Polyfactors method examination on the transition process (a-phase) of a milking machine pulsation system

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Abstract. ***a***-*phase determines a transient process of milking machine pulsation system, that have an essential influence on the machine milking process. The idea is to create a milking machine with shorter transient process with higher rate (for example 2 Hz), that will be adequate to calve suckling process. In this study was proved that the minimum time of transition process of* ***a****-phase, which can be received in a normal milking cluster is 60,85 ms in the following combination of the controlled factors: f = 1 Hz (60 min*$^{-1}$*) , pulsator capacity (*Q_0 *= 838,3 cm*^{3}*/s). The possibilities for shorter transition processes can be searched mainly in the capacity of the pulsator to suck the air from pulsation tract, which means that it is necessary to be looked for new constructive solutions for faster operating pulsators.*

Keywords: milking machine, pulsation rate, transient processes.

Inrtoduction

As it is known, the milking process can be divided in four phases: **a, b, c** and **d** while for the transition phases **a** and **c** it is recommended to be minimized in order to be increased the share of the working **b** and **d** phases within one milking (pulsation) cycle.(Craig at al., 1991; Peris at al., 2002; Rosen at al., 1983; Wilson at al., 1991). The maximizing of **b** and **d** phases is at the expense of the minimizing of the transition **a** and **c** phases. (Billon and Gaudin, 2000 and Restima at al., 1981). This will lead to an augmentation of the effectiveness of the milking cluster, i.e. of its flow capacity (by the increase of the milking **b**-phase) and its stimulating and healthy function (by an increase of the massage **d**-phase). As a result, in the end this will lead to a reduction of the milking time and safer milking regime. From the two transition **a** and **c** phases, the **a**-phase, which is influenced more by the factors of the milking process, is of bigger interest. This way, formally, the aim of the planned experiment can be presented by the function of the response: ***a*** *= Y min.*

Material and methods

On the basis of the carried out single factor experiments (Banev and Peychev,1999; Banev, 2001) it can be supposed that the biggest influence on the phase of the milking process have the pulsation rate, the machine vacuum, the working capacity of the pulsator and the capacity of the liquid (the milk) through the milking liner. That is why the following are chosen as controlled factors during the execution of the planned experiment: x_1 – pulsator rate (range of change from 60 to 120 min^{-1}), x_2 – machine vacuum (with range of change from 30 to 50 kPa), x_3 – capacity of the pulsator (with a change from 258 to 1032 cm^3) and x_4 – flow rate into the milk track of the milking liner (range of change from 30 to 60 l/min).

The carried out a priori, theoretical single factor examinations (Banev, 2001; Peychev, 2001) show that the phases of the milking process are in complicated relations to one another as well as to the numerous outer factors, many of which are not given an account here (for example: material, shape and measurements of the milking liner, type of the pulsators, size and shape of the collectors of the milking machines, etc.). All of this imposes planning of the experiment from a higher level, i.e. construction of a more compound regression model appearing as a second degree polynom:

$$Y = a_0 + a_1.x_1 + a_2.x_2 + a_3.x_3 + a_4.x_4 + a_{1,2}.x_1.x_2 + a_{1,3}.x_1.x_3 + a_{1,4}.x_1.x_4 + a_{2,3}.x_2.x_3 + a_{2,4}.x_2.x_4 + a_{3,4}.x_3.x_4 + a_{1,1}.x_1^2 + a_{2,2}.x_2^2 + a_{3,3}.x_3^2 + a_{4,4}.x_4^2, \quad (1)$$

where Y is the function of the response;

x_1, x_2, x_3, x_4 – controlled factors;

a_0, ..., a_{22} – coefficients.

For this purpose plan B4 of the experiment was used.

A regression analysis based on the software product Statistica 7 is used for analyzing the results. Its symbols for each element are as follows:

R – coefficient of multiple correlation;

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R^2 – coefficient of determination (it is used to define the quota of the controlled factors in the description of the examined process);

F (9,15) – Fisher criteria;

P – probability of the received mathematical model to be adequate. The model is adequate if P<0,1, i.e. below the level of the trust probability from 0,1.

It appears that the transition phase of the impulse has the strongest influence on the reduction of the whole time of the transition process. This the reason why the accent in the present work is put on the transition process from "massage" regime to "milking" regime (**a-**phase).

Results and discussion

In that case mathematical model is searched

$$a = f\,(f, H, Q_0, Q_m), \qquad (2)$$

where a is time of the transition process from massage to milking (so called phase a);

f – pulsation rate of milking liner;

H – vacuum level;

Q_0 – capacity of the pulsator;

Q_m – flow rate into the milk track of the milking liner.

