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An inspection system to master dimensional and technological variability of fashion-related products: A case study in the eyewear industry

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ABSTRACT

Innovation of fashion-related products implies the continuous search for new and appealing shapes and materials in a short period of time due to the seasonality of the market. The design and manufacturing of such products have to deal with a dimensional variability as a consequence of the new shapes. An additional difficulty concerns properly forecasting the technological behaviour of the new materials in relation to the manufacturing process phases. The control of dimensional variations requires time and resource intensive activities. Human's manual and visual inspection solutions are more common than automatic ones for performing such control, where skilled operators are typically the only ones capable of immediately facing non-standard situations. The full control of such variations is even more subtle and mandatory in the field of spectacles, which are fashion-related products and also medical devices. This paper describes an inspection system developed to monitor the dimensional variations of a spectacles frame during the manufacturing process. We discuss the methodological approach followed to develop the system, and the experimental campaign carried out to test its effectiveness. The system intends to be an alternative to current inspection practices used in the field, and also to provide a methodological approach to enable engineers to systematically study the correlations existing among the frame main functional and dimensional parameters, the material behaviour and the technological variables of the manufacturing process. Hence, the system can be considered a method to systematically acquire and formalise new knowledge. The inspection system consists of a workbench equipped with four high-quality commercial webcams that are used to acquire orthogonal-view images of the front of the frame. A software module controls the system and allows the automatic processing of the images acquired, in order to extract the dimensional data of the frame which are relevant for the analysis. A case study is discussed to demonstrate the system performances.

1. Introduction

In order to remain competitive in the market, companies need to continuously capture and fulfil customers' expectations and put on the market a wide range of new products and services that must be highly customisable. The fashion industry (e.g., textile and apparel manufacturers) has to deal with this challenge since the shift from one season to the other settles the short time to market of their collections [1]. Together with time constraints, one has to consider also the intrinsic variability of the geometries/shapes designed as well as of the materials used, due to the commitment of constantly innovating the product from both the aesthetic and technological point of view. Additionally, guaranteeing high quality standards is a must-have requirement, especially in case of high-end products.

The eyewear industry is affected by these challenges (e.g., see [2–5]). In addition, the eyewear industry faces a further level of complexity. In fact, spectacles are wearable medical devices; they must be compliant to dedicated medical/safety standards, which vary according to the market where the product is sold (e.g., just for the frame we can mention ISO TS 24348, ISO 7998, ISO 8624, ISO 10685-1, ISO 10685-2, ISO 10685-3, ISO 12870, ISO 13666, and ISO 16034). Their shape must also fulfil specific morphological requirements in order to guarantee comfortable wearability. For example, the frame geometry and mechanical behaviour plays a key role in guaranteeing the proper position of the optical centre of

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the lenses and of the temples, while different variants of the same frame are necessary when a collection has to be sold in the Asiatic or in the European markets, because of the different morphological characteristics of the population (e.g. see [6]). As a consequence, the range of marketing, technical, medical, ergonomic and manufacturing requirements that engineers have to simultaneously take into account, when designing spectacles, is wide and articulated.

Innovation in the domain of materials opens up new possibilities concerning the aesthetics of spectacles. However, this represents a further challenge to tackle since getting a complete and quick characterisation of the technological properties of these materials is not always possible due to: the short lifetime of the product development process; the high number of variants of materials to manage in parallel (which are required by different brands/collections); the fact that the new materials may not have been used before for manufacturing spectacles.

In order to fulfil high quality standards, ad-hoc post processing and finishing activities have to be planned in advance and then performed on the product, in order to eliminate any dimensional/finishing variations. For example, despite of cellulose acetate has been used for years to manufacture frames, eyewear manufacturers are continuously looking for new variants in terms of e.g., colours and textures. Dedicated technological processes together with the change of the material chemical composition (e.g., adding specific colourants or plasticisers) have given in years the possibility to fully exploit the chromatic potentials of the material [7]. However, these changes can lead to acetates having major differences for what concerns their manufacturability. The variability related to the technological properties of the material could alter the shape of the frame. As already discussed, ad-hoc post-processing and finishing activities have to be planned on the product. Such activities even if effective, make longer and more complex the manufacturing process. With the aim of mastering variability, we have developed an inspection system and a dedicated software tool that can rapidly acquire and evaluate the main geometric/dimensional variations of spectacle frames during pilot productions (which is the phase when design changes are not recommended but still feasible). The objective was to develop an approach and a dedicated system to support engineers in deepening the correlations existing among the frame main geometric parameters, the material behaviour and the technological variables of the manufacturing process. We wanted to develop a technique able to systematically collect and generate as much knowledge as possible to be used as design indications during the early phases of the design process in order to improve the overall process efficiency and the product quality (e.g., see [8]).

