer simulation ([5]). Figure 4 presents the cam barrel designed in SolidWorks.

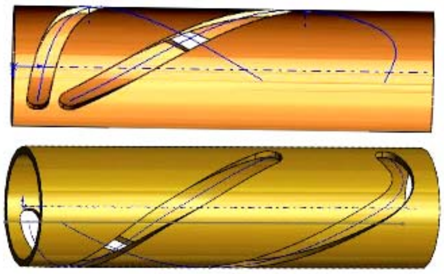


Fig. 4. Cam channels simulation

Any error or profile irregularity can be easily detected. The next step is to start the design of the optomechanical system. This stage ends with a new computer simulation. Figure 5 presents the entire zoom system designed in SolidWorks.

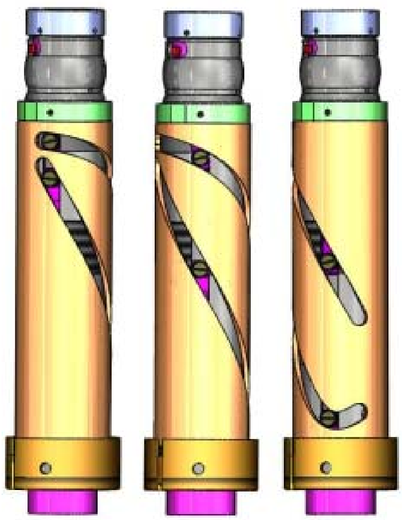


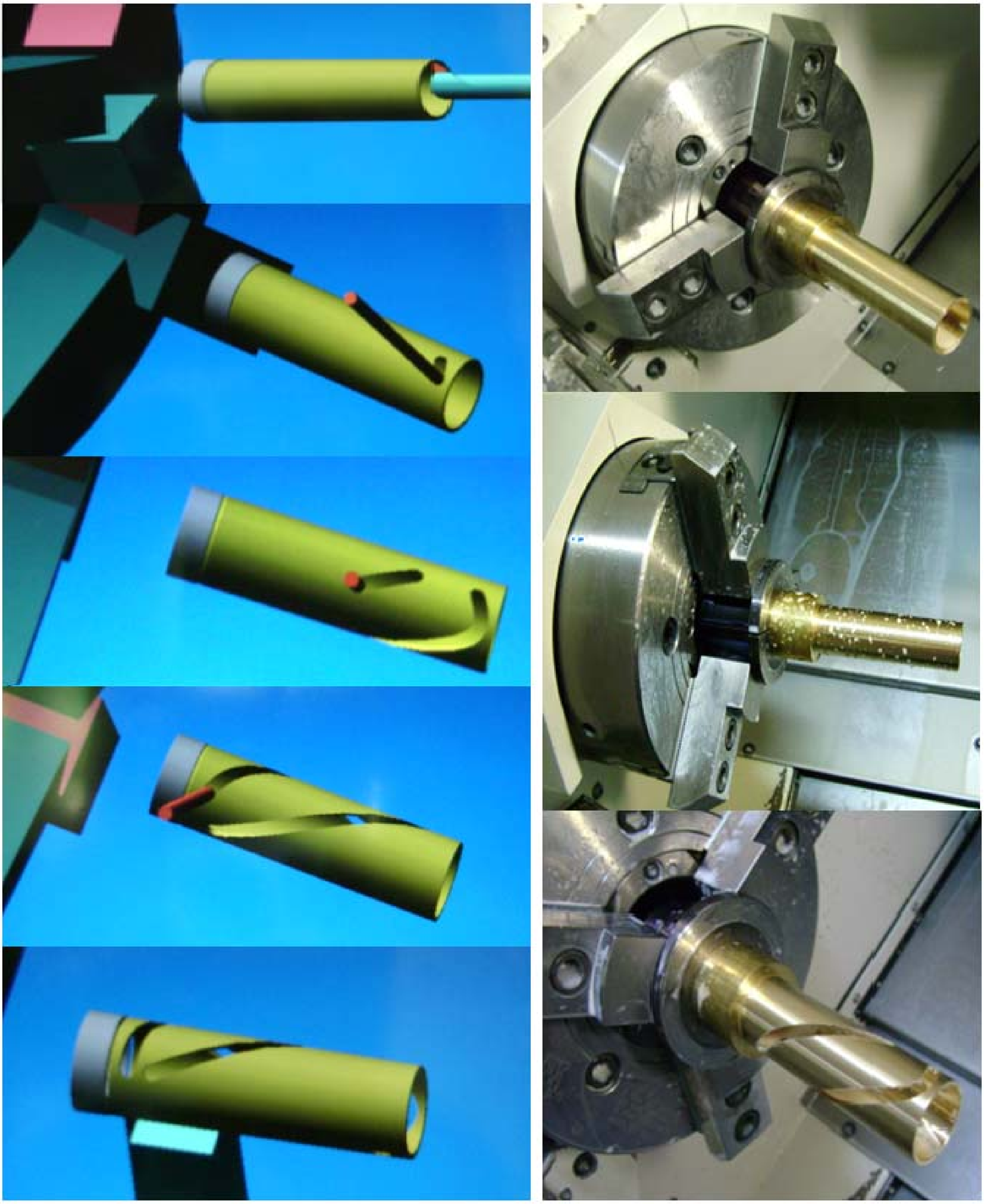
Fig. 5. Zoom system simulation

Once the cam channel profile is established, the designer can prepare the necessary data for the manufacturing on computer controlled machining tools, more specifically the points for the two curved cam channels. The number of points is important because the grooves surfaces must be smooth and without burrs. The newer CNC increased memory allows a larger number of points. In the latest systems ([3], [4]) more than six hundred points for each channel are used. The lens movement improvement was obvious.

4. Manufacturing

The CNC manufacturing engineer designs the technological process. The latest CNC machining tools models allow a computer simulation of the entire execution process. A final check is recommended. Figure 6(a) presents the cam channel execution, step by step. After the turning of

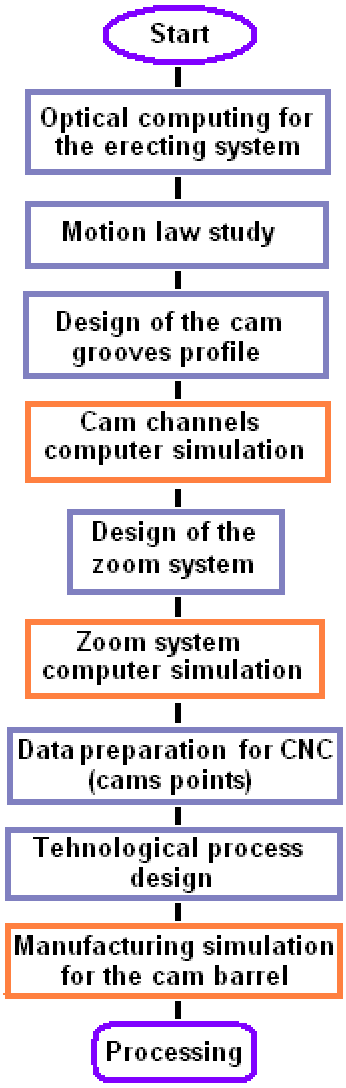
the outside and inside barrel diameters, the two grooves are cut. It is possible to verify if the system design and CNC data, are both correct.
