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Research on the influence of the technical conditions of a homogenizer pump on the quality of the process of pressure homogenization

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A b s t r a c t. The research presented in this paper refers to the role of the technical condition of the plunger pump's working units vis-a-vis the quality of homogenised emulsion. Technical condition was determined 'on line' by analysing the measured value of the signal of homogenisation pressure. This signal contains - among other things - some information about the condition of the plunger pump's valve unit. The process quality was determined by the process affecting value changes of the dispersion phase characteristic dimension. The particle size was measured using a microscope.

The influence of the pump's working condition estimates on a homogenised product's quality was researched by a correlation-regression analysis. As a result of that procedure a strong stochastic relationship between the product quality and the values of the chosen estimates of the pump's technical condition was found. Among many factors of major importance influencing product quality, the mean value of homogenisation pressure is not alone; the energy distribution observed in the signal's amplitude spectrum also is of considerable importance. Exponential regression models were obtained for the relationships investigated.

K e y w o r d s: homogenisation, monitoring

INTRODUCTION

During recent years a strong tendency towards quality improvement is being observed in the production of food-processing machinery. This is combined with the high quality requirements demanded from food products. Apart from the need of supervising each step of the production process, the real time monitoring of these machine units, which determine directly the product quality, is also necessary. Such monitoring enables the device's work to be evaluated currently, to predict its future states and to detect sudden emergency situations. The quantitative determination of the relationship between a machine's technical condition and the product's quality parameter has therefore become substantial [1].

This paper presents research concerning the role of the homogeniser pump's technical condition on the quality of products manufactured using pressure homogenisation.

MATERIALS

A mathematical description of working processes occurring inside the homogeniser's chamber and head is inadequate because of many simplifying assumptions; it may be used however mainly for qualitative analyse. Without neglecting the role of models, it may be said, that there is no sense in searching for them to determine precisely the device's technical conditions as many alternative solutions exist. Such alternative solutions are those methods of machine diagnostics, based mainly on statistical knowledge, engineering and mathematical logic [3].

In the approach based on the systems theory, the major role in describing working processes occurring inside the pressure homogeniser is played by the signal generated by homogenisation pressure measurement. This signal contains some information concerning the technical condition of the homogeniser pump's forcing system and valve unit . The measurement and the relevant digital conversion of the pressure signal enable the technical condition of the above mentioned units to be determined. In order to choose a researching method allowing the information needed to be saved for the investigation process, the preliminary test on the station for testing pressure homogenisers was carried out and its results were converted by using some methods of analysing discrete time series. The following methods were taken into account:

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– a classic, statistical analysis of time series using the decomposition method,
– analysis and modelling of the Auto-Regressive Integrated Moving Avarange (ARIMA) time series,
– a method of correlative identification using the functions of mutual
– correlation and the mutual spectral density of signal powers,
– a method of orthogonal identification,
– spectral analysis of time series based on the Fast Fourier Transformation (FFT) procedure.

As a result of the actions carried out, the structure of the monitoring system was based on a general pattern recognition algorithm. The synthesis of particular tool algorithms needed for making the next steps of that method was performed by using the following research methods:
– conversion of digital signals including spectral analysis and homomorphous filtration in order to eliminate convolution disturbances,
– experiment planning, the PS/DS-P3-1 plan was used,
– cluster analysis,
– discriminatory analysis.

An evaluation of the pressure homogeniser pump's constructional and exploitational condition was carried out by giving simple estimates of the pressure signal in the time and frequency domain.

The value change of the dispersion phase particles' characteristic size - d estimator was assumed as the homogenisation product's quality measure. Depending on the distribution of the characteristic size, one of central distribution tendencies like the arithmetical mean, median or mode was used as an estimator. The choice was based on distribution symmetry. Tests of the role of the pump working state estimates in the homogenised product's quality were carried out using correlative and regressive analysis.

In order to take the measurement and the analyse the signal generated by the homogenization's pressure of the examined homogenizer type CH 010 a test stand was made; a scheme of this is presented in Fig. 1.

Figure 2 shows the general scheme for performing the test procedure.

The equipment of the testing station permitted the measuring and recording of the pressure and temperature courses at the homogeniser's input and output, the pressure inside the working chamber, the temperature inside the crankcase, electricity consumption, crankshaft rotation speed and the volumetric flow rate.