The paper describes the methodology used to develop the inspection system and to test its performances for what concern its level of usability/implementability, within a real production environment, and the kind of knowledge the system is able to generate. The case study, developed in collaboration with an eyewear company, is focused on monitoring acetate frames. Hence, the discussion of the methodological approach is focused on this type of material, although potential extension to different materials, objects and processes is apparent.

2. Variability issues of fashion products

2.1. A focus on the eyewear industry: spectacles frames

The quality of a frame is strongly related to the finishing characteristics of its surface, and to the fulfilment of the dimensional/geometric requirements stated for the main dimensional parameters. These parameters, as it will be detailed in Section 3.1, are the ones influencing the functionality, wearability and aesthetic of the spectacles. Their values can vary according to fashion-related aspects, which determine the changes to be applied both at the shape- and material-level. This fashion-related variability is a peculiarity and a plus of the product. However, it is also a challenge that concerns forecasting, already at the design phase, the technological properties of the new material in relation to its adaptability to the eyewear manufacturing process. Indeed an unexpected behaviour of the material could lead to a dimensional variability of the shape of the frame.

The difficulties in controlling this variability are several if we consider also the kind of dimensional parameters to be controlled. Indeed, most of them are angles, whose measurement is mainly performed manually on the physical object, by means of dedicated devices/supports. For example, in Fig. 1 it is provided a simplified explanation of how one of these manual strategies works: the proper placement of the frame on a graduate map enables the extrapolation of the face-form angle of the spectacle frame (see Fig. 2). Such angle, as it will be explained in Section 3.1, determines the curvature of the front of the frame. Considering the high variability of the shapes of the frames, good manual skills and expertise are required to guarantee the proper placement of the frame on the map as well as the reliability and repeatability of the measurement. For these reasons, such measurements are usually performed by skilled operators.

In such a challenging context, experienced eyewear engineers/designers play a key role. Thanks to the knowledge and skills they have acquired along the years, they have the background knowledge necessary to forecast the technological behaviour of the raw material. Notwithstanding, as already underlined, ad hoc post-processing activities are usually necessary to eliminate any

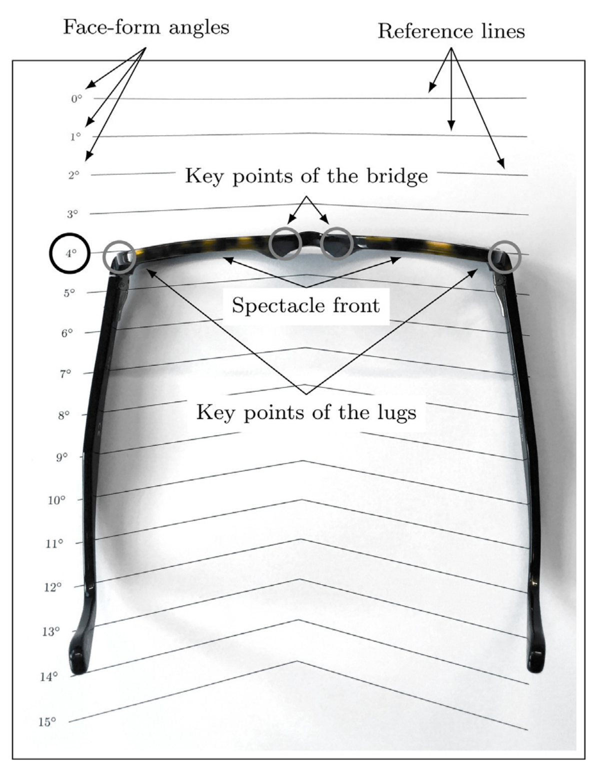

Fig. 1. A simplified representation of the procedure used for measuring the face-form angle of a spectacle frame, by means of a graduated map (the image provides a simplified version of this map). The value of the angle is derived by manually superimposing the front of the frame on the reference lines. The correct value of this angle corresponds to the best fitting configuration between the frame curvature (using as reference some key points of the frame, such as the extremities of the bridge and of the lugs for each side) and the grade of the reference lines. In this case, the correct value is 4°.