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Wear resistance of blades in planetary concrete mixers. Part II: 3D validation of a new mixing blade design and efficiency evaluation

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ABSTRACT

This paper presents an improvement of a previous work, where the optimization of a two stars' planetary concrete mixer in terms of wear resistance of blades was proposed and a new design of the mixing blades' shape was shown and discussed. Authors propose a new validation procedure of the mixing blades in terms of wear resistance and efficiency, based on 3D optical scanners. This new wear measuring procedure is classifiable as a digital wear evaluation method, included in the field of digital tribology. All the steps and results are presented and discussed. In addition, experimental tests and results about the efficiency of the new blade in terms of discharge times are shown. The results demonstrate that the proposed new blade's geometry improves the wear resistance, extends the useful-life and enhances the discharge operation.

1. Introduction

This paper represents an extension on the paper [1] where an improved geometry of mixing blades for planetary concrete mixers in terms of wear resistance was shown and discussed. In particular, the authors proposed a new blade's design on the basis of a theoretical qualitative approach (fresh concrete model [2–5] actions on the blades [6–9] power consumption [10]), and then they performed experimental campaigns in order to study and demonstrate the efficiency of the new blade's geometry. Experimental results, based on a 2D comparison of worn profiles, showed that the new designed blade was the best one in terms of wear resistance and lower power consumption if compared to the standard T blade normally used in planetary concrete mixers.

The goal of the previous paper was not to quantify the true wear rates of the blades but just to assess which of the new shaped blade was the best in terms of wear resistance and if the new design allowed lower wear rates and longer durability. The goal of this paper is to quantify the volumetric wear rates, to build a 3D wear map showing the true 3D distribution of material losses over the blade's surface and to assess the discharge efficiency.

There are many methods to analyze and evaluate wear and material losses. Açmaz in [11] classifies wear measurement methods into direct and indirect.

In applications where the direct contact with the worn surface is feasible, direct methods are usable and they result to be the best in terms of efficiency, rapidity and accuracy.

The modern measuring technologies are becoming smarter and smarter in many industrial, medical and applied research fields. In the field this paper deals with, the innovative wear measuring techniques can be included in the area of what the authors like to define as "digital tribology". Digital tribology is definable as the totality of the digital techniques applicable in tribology, for wear detection and evaluation [12–15] and for the analysis of contact [16] and lubricating conditions [17].

Among the direct and digital methods to evaluate wear, a very smart technique implies the use of optical non-contact profilometers, 3D scanners and microscopes. The use of those instruments is really recommended as it allows great versatility, reliability and accuracy, as most of the times the use of those instruments does not require the specimen to be dismounted.

Furthermore, excepted the profilometers, they can be the best solution when the specimen has a complex shape. Particularly, the use of 3D optical scanners can give the advantage of being portable, allowing the operator to scan also undercuts in a very simple way. At the same time some of those instruments are also able to generate a full 3D digital model of the specimen in real time and automatically, in order to evaluate the wear 3D distribution by comparison with a non-worn model.

As explained in [1], mixing blades are the concrete mixer's components mostly interested by wear, that is mainly abrasive and erosive. Although their name would suggest the mixing blades are in charge of the mixing procedure, in the studied planetary

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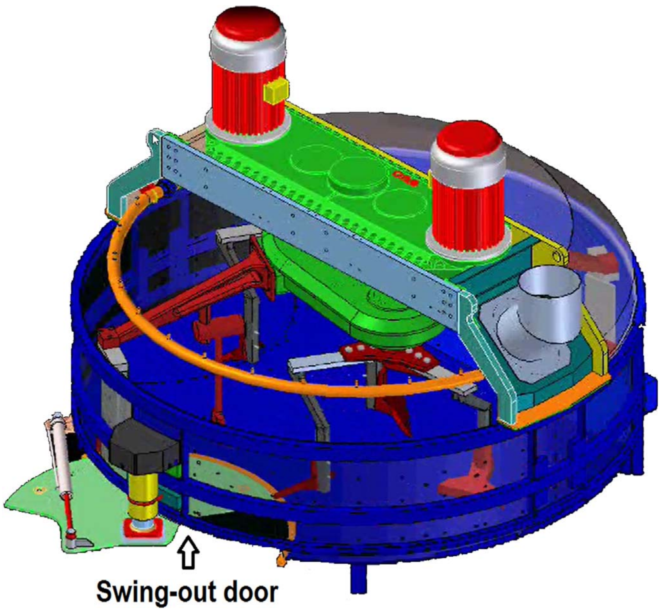

Fig. 1. Discharge swing-out sector door.

