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Wear resistance of blades in planetary concrete mixers. Design of a new improved blade shape and 2D validation

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ABSTRACT

Wear of machine components is one of the main phenomena to control and limit in order to improve the performance and reduce the production costs. In this paper, the optimization of a planetary concrete mixer in terms of wear resistance of blades is proposed and a new design of the mixing blades' shape is shown and discussed. Experimental tests performed with two stars planetary concrete mixers are described and achieved experimental results are shown. Those results display the progress of blades' wear over time and prove that the proposed modified blade's geometry improves the wear resistance and extends the useful-life.

1. Introduction

Performance optimization of a concrete mixer is an issue of great significance in many industrial technologies and wear is one of the main phenomena to forecast and test during the design and working of mechanical components. The wear effect is the progressive modification of surfaces' morphology that brings the mechanical components to inefficiency.

An overview of the various types of mixing methods and concrete mixers commercially available are described in [1–5].

In the present paper, a planetary concrete mixer is studied and the wear resistance of mixing blades is investigated. The analysis of the concrete mixer is based on the forces exchanged among mixing arms, blades and concrete.

Only a few published articles present experimental and theoretical researches about planetary concrete mixers. For instance, Cazacliu and Legrand [6] present the results of tests on planetary concrete mixers and investigate the correlation between the paste composition and the power necessary for the mixing operation. Cazacliu [7] presents a model of the power consumption as a function of the planetary motion.

Braccesi et al. [8] show that the Brinch-Hansen formula [9] and the Bingham theory of fluids [10–12] can be used to describe the behavior of concrete in the so-called dry and final mixing phases. A calculation of blades' forces resulting from the application of a model is proposed in [13] and [14] in order to evaluate the useful-life of the gear units of the planetary concrete mixer. Some mixing performances are analyzed by Yao et al. [15]. Relationships between mixing methods and both rheological properties and microstructure of cement pastes are described in [16].

Since the mixing blades suffer wear more than other components, they are designed to be easily replaced in all the concrete mixers' types. However, their decay is low and slow when they undergo the proper maintenance program.

In this paper, the authors present the study of wear of mixing blades used in planetary concrete mixers and propose a new improved blade design allowing longer durability.

The machine and the mixing process are described, together with the models presented in literature, in order to characterize the process. The main factors influencing wear of blades are: kinematics, friction between slurry and blades, friction due to the leakage between vessel and blades and also an inadequate maintenance of the mixer.

The authors will examine the wear behavior of some prototypes of the proposed new blades by comparing the experimental data obtained in a concrete batching plant during typical production days.

2. Description of planetary concrete mixers and mixing cycle

Planetary concrete mixers are highly suitable for experimental studies because they guarantee the homogeneity of the mixture and the repeatability of the tests.

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Planetary concrete mixers are mainly divided into two categories: single and double star mixers (Fig. 1). They have a vertical axis, a fixed tank and they realize a planetary motion by gear units.

The main components of a planetary concrete mixer are:

(i) Electric motors: there is one motor for each star, 1 to 3 depending on the tank's size.
(ii) The gear box: it contains two mechanisms, one is the ordinary reduction gear train and one is the planetary gear train which transmits the planetary motion from the motors to the stars.
(iii) Stars and mixing arms: each star includes three arms, which are the main components in charge of the mixing function. The mixing arms are peripheral and obtained by steel drill rods.
(iv) Mixing blades: although their name would suggest that the blades are in charge of the mixing procedure, their main function is the discharge operation and their presence does not influence the homogeneity of the final mixture. Blades are the concrete mixer's components mostly interested by wear.
(v) Mixing tank with the swing-out doors: the mixing blades carry out the discharge operation throughout swing-out sector doors, sealed in rubber and hydraulically powered. Mixing arms can reach each point of the tank bottom. The mixing tank is made by extremely thick steel sheets. The entire tank is protected by a case to prevent dust escaping.

The composition of gear rotation and revolution movements of arms generates the planetary mixing motion. Fig. 2 shows the planetary system gear boxes and corresponding kinematic schematics. The first gear box and schematic refer to single star mixers, while the second ones to double star mixers.