Dependence (2) can be presented in the statistical space according to the symbols in 1 as:

$$Y_1 = f\,(x_1, x_2, x_3, x_4) \qquad (3)$$

After analysis of the data using Statistica 7 can be found the statistically significant coefficients.

Based on the data of table 2 it can be written the following regression equation:

$$Y_1 = 11{,}685 + 4{,}644.x_1 + 2{,}500.x_2 - 2{,}956.x_3 + 0{,}133.x_4 + 0{,}650.x_1.x_2 - 0{,}800.x_1.x_3 + 0{,}075.x_1.x_4 - 0{,}625.x_2.x_3 + 0{,}665.x_2.x_4 + 0{,}200.x_3.x_4 + 0{,}034.x_1^2 - 0{,}466.x_2^2 + 4{,}234.x_3^2 - 0{,}766.x_4^2 \qquad (4)$$

In this case the coefficient of determination is $R^2 = 0.9906$. This means that the quota of the input (controlled) factors cause 99,06% influence on the change of the output parameter Y1. The probability P<0,1 which means that the mathematical model (4) is adequate and describes correct the examined process.

The question is: what is the influence of each input factor on the change of the output parameter? In order to answer to this question it has to be repeated the calculations while every one of the input parameters x_1, x_2, x_3, x_4 is excluded in strict order. In that case R^2 is again analysed – the smaller the indicator, the more significant the excluded factor. In this case the following results are received for R^2:

with all factors: $R^2 = 0{,}9906$

without x_1: $R^2 = 0{,}4605$

without x_2: $R^2 = 0{,}8132$

without x_3: $R^2 = 0{,}7029$

without x_4: $R^2 = 0{,}9747$.

The importance of the controlled factors can be ranged in the following way: x_1, x_3, x_2, x_4.

The significance of x_1 (pulsation rate) is dominant on the transition process from "massage" to "milking" (**a**-phase). The rest of the factors in order of importance x_3, x_2, x_4 cause considerably weaker influence, more over that for the three values the probability, calculated using the Fisher' criteria, is smaller than the trust one, while for x_1 this probability is bigger.

For the analysis of the regression equation it is convenient to draw the graphic relations for the first two in significance input factor x_1 and x_3. In Figure 1 it is showed 3D graphic of the function $Y_1 = f\,(x_1, x_3)$, and in Figure 2 – the lines of similar response. From the graphics can be concluded that Y_1 min is received in values of the controlled factors about x_1=-1 and x_3=0,3 (in real dimensions x_1=60 min^{-1} and x_3=838,3 cm^3/s).

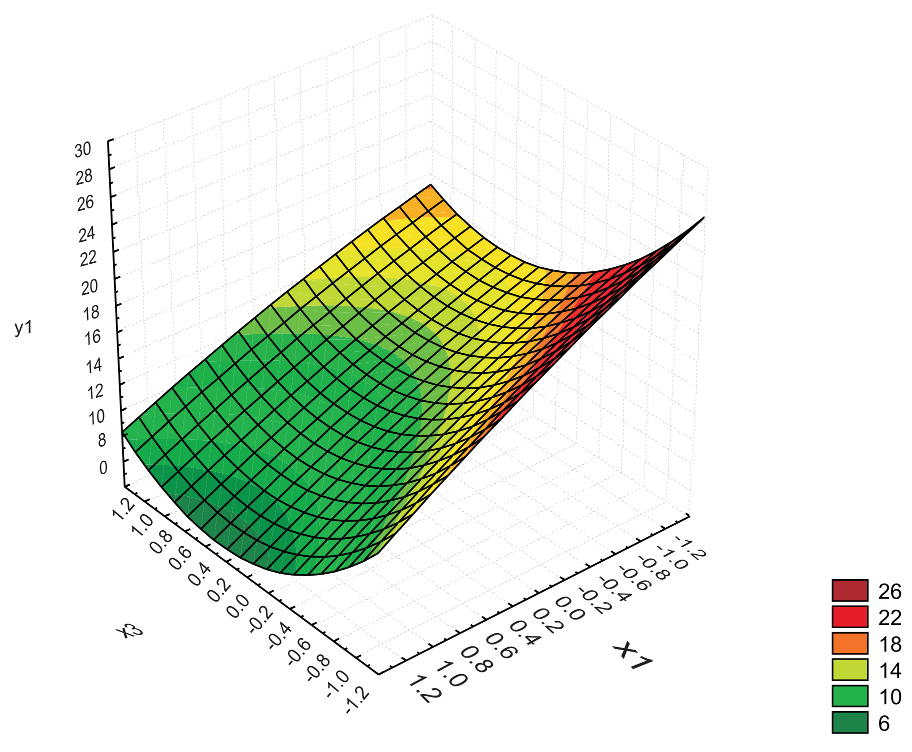

Figure 1. 3-D graphic of the function $Y_1 = f\,(x_1, x_3)$.