To compare the simulated to the real cam barrel processing, Figure 6(b) presents real time processing sequences. First the outside and inside barrel diameters are turned, than, the two grooves are cut.



a) Process simulation *b) Real cam barrel processing*

Fig. 6. Cam execution process

Summarizing the above presented, the following sequence can be proposed, for cam channels design and simulation:



Very suggestive for the accuracy and usefulness of this step by step design-simulation process is the image presented in Figure 7, representing the cam barrel simulated model (in SolidWorks) and the real processed piece.

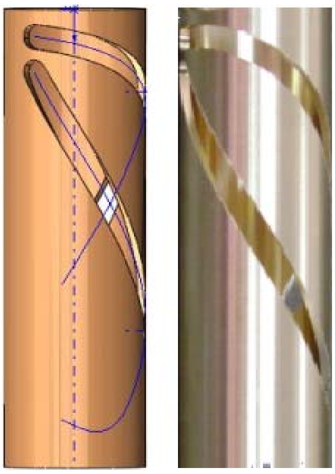


Fig. 7. Cam barrel: simulated and real piece

5. Conclusions

The zomm erecting system of a telescopic sight is one of the more complicated assemblies of the scope. To design a performant zoom system multidisciplinary knowledge is required. The riflescope development in the last years has seen a very rapid evolution which can be supported only by applying modern technologies.

For riflescopes with high zoom factor it is extremely important to ensure a very accurate cam channels design and manufacturing process. In Figure 8 is presented the new series of IOR riflescope with *zoom factor 8*, developed within a recent research project.

Fig. 8. Riflescopes series LUTAZ: 2-16x42; 3-25x50;5-40x56

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