The mixing operation will be interrupted by a micro-switch if the door at the front is opened. One or two peripheral arms work as scrapers. The slurry level has to be about one third of the thank's depth.

Fig. 3 shows a drawing of a star in the horizontal plane. The analyzed concrete mixer has two stars and six blades (Fig. 1b).

Fig. 4 shows the trajectories of the three arms in a single star mixer at different mixing stages [14].

As already mentioned, the mixing blades are not in charge of the mixing function and their presence does not affect the homogeneity of the mixture. This can be demonstrated also by observing Fig. 4, where it is shown how the trajectories of the mixing arms reach each position at the tank's bottom surface. In addition, according to technical reports made by customers and to the manufacturer's experience, it is known that the mixing efficiency does not change significantly during the wear progress of the mixing blades, also when the blades are at the end of their life.

The phases of the mixing procedure, during a mixing cycle are:

1. Aggregates (sand) introduction
2. Cement introduction
3. Dry premixing stage
4. Water addition
5. Additives loading
6. Final mixing (regime) before discharge
7. Discharge

All the sub-mentioned phases can be highlighted in the evolution of absorbed power, during a mixing cycle. For example, Fig. 5 shows a measured evolution of absorbed power during a typical mixing cycle, in the studied two stars planetary concrete mixer. All the phases of the mixing procedure are labeled on this power consumption curve.

At the beginning of the cycle, the resistance of the paste tends to increase until the water is loaded into the mixing tank. Some seconds later, the cement paste starts to form and a lubricating action arises, thus the resistance of the mixture starts to decrease.

Therefore, the entire mixing procedure can be further divided into three macro phases:

(i) Dry phase: sand and cement are introduced together into the mixer without water.
(ii) Wet phase: a proper quantity of water is added to the dry mixture for final mixing. During the wet phase, the physical property and behavior of the mixture change.
(iii) Final mixing phase (regime): it starts after the water addition phase is completed. The mixer is still working for some time to allow a complete homogenization of the mixture.

In Fig. 5 one can observe that the power consumption is at its maximum value in the phase when the additives are loaded into the tank, while the regime phase is between the phase from 5 to 7. Since this is the longest phase of the mixing cycle, it can be considered as the most responsible of wear phenomena affecting blades. This is the reason why this paper is concerned with the regime phase and all the following models regard this phase.

2.1. Fresh concrete's model in the regime phase and actions on blades

During the regime phase (starting from point 6 in Fig. 5), the fresh concrete can be considered as an incompressible non-Newtonian fluid. The stress tensor for incompressible non-Newtonian fluids is given by

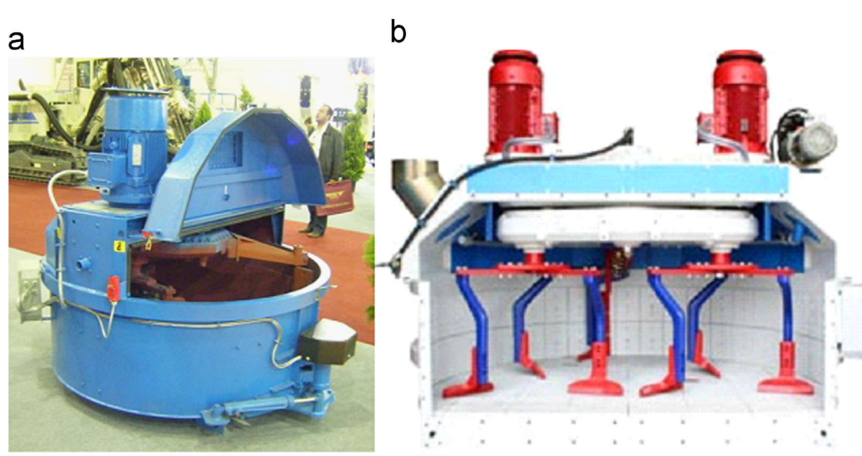

Fig. 1. Planetary concrete mixer: (a) single and (b) double star.