STUDIES AND RESEARCHES ABOUT THE MIXING PROCESS OPTIMIZATION AND ABOUT MIXING DEVICES IN CASE OF THE NON-NEWTONIAN MIXTURES

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Abstract: The study has as objective the optimization of the mixing process of products with variable viscosity by optimum chooses of function parameters.
To achieve the objectives of this study it was made researches about the viscosity of non-Newtonian mixtures by S-L, propriety which characterise the homogenisation degree and power consumption.
To realise the experimental researches, it was used a laboratory stand which allows the study of mixing process of non-Newtonian mixtures with variable viscosity.
During the study it was made the simulation of mixing process hedged by ANSYS soft, based on the method of finite element.

Keywords: non-Newtonian mixtures, the method of finite element, mixing process.

1. INTRODUCTION

The mixing process of non-Newtonian phases is complicate, because the flow resistance of this phase is modified with the change the shredding force speed making their flow no uniform.

The non-Newtonian mixtures are characterized by apparent viscosity (consistence) defined as the monphasic final system viscosity, homogeneous and isotrop which in similar flow conditions generate the same load lost like a nonhomogenous final system.

Because of this, the non-Newtonian mixtures (final products) obtained from mixing process, rheologicaly speaking, can be grouped in three categories:

- non –Newtonian mixtures with viscosity independent by time (ex. Suet, soft pastes of cheese, the margarine);
- non – Newtonian mixtures with viscosity dependent by time (ex. the mashed fruits, the mayonnaise between certain limits of temperature, etc.);
- viscoelastic mixtures (ex. panification doughs).

A major part in the mixing process optimization for non-Newtonian mixtures is given by the value of the structural apparent viscosity in function of this rheological propriety, can be selected the next parameters:
- the type, the shape and the dimensions of the mixing devices;
- the revolution of the mixing device;
- the position of the mixing device reported to the mixing tank axis;

- the time needed to realise the mixing process etc.

The knowledge of these parameters influences directly the obtaining of the mixing homogenisations degree (the reduction of the temperature gradients and/or concentration) and power consumption needed to realise the mixing process.

The mixing operation is more efficient if the mixture resulted is uniform and is obtained with a low consumption of power in a short time.

According to affirmations from above, we try to determine the structural apparent viscosity by measuring the resistance opposed in a non-Newtonian mixture, creates in mixing devices arm and shaft a deformation shape which cam be correlated with the value of the torsion moment.

The correlation of the deformations value with the torsion moment value was realised with Catman 8 soft.

In consequence, it was determinated the calculus relation for structural apparent viscosity in function of the torsion moment:

$$\eta_a = \frac{3 \cdot M_t}{2\pi \cdot \omega \cdot R} \qquad (\mathrm{Pa \cdot s}) \qquad (1)$$

where:
η_a the structural apparent viscosity, Pa·s;
ω - the angular speed of the mixing device, rad/s;
R – the radius of the mixing device, m;
Mt – the torsion moment from the mixing device's shaft , N·m.

2. THE EXPERIMENTAL TECHNIQUE

2.1. The establish of the non-Newtonian mixture

For the experimental study, it was used a binary non-Newtonian mixture by type solid-liquid (S-L), with the next characteristics (table 1 and table 2):

Table 1: The type, the nature and the participation of the phases.

No. crt.	The nature of the phases	The type of the phases	The participation %
1	Liquid	Water	75
2	Solid	Superior meal 000	25

Table 2: The proprieties of the phases

Nr. crt.	The propriety	U.M.	The type of phases	
			Water	Superior meal 000
1	The density in bulk of the mellow meal	kg/m^3	-	530
2	The density to work temperature	kg/m^3	998.2	-
3	The temperature	°C	20	20
4	The umidity	%	-	11,5
5	The viscosity of the meal	Pa ·s	-	1915

2.2. The experimental stand

In figure 1, is presented the schema of the laboratory stand used for the analyse structural apparent viscosity of the non-Newtonian mixture by soft consistence.

