A Framework of a Process Modelling and Optimization System for the Design, Fabrication and Evaluation of Progressive Lenses

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Abstract

To provide a clear and comfortable intermediate vision for presbyopic patients, there is a growing need to replace the traditional single vision, bifocal and trifocal lenses by Progressive Addition Lenses (PAL) with a small interval of degree. They are mainly tailor-made and expensive. Injection moulding of PALs is suggested in this paper to reduce the cost, so that more people can afford to have one. Ultra-precision freeform polishing (UPFP) is a technology that can machine precision moulds with sub-micrometer form accuracy and surface finish in nanometer range. In this paper, a framework of a process modelling and optimization system is presented for supporting the design, fabrication and measurement. A pilot experiment has been done to verify the framework and encouraging results have been obtained.

1 Introduction

Almost all people suffer from presbyopia at their late adulthood and it starts to show up at 40s [1]. PALs are multifocal lens which provides presbyopic patients a gradient change of clear and comfortable vision of objects at various distances, i.e. distant and near objects. The form accuracy and surface finish of their moulds are highly restricted. Also, they are designed with freeform surfaces. UPFP provides an important means for the fabrication of the precision moulds with sub-micrometer form accuracy and nanometric surface finish [2]. To suit the market need, a series of PALs have been developed which require numerous precision moulds. It is a waste of resource without an optimized fabrication process of mould inserts. Hence, a process modelling and optimization is much needed and presented in the present study so as to increase the efficiency and effectiveness.

2 Framework of process modelling and optimization of PAL fabrication

A framework of a Process Modelling and Optimization System for the design, fabrication and evaluation of progressive lenses is presented as shown in Figure 1. It consists of Optical Design Module (ODM), Data Exchange Module (DEM), Model-based Simulation System (MSS), and Polishing Process and Measurement and Characterization Module (PPMCM). The system starts with optical design with the assist of a software, named Zemas, which allows for the simulation, optimization and evaluation of the optical performance of PALs design. The design parameters are used for the generation of the CAD specifications and CAD exchangeable file of the PALs for DEM. In the DEM, point cloud data and mathematical equations are interchanged for different purposes. Before finalizing the design of the PAL, Advanced Human Eye Model (AHEM) are conducted to simulate and test the optical performance of the progressive lens design.

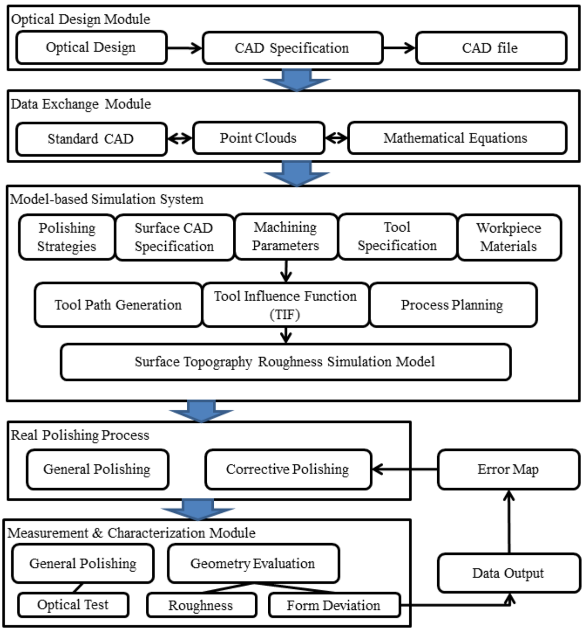

Figure 1: A Framework of a process modelling and optimization System

3. Implementation and Experimentation

With the design, the polishing process planning and the simulation of surface generation are undertaken by the model-based simulation system which is purposely built [3]. The model built with the consideration of the geometry of Tool Influence Function. Experiments were carried out to verify the system with parameters as shown in table 1.

Table 1: Parameter of verification experiment

Polishing mode	Raster
Precess angle (deg)	15
Head speed (rpm)	1200
Polishing depth (mm)	0.3
Tool pressure (bar)	1
Surface feed (mm/min)	50
Polishing cloth	Cerium oxide D'16
Workpiece material	NiCu Alloy
Polishing slurry	Al_2O_3 (1.5um)

Polishing is undertaken by using a 7-axis computer controlled ultra-precision polishing (CCUP) center (i.e. Zeeko IRP200). The polished surface of PAL is then analyzed by the measurement and characterization module. In this stage, the form error and surface finish of PALs are determined. The form error can be used to produce the error map for corrective polishing to achieve better form accuracy.

3 Results and discussions

3.1 Verification of simulation system

Figure 2 shows the simulation results for the design of the PAL using Advanced Human Eye Model (AHEM). Moreover, two data sets were collected: 1. Predicted (P): 14.66nm; Measured (M): 23.36nm 2. P: 13.38nm; M: 13.86nm. Although there are some differences between the values, they are close. To improve the model, other influence factors, such as polishing fluid and sample materials, should be considered.

3.2 Implementation of PAL fabrication process

The whole manufacturing process was implemented from optics design of the PAL to injection moulding. Fig. 3 shows the polished mould inserts and the moulded PAL. After polishing, a super mirror finished surface (figure 3a) can be achieved with average areal surface roughness Sq=39.30nm for the freeform cavity and Sq=53.16nm for the spherical core by white light interferometry. For the moulded lens as shown in figure 3b, the surface finish of the freeform side of the progressive less is Ra=9.67nm while that for the spherical side is Ra=14.77nm as measured by profilometry.

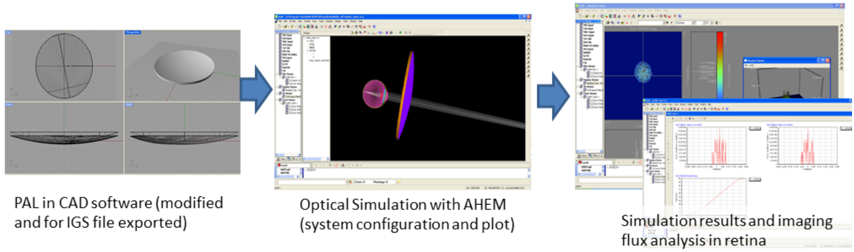

Figure 2: Optical simulation using Advanced Human Eye Model (AHEM)

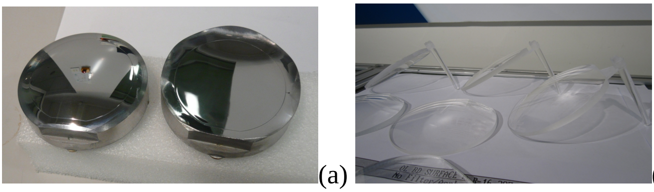
(a) (b)

Figure 3: (a) Polished Mould insert and (b) Moulded PAL

Acknowledgement

The authors would like to express their sincere thanks to the Research Committee of The Hong Kong Polytechnic University and the Innovation and Technology Commission (ITC) of the Government of the Hong Kong Special Administrative Region (HKSAR) for the financial support of the research work under the project codes RGYW and ITS/389/09, respectively.

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