Automatic quality control in optical lenses

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1 Problem statement

Indizen Optical technologies (IOT) is a company that offers products and services to the optical industry. Our customers are ophthalmic eyewear lens manufacturers. One of the services we provide is quality control of the lens production. In this line one of the most demanding products are the progressive addition lenses (PAL) [1].

Modern ophthalmic lenses are manufactured using a technology called free-form surfacing that consist mainly in two steps: generation (a lathing process) and polishing. In the ophthalmic case the surface quality must be about 0.5 μm. In figure 1 we show a picture of the generation process where an ophthalmic lens is generated by a lathing tool as the lens spins.

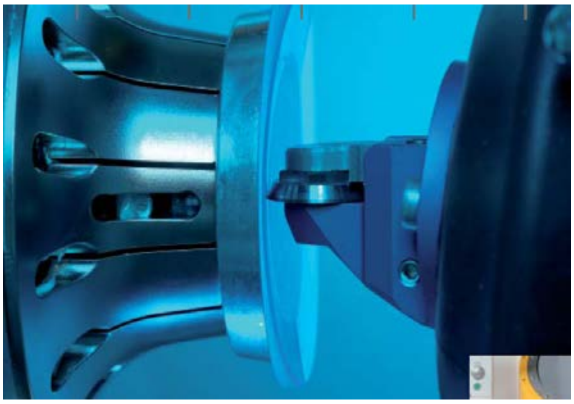

figure 1 Lens surfacing by a lathing tool

Although all the process is computer controlled, the manufacturing process is affected by multiple factors as tool aging, misalignments and miscalibrations. The optical power perceived by the user is linearly related with the local curvature of the lens surface. Thus, even in the case of achieving the correct roughness, low spatial frequency waviness can produce errors in the perceived power above the 0.12 D ISO tolerance as shown in figure 2

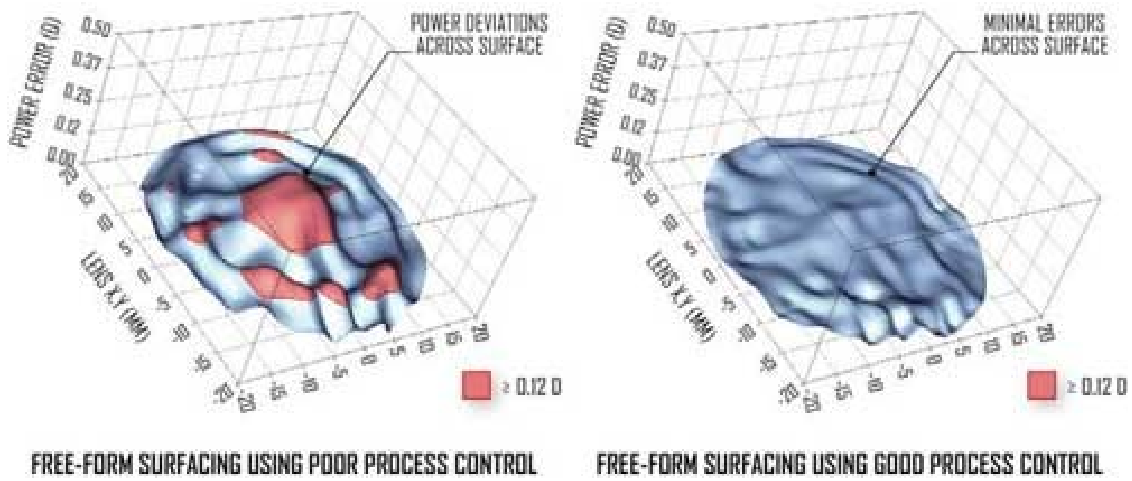

figure 2 Free-form surfacing can actually produce lenses with unwanted variations in power and waviness over the surface [2]

The optical power of the lenses can be measured using lens mappers. These instruments generate a measurement of the though power map of the lens sampled as a 40 × 40 matrix. Mappers also produce the error power map from the measured and the theoretical power maps. In figure 3 we show the measured, theoretical and error maps of a PAL lens corresponding to the spherical power.