Fig. 2. Go!SCAN 20.

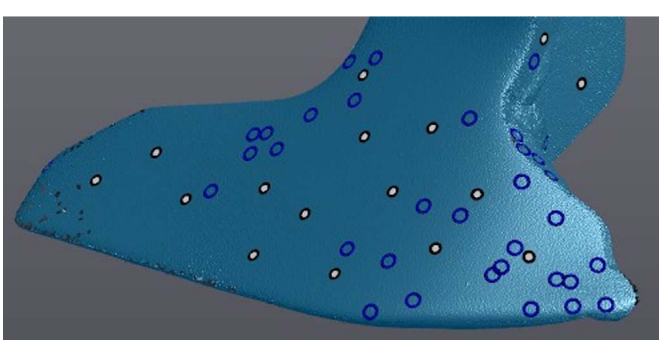

Fig. 3. Positioning references.

concrete mixer their main function is the discharge operation and their presence does not significantly influence the homogeneity of the final mixture. Nevertheless, the mixing operation is the most responsible of blades' wear and generates wear mostly on the outer side of the blade. The geometry of this part has not a great influence on most of the mixing procedure but it has a fundamental role during the discharge operation, which is the last phases of the mixing procedure. The mixing blades discharge the concrete from the mixing tank throughout swing-out sector doors, sealed in rubber and hydraulically powered, as shown in Fig. 1. The discharge door opens at the end of the regime phase of the mixing cycle and the mixed material exits the mixing chamber. The discharge door then closes and the next cycle is ready to begin.

Table 1
Go!SCAN 20 specs and performance parameters.

Specs	Go!SCAN 20
Measurement rate	550,000 measures/s
Scanning area	143 $\times$ 108 mm
Light source	White light (LED)
Resolution	Up to 0.100 mm
Accuracy	Up to 0.100 mm
Volumetric accuracy	0.300 mm/m
Positioning methods	Geometry and/or color and/or targets
Stand-off distance	380 mm
Depth-of-field	100 mm
Part size range	0.05–0.5 m
Texture resolution	50 to 250 DPI

2. Instruments and 3D wear measuring method

As a consequence of the considerations mentioned in the introduction, in this work a portable optical 3D scanner was used in order to perform wear measurements.

The aim of the research work was to directly measure the worn volumes and the volumetric wear rates of two different mixing blades in order to quantify the better efficiency of the new designed blade with respect to the standard T one, already investigated in [1].

Although in [1] a 2D evaluation was presented by analyzing the whole profile of the blades on the horizontal plane (at a certain distance from the vessel floor), these 2D measurements were not exactly related to the worn volume. Thus, in order to obtain a complete scenario of the material loss, measurements of worn volumes have been performed by means of a 3D metrological instrument.

Since full 3D digital models are directly obtained, the use of this instrument allows a direct comparison of worn volumes, even though the shapes of the two studied blades are totally different over the area interested by wear phenomena.

2.1. Instruments

The metrological device used in this work is Go!SCAN 20 by Creaform (Fig. 2), a latest generation portable non-contact 3D scanner for many industrial applications such as deformation and geometry analysis, quality control, inspection and reverse engineering.

This device works according to the principle of active triangulation and the light sources are white LEDs, projecting QR coded patterns on the scene. The scanner is able to reconstruct the full 3D digital model of any target object in real-time and in color, providing a triangle mesh as a result. The real-time reconstruction is performed by using a common reference system, where data from every scanned frame are merged into a complete model. This process is called dynamic referencing registration and is based on three different types of self-positioning references: physical targets, virtual targets and geometries.

Physical targets are light adhesive circles made of reflective materials with or without black contours for an easy detection by the optical device. In the case represented in Fig. 3 physical targets