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ON THE INFLUENCE OF THE WORKING TOOLS SHAPE IN THE MIXING PROCES

PhD. Lecturer Carmen DEBELEAC
PhD. Lecturer Silviu NASTAC
"Dunarea de Jos" University of Galati,
Engineering Faculty of Braila
Research Center for Mechanics of the
Machines and Technological Equipments

ABSTRACT

Optimisation of the working tools used in industrial factory becomes a fast and effective method to be implemented easier in the production process. The article presents more design variants of a concrete mixer tools. The new obtained solution was the result of an optimisation process of constructive parameters, such as dimension, thickness, mass and shape. The numerical modelling was performed in Inventor 9 software. The function objective was to decrease the overall mass of mixer tools while improving its structural integrity.

KEYWORDS: concrete mixers, design, palette, mixing, resistance force circuit boards, vibration

1. INTRODUCTION

Concrete production consists of multiple interrelated steps, formatted by batching, mixing, consolidation, finishing, and curing. Each step of the entire process brings a unique contribution to the quality of the final concrete product. The aggregates that have pre-dosages, mixing, drying, anti-dustiness, selection and dosages, are introduced into the mixing equipment, in the same time with the binding. The mixing activity constitutes the last phase of the fabrication process and its efficacy depends on the mixture's quality. There are two main types of the mixers: batch and continuous. According to the mixing method, the mixers can be divided in to two groups: with compulsive and gravitational mixing [6].

2. PERFORMANCE CRITERIA FOR ESTABLISHING THE MIXER EFFICIENCY

The mixing process is feasible through the selection of a compromise between three technical and economical conditions:

- satisfactory homogeneity for the repartition of the granules and binding;
- necessary time for their obtaining;
- the energy needs into mixing process, such as indirect expression of the cost.

Also, into the mixing process intervene three factors:

- shearing, which is produced by the palettes during the mixing time;
- the effect of the velocity gradient (shear rate) of mass in a motion state;

turbulent dispersion, conceived through the Péclet's number notation with (Pe).

At the exit of the mixing equipment, the Péclet's number has the following expression:

$$Pe = \frac{vl}{c_d}, \tag{1}$$

where: v represents the transport velocity; l – length of equipment; c_d – diffusion coefficient.

It was observed [8] that when a small particle-sized dispersion is sheared, the effect of Brownian motion is longer lasting along the shear rate axis, and higher values of shear rate are needed to produce the same amount of shear thinning, see Figure 1. The mixing process is exothermic and the energy required to do this can be mathematically expressed as:

$$\frac{E}{m} = \frac{k\omega^{2t}t}{V} \qquad (2)$$

where:

E - mixing energy;
k - coefficient founded experimentally;
t - mixing time;
ω - rotational speed;
m - mass of the mixture;
V - volume of mixture in the mixer vat.

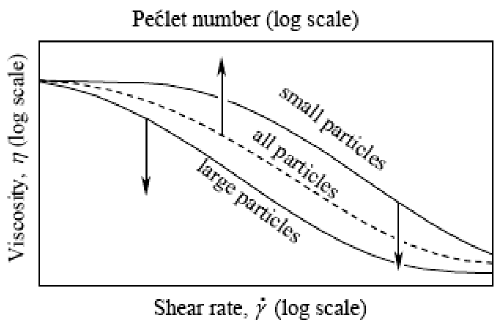


Fig. 1. A schematic diagram of the viscosity as a function of shear rate or Péclet number

In according with eq.(2) it results that the mixing time and rotational speed are the two parameters can affect the mixing energy for preparating any tip of mixture.

The quality of the concrete produced by the mixer equipments can be determined based on the new methodology that introduces the concept of “mixer efficiency”. Hereby, the mixer equipment is efficient “if it distributes all the constituents uniformly in the container without favouring one or the other” [1]. In practice, for evaluating efficiency of the mixer, two main properties of the mixing such as segregation and aggregate grading throughout the mixture should be monitored.

Behind many tests, from the concrete discharge, the average of measurements collected for specific parameter (fine element, water, etc.) and the standard deviation was calculated. Based on this information we can evaluate of the coefficient of variation (ratio of standard deviation to the average, *COV*) that will give a measure of the homogeneity of the concrete produced, i.e., a smaller *COV* implies a uniform mixture, see Table 1.