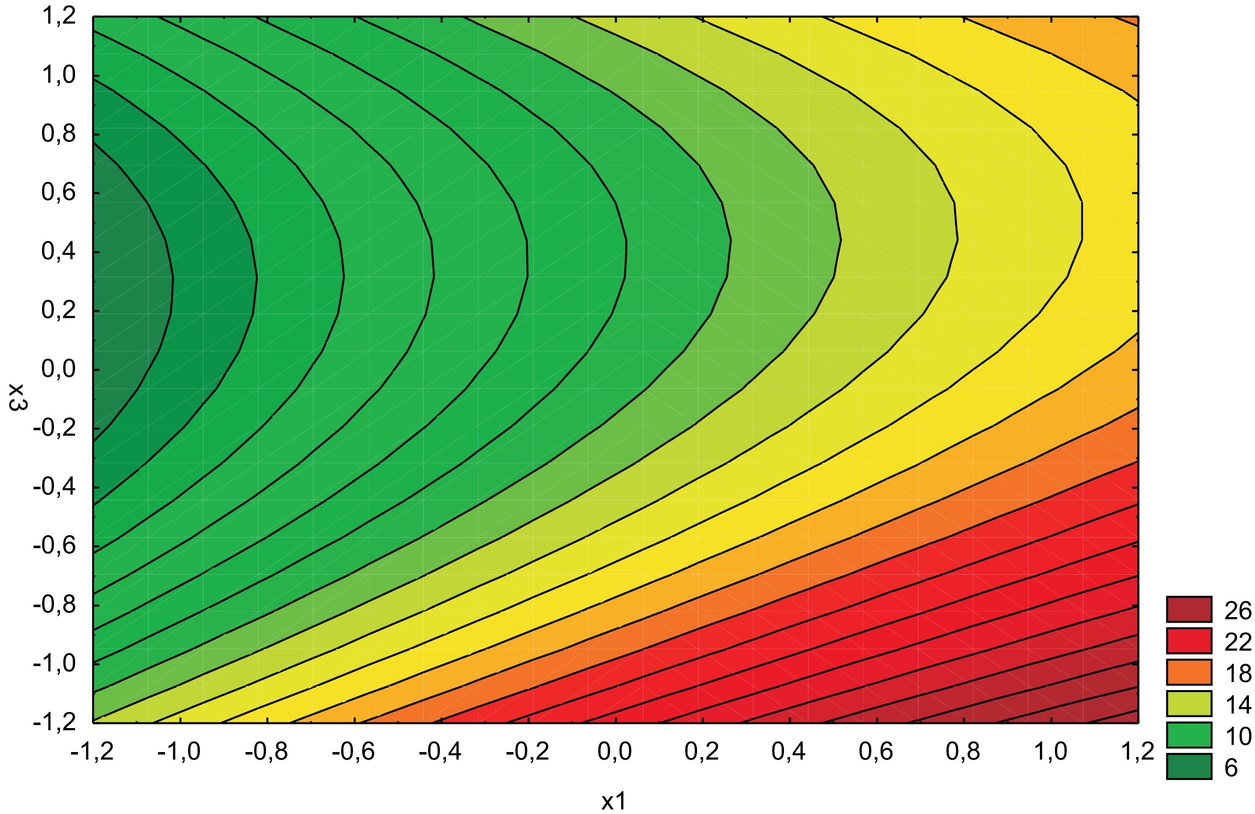

Figure 2. Lines of similar response.

Conclusion

The minimum time of transition process of phase a, which can be received in a normal milking cluster is 60,85 ms in the following combination of the controlled factors: f = 1 Hz (60 min^{-1}), pulsator capacity (Q_0 = 838,3 cm^3/s). The possibilities for shorter transition processes can be searched mainly in the capacity of the pulsator to suck the air from pulsation tract, which means that it is necessary to be looked for new constructive solutions for faster operating pulsators.

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