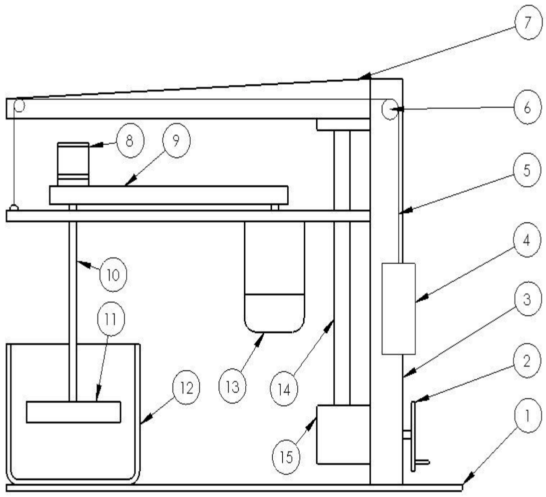


Fig. 1. The schema of the laboratory stand:
1 – the bare plate, 2 – the wheel, 3 – the frame, 4 – balance weight, 5 – cable for equilibration,
6 – windlasses, 7 – –cable for equilibration, 8 – collector ring, 9 the transmission by cogged belts,
10 – shaft, 11 – arm, 12 – cylindrical tank, 13 – electric engine, 14 – adjustment by height of the mixing device,
15 – gear

2.3. The measuring schema

The parameter studied – the structural apparent viscosity- is determinated indirectly by measuring the torsion moment of the mixing device’s shaft.

The deformations value will be transformed with Catman software in torsion value.

For the torsion moment determination, which born into the mixer device’s shaft is utilized electro resistive transducers TER. These transducers are applied into a shaft section in two exactly opposite points; each pair of points is arranged at 45º, reported at that shaft axis (fig. 2). The four electro resistive transducers are bond in a complete bridge (fig. 3).

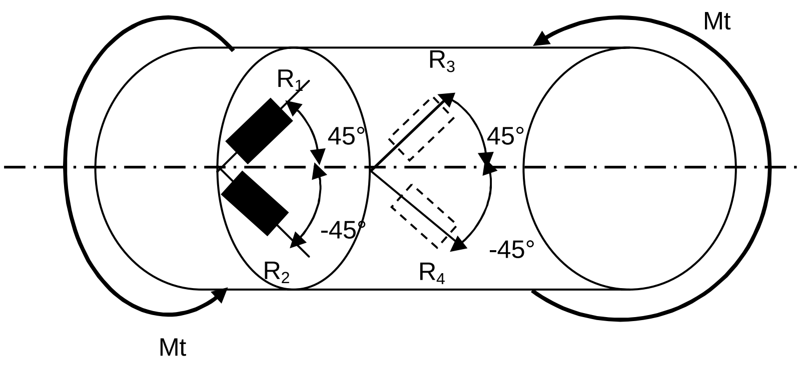


Fig.2. The schema of disposing of the TER marks on shaft.

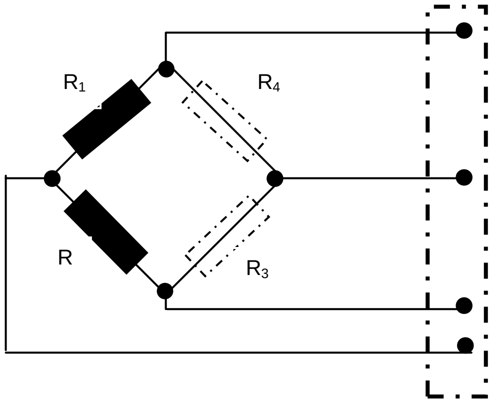


Fig.3. The schema of connection in bridge of TER marks.

In figure no.4, is presented the measuring scheme of parameters which influence the mixing process.