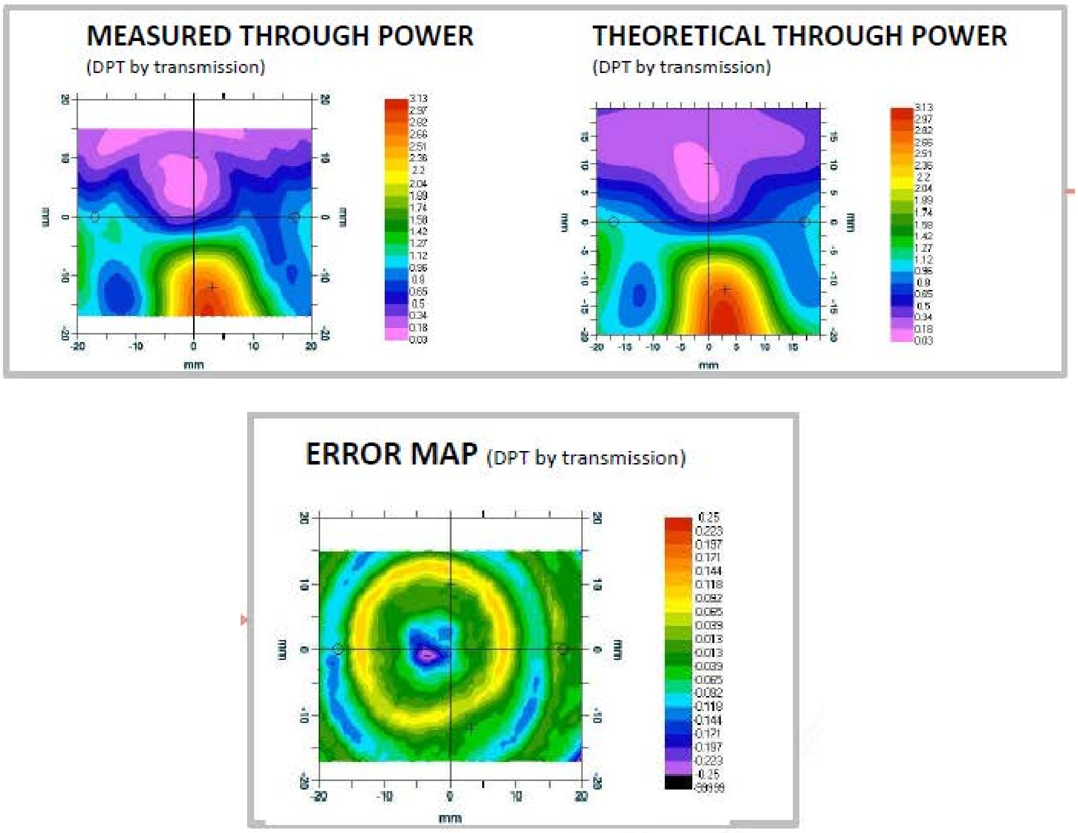

figure 3 Sphere error map for a PAL lens. In this case the error map shows a wave-like structure. In this case the maximum amplitude of the error is about 0.10D

In principle, to determine if a lens is well manufactured or not can be done just checking if the maximum magnitude of the error map is above the 0.12 D ISO tolerance. However for a PAL the error magnitude is not enough to classify the lens because it is also important the location and the spatial structure of the error. In addition, the prescribed power is also relevant in determining if a given error map makes a lens unfit for the final user or not.

A better approximation will be the extraction of features from the error maps and using the calculated feature vector to classify the lens in two classes as "good" or "bad".

The objective of this work is to design an automatic quality control system based in the use of a supervised learning algorithm by evaluating different classifier approaches (i.e. logistic regression, neural networks, SVM, etc).

The work will include the performance analysis using the precision, recall and F-score. Another aspect of the work will be the determination of the most important features that describe the lens classification process.

For the supervised learning, IOT will provide a training set consisting in a matrix of feature vectors "X" extracted from the lens prescription and the error map and a vector "y" of labels. Each row of the matrix "X" corresponds to the features of a lens and the corresponding label, "good" or "bad", is given by the vector "y". This training set has been produced by the IOT customer support team using actual lenses as well as the final classification result.

2 References

[1] Progressive Addition Lenses, Ophthalmic Optics Files, Essilor. pdf

[2] Darryl Meister "Optics of Free-Form Lenses – Part 2, Single Vision" link