Table 1. RILEM efficiency criteria for concrete mixers [1]

Property	Performance criteria		
	Ordinary mixers	Performance mixers	High performance mixers
W/F with d_f<0.25 mm	COV<6 %	COV<5 %	COV<3 %
F content with d_f<0.25 mm	COV<6 %	COV<6 %	COV<3 %
D/2 to *D* content	COV<20 %	COV<15 %	COV<10 %
Air content		ΔM<2 % s<1 %	ΔM<1 % s<0.5 %

Legend:

F is the fine-element content (units are those of mass or mass/volume)
W is the water content (units are those of mass or mass/volume)
ΔM is the maximum residual
d_f is the maximum size of the fine aggregates (mm)
D is the maximum size of the coarse aggregates (mm)
s is the standard deviation

3. CONSIDERATIONS ABOUT MIXING PROCESS

The intensification of the process of mixing aggregates can be realized through technological methods (mixing composition, working regime, the components dosage, etc.) and constructive methods (the tip, the shape and the orientation of the working tools). At the mixer with horizontal axes with palettes, the material is driven up in direction of motion. Each palette transports a flow by material, which slides on the frontal side (fig.2).

In Figure 2 were schematized the forces that act over the palette. The components F_t and F_a move the material at transversal and longitudinal direction of the mixer equipment.

In present, the constructive solutions of the arm consist of steel bar with linear profile. The modification of this profile into a shape with a dynamical profile accomplishes an important requirement such as the intensification of the process of mixing through conduction of the concrete components along the arm with onward velocity.

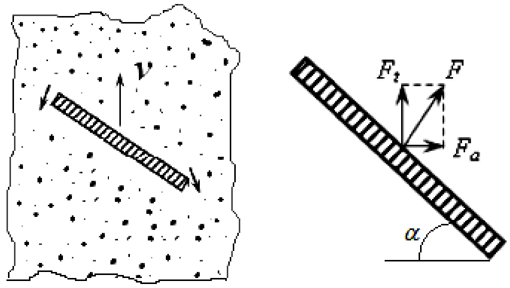


Fig.2. Scheme for palette action
a) the palette takes over the material; b) the forces that act on the palette

4. COMPULSIVE MIXING EQUIPMENTS

Compulsive mixing equipments (Fig. 3) are composed by the main parts as follows: vat, palettes, electric engine and transmission, hole for discharging and drive system for their manoeuvre.

With these equipments we obtain in a short period of time a very good quality of mixture but with more specific consumption (1…1,6 kW/m^3) because of a high resistance force which is developed on mixing at tools-aggregates interface.

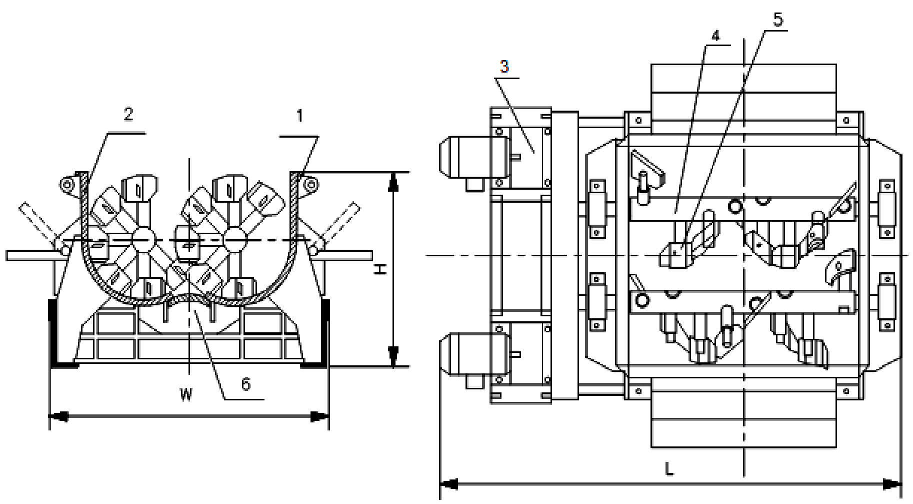


Fig. 3. Constructive scheme of the mixer with horizontal axes
1. vat; 2. plate; 3. drive system; 4. axes with arms; 5. palette; 6. hole for discharging.

Unfortunately, their structural configurations are more complex than others and lead both to the working tool damage increasing, and the exploitation expenses.

Hereby a greater specific power and mass results. Mixing resistance increasing is supplied by the friction between aggregates-pallets, and by the occlusion between pallets and vat.

The initial parameters used in this study were acquired from concrete mixer in operation in Romania. The technical data of the mixing equipment model consists of:

- power P_m=30 kW;
- productivity Q_T=50 m^3/h;
- time per cycle for mixing T=1.86 min.;
- number of palettes 16;
- index loading of vat k_u=0.6;
- internal radius of vat: R=0.550 m.

5. OPTIMISATION BASED ON STRUCTURAL DESIGN CRITERIA

Many researchers [3], [4], [5] developed multi-criteria optimisation tasks in order to evaluate geometrical variants of the solid body defined by design functionality requirements (e.g. minimizing mass, maximizing stiffness, etc) and, financial requirements.