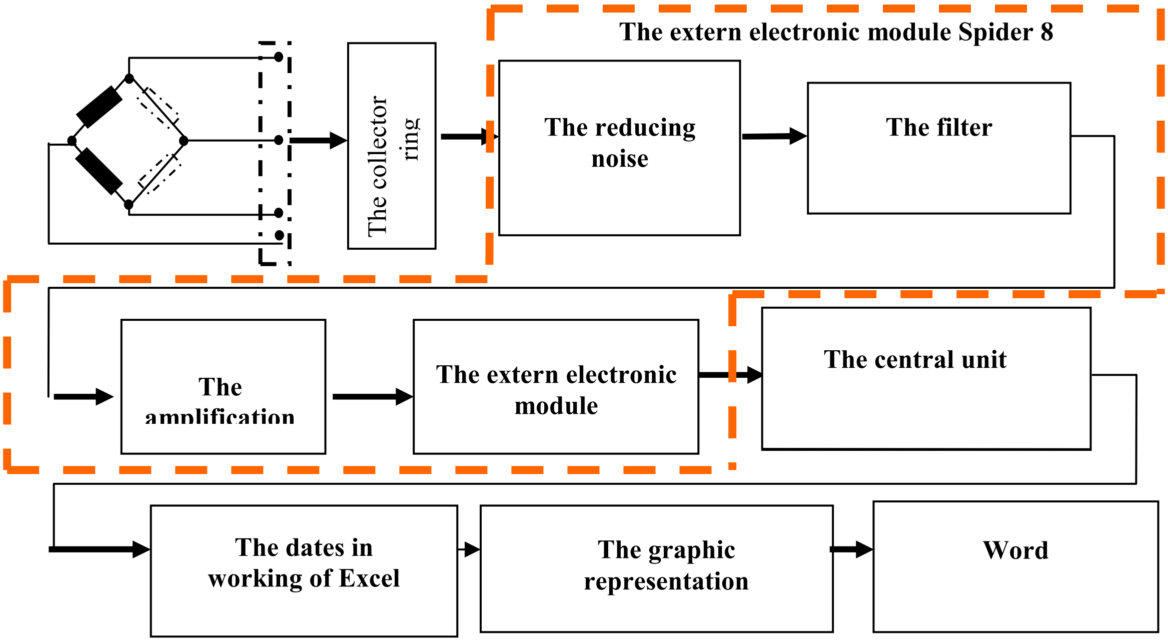


Fig. 4. The schema of measurement for the torsion moment.

3. OBTAING RESULTS

The variation mode of structural apparent viscosity depending on time for a mixture with average consistence (25% meal participation and 75% water participation), for constant revolution n = 90 rot/min and 50% filling degree is presented in figure 5.

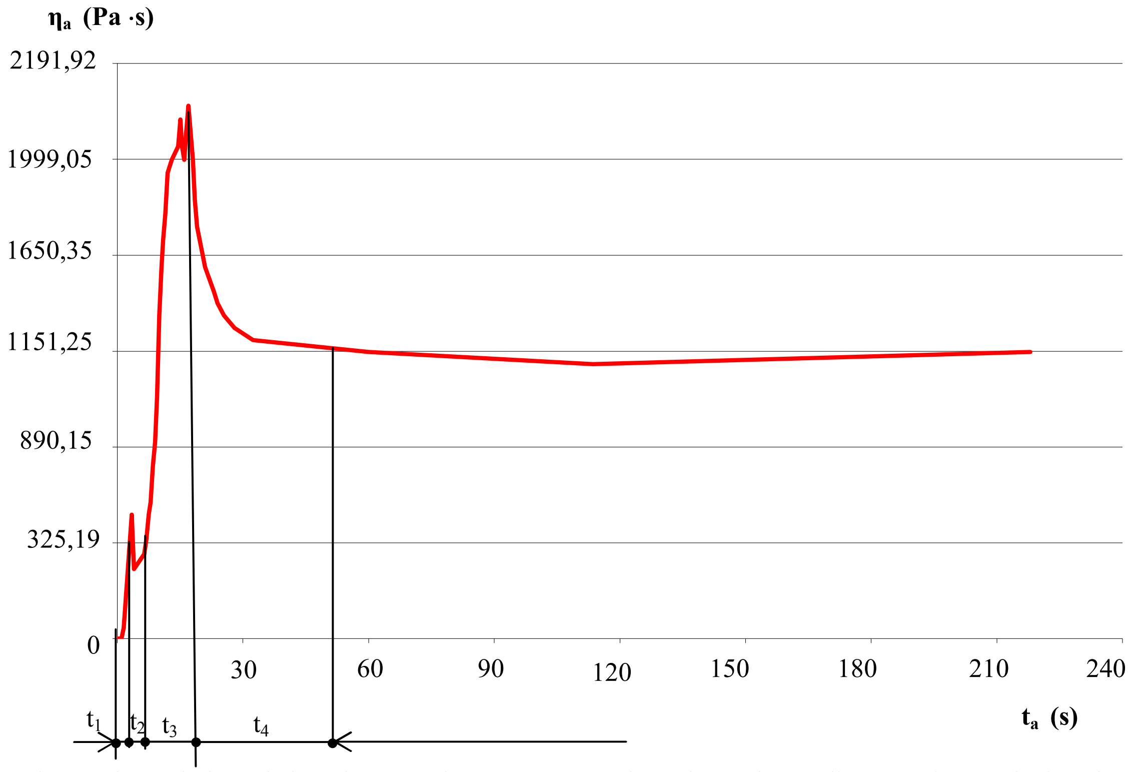


Fig. 5. The variation of viscosity (η_a) for a non-Newtonian mixture by medium consistence in function of mixing time (t_a), at constant revolution:
t_1 – time when in the mixing tank is only the solid phase, s;
t_2 – the introduction time of liquid phase, s;
t_3 – time needed for forming of the viscous mixture, s;
t_4 – the homogenization time, it is considered the maximum homogenous degree when the torsion moment become constant, so, the viscosity is constant