Thus, the main innovations that are currently being worked in the speciality literature can be summarized as follows: producing mixers that reduce energy consumption and the time of mixing without affecting the quality of the concrete produced.

The speciality literature states two major objectives when designing details for a part [7]:

- obtaining the desired shape;
- using the state-of-the-art technology and material;
- accomplishing the function for which it was created.

The author considers that alternative design features to obtain better working tool shapes should correct three important aspects:

- diminishing of working tools usury;
- decreasing the resistance force in the mixing process by adopting the elliptical shape of mixer arms and palettes form;
- good homogenisation of concrete through choosing the longitudinal shape for the mixer arms.

The mechanical characteristics of the blending components have the influence on the resistance at the mixer-working tools that are evaluated through instrumental tests.

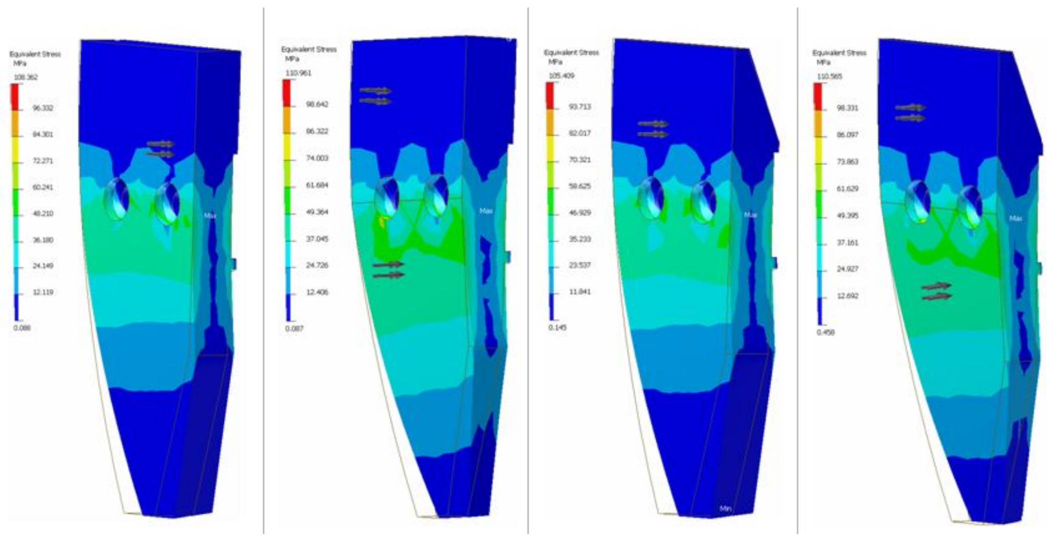
The loads case consists of the pressure at the side of the palette and at the arm, coming from the concrete mixture (e.g. p=1.5 daN/cm^2).

The modelling and FEM analysis was performed with Inventor 9 software [8].

The montage angle of the palettes to the spindle has to be 45^o because of the minimal probability of blocking for the blend particles between the end of the palette and the mixer drum.

In Figure 4 is depicted the influence of the palette shape on the stress configuration under the blend resistance action.

The objective function requisites for optimisation process were formulated as to minimise the weight of the working tool. The optimisation constraints are formulated based on the decreasing of the strains in different parts of the tools.



a) b) c) d)

Fig. 4. Optimisation of palette shape
a) initial shape; b) –c) intermediary shape; d) final shape.

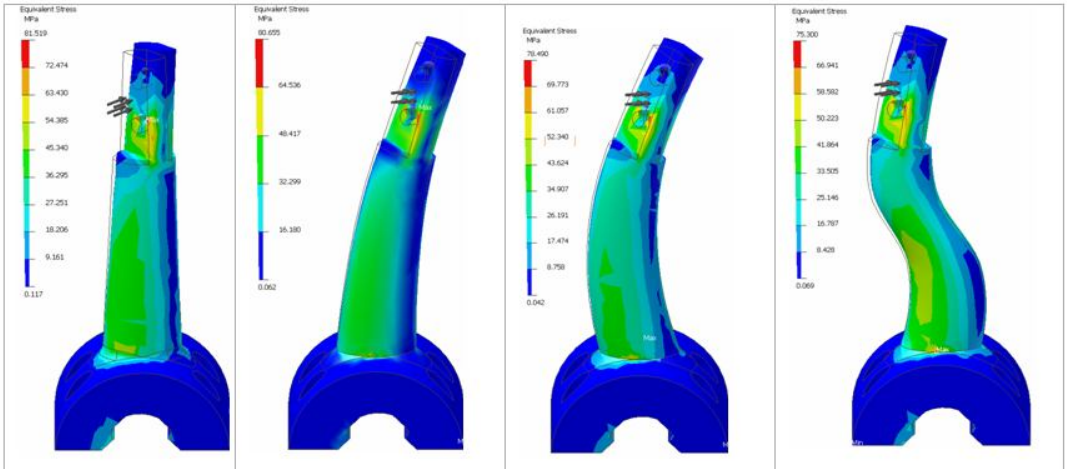
From constructive considerations, the arm can have several shapes of transversal section such as: rectangular, elliptic, oval, etc. Through all these sections, only elliptical shape opposes a minimal resistance force during the mixing process [1]. For this motivation, in this study, the author has adopted an elliptical section for mixer arms, with dimensions: a = 0.132 m, b = 0.064 m and the arm length l = 0.400 m.