4. THE MIXING DEVICE`S OPTIMISATION BY FINIT ELEMENT METHOD

The results frequently used after MEF analyse are concerning about determination of deformations, along to the three axis of the reference system, by normal tensions, tangential tensions, principals, after each direction (from three of them), going through remanent tensions, pressure variations, temperature, forces and resultant moments, until the variation curve of the total energy or of the deformation kinetic energy.

The basic steps into finite elements analyse (fig.6) helped by ANSYS soft are:

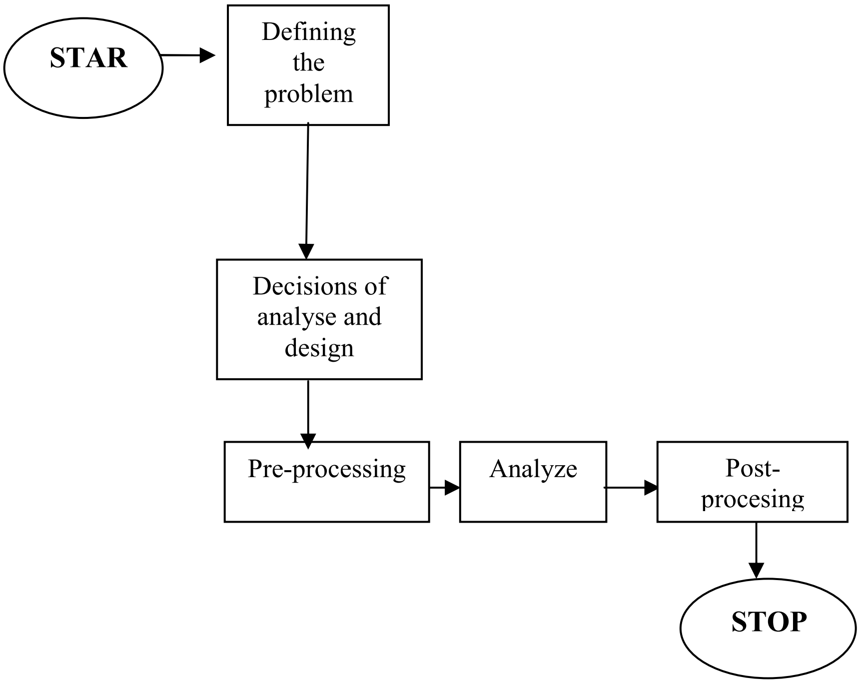
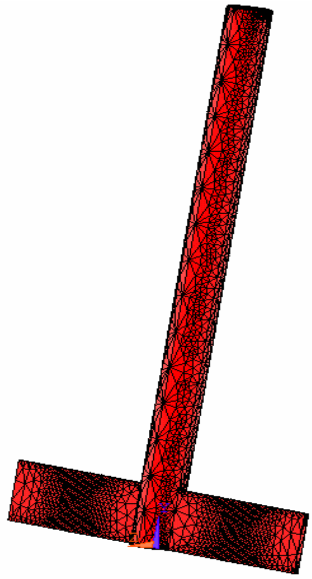


Fig. 6. The steps of finite elements analyze

The figure 7, presents the finite knots network generated in the mixing shaft and paddle.



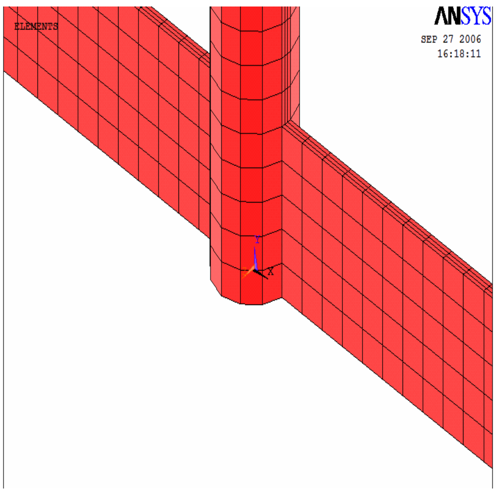


Fig. 7. The mixing devices division

Figure 8, presents the torsion moment variation under graphic shape.