The imposed performance requirements of mixer arms must be:

- resistance;
- easy technology for its execution;
- easier maintenance;
- minimum resistant force developed during the mixing process.

The objective goal of this analysis is that the arm shape contributes to the dynamics of the aggregates movement into the mixer vat.

According the last requirements, the arm shape had a different design by adopting dynamical longitudinal form, which will be analysed with modelling software, and the results was shown in Fig. 5.

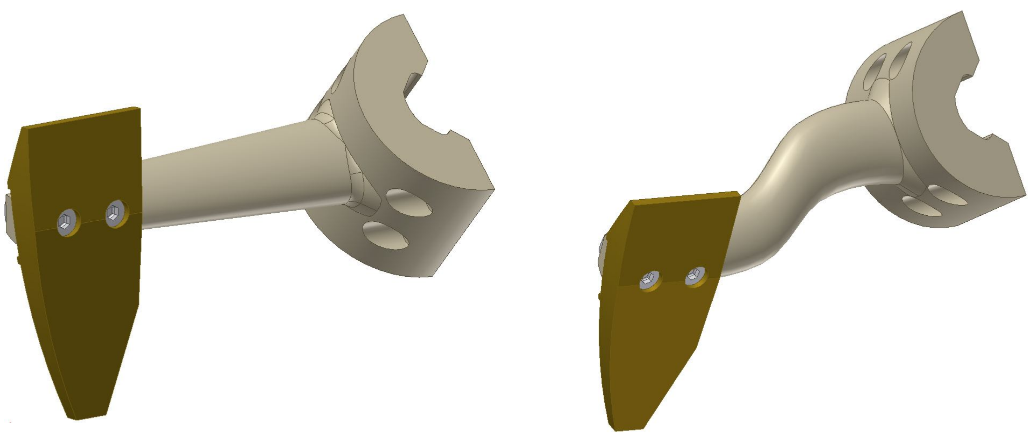


a) b) c) d)

Fig. 5. The analysis of stress state for the mixer arm

a) initial shape; b) –c) intermediary shape; d) final shape.

In Figure 6, two designs for mixer working tools are presented. In figure 5a is given the initial shape of the arm-palette ensemble which has been improved and in Figure 5b is represented the final shape which has been analysed with FEM and it results lower resistance force in the mixing process. The best solution obtained in the course of optimization displays lower average stiffness in relation to the initial model, as it can be see in Table 2 (for the same concrete blended).



a) b)

Fig. 6. Arm-palette ensemble

a) initial shape; b) final shape

Table 2. Optimisation results

Parameters	Working tool shape			
	Case from fig. 4a	Case from fig. 4b	Case from fig. 4c	Case from fig. 4b
mass, in kg	9	7.7	7.8	8
σ_{echiv},in MPa	81.51	80.65	78.49	75.30
ε, in mm	0.674	0.636	0.629	0.690

6. CONCLUSIONS

This paper contributes to improving the mixing performance of a mixer equipment with two horizontal axe, with compulsive mixing, by optimisation of the working tools with the view of reducing mass, resistant force per pallets (through changing the mounting angle on arm). All these diminish the power needed for equipment operation.

The result of the optimization process of geometrical parameters of the working tool mixer is a compromise between structural integrity (stiffness value) and low weight.

This study demonstrates that inclination of the arm face to axle and the inclination of the palette face to arm influence the tensions state and the deformations of the palette-arm ensemble during the mixing process.

The new shape of mixer tools ensures the optimal homogenous of blending for a less length of the mixer vat.

The optimization process resulted in the reduction of the tools (palette and arm) weight, as compared to the initial variant, at the level of 11 %.

The new shape of equipment arms increases the process quality for the blending of mixture components. Hereby, the intensification of the mixing process leads to the improvement of concrete quality and, at the same time, to the diminishing of the mixing time.

In situ tests will enable the proposed solution to prove its efficiency because it is the only way to test the homogeneous degree of the mixing, after changing the tools shape.

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