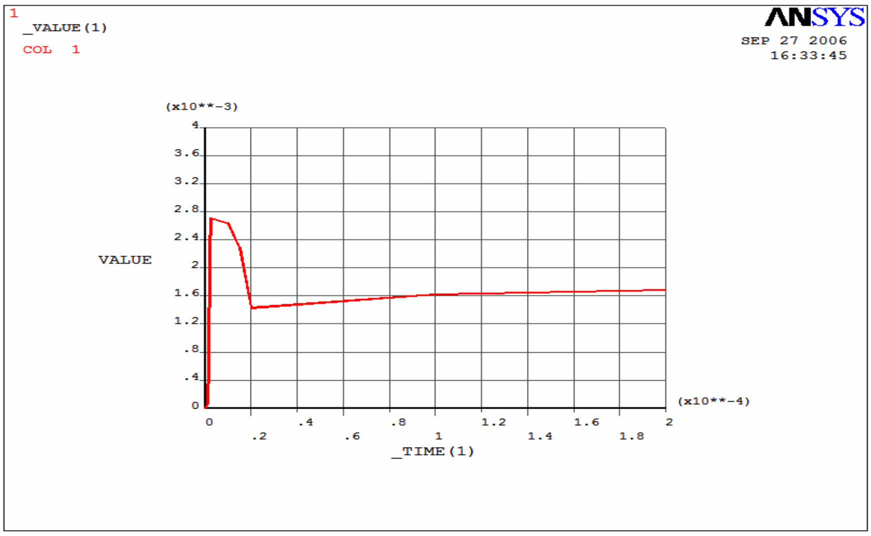


Fig. 8. The torsion moment variation in time in function of solicitation state

Figure 9 and 10 presents the deformation shape for a shaft with a full circular section and for a shaft with tubular section.

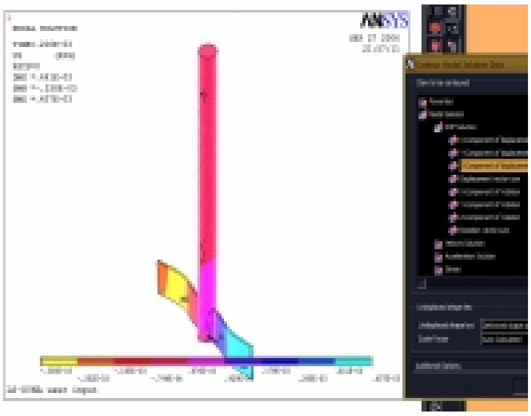


Fig. 9. The deformation shape for a shaft with full circular section

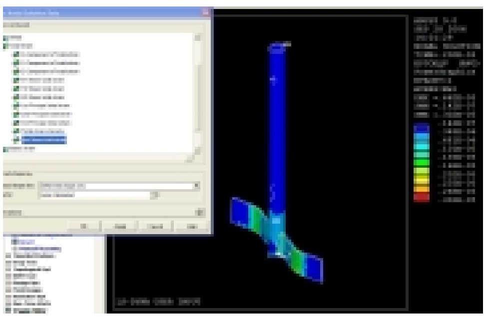


Fig. 10. The deformation shape for a shaft with tubular section

5. CONCLUSIONS

The structural apparent viscosity of the non-Newtonian mixture by soft consistence varieties in direct proportion with the torsion moment value and in indirect proportion with angular speed of the mixing device.

According to the relation 1, after a mixing time, the structural apparent viscosity became constant, which it meens that the resistance force opposed by work environment was defeated.

The constant value of structural apparent viscosity meens that it was obtained the homogenization degree needed.

Knowing the structural apparent viscosity, could be established the dimensions and the working regime of the mixing device.
Comparing the results obtained on deformations which born in shaft with full circular section and in shaft with tubular section, it is recommended to obtain a non-Newtonian mixture by soft consistence, to use shaft with tubular section. Because, the shaft with tubular section resist to the same solicitation shape like the shaft with the full circular section. From this point of view, the shaft by tubular section is economically more viable (low consumption of material).

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