Tests were performed at a dairy shop using the CH010 pressure homogeniser installed in the milk processing line. Pasteurised milk of 1.8 % fat content used for the production of yoghurt was examined. Process effectiveness tests were done at the Chair of Food Processing Machinery, Technical

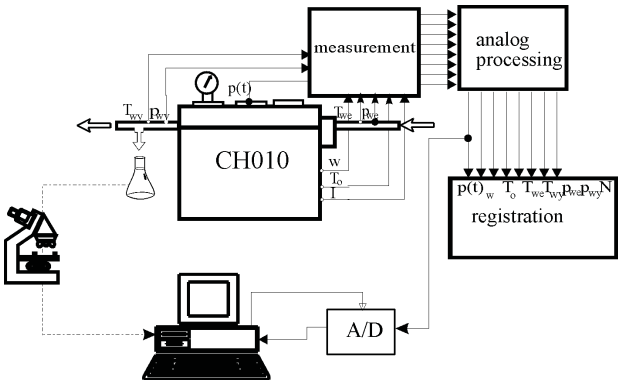

Fig. 1. Scheme of the testing station.

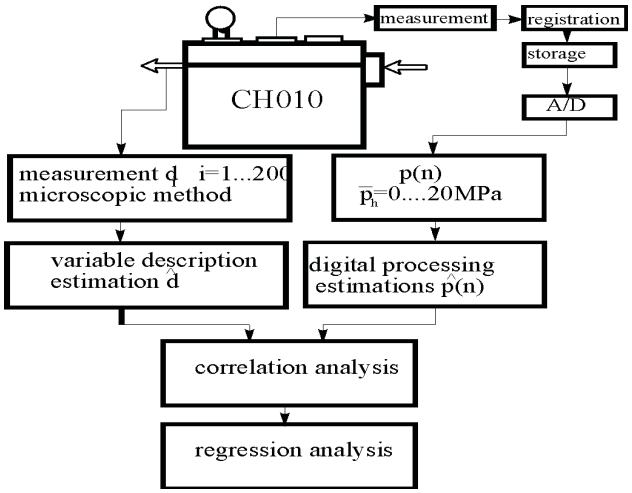

Fig. 2. Scheme of the test algorithms.

University of Lublin. Two measurement series after 10 and 500 homogeniser working hours were performed.

RESULTS

The classification analysis performed in 2-dimensial space allowed the homogenizer's working condition to be divided and grouped into 4 classes:
A – failure case;
B, E – work before failure;
C – proper work.

Figure 3 shows the graphic form of the cluster analysis applied in two-dimensional space of the test object's characteristics. The A estimate is the standard deviation normalised signal amplitude value in the time domain and the ζ estimate is the ratio of the Fourier transform coefficients.

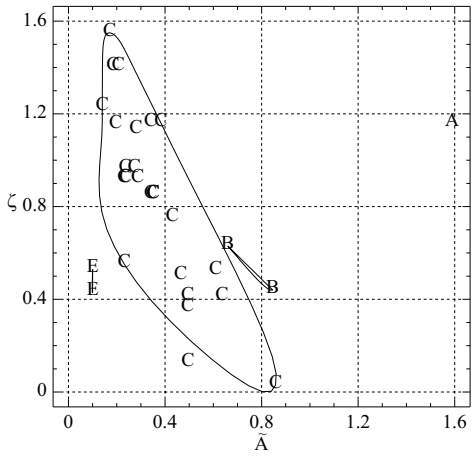

Fig. 3. A graphic form of classification analysis results. A two-dimensional space of the test object's characteristics. A - failure cases, B, E - work before failure, C- proper work.

The correlation analysis showed that there is a highly statistically significant stochastic relationship between the size of the particle of the dispersion phase and the the amplitude and the homogenization pressure variance: r =- 0.6 and r = - 0.47 using the exponential regression models. There is also a relationship between the characteristic size of particles and estimate of the pressure spectrum.

Table 1 shows the results of the inter-relationships of the variables.

Figure 4 shows the regression curves with Neyman's confidence intervals marked for $\alpha = 0.05$ and $\alpha = 0.01$.

CONCLUSION

As a result of the procedure being conducted, a high stochastic relationship between product quality and the values of chosen estimates of the pump's technical condition was found. It must be emphasised, that the highest value of the correlation calculated and the determination coefficients was obtained for a relationship determining the influence of the signal amplitude spectrum energy distribution as a measure of the pump's constructional and exploitational condition and the homogenisation product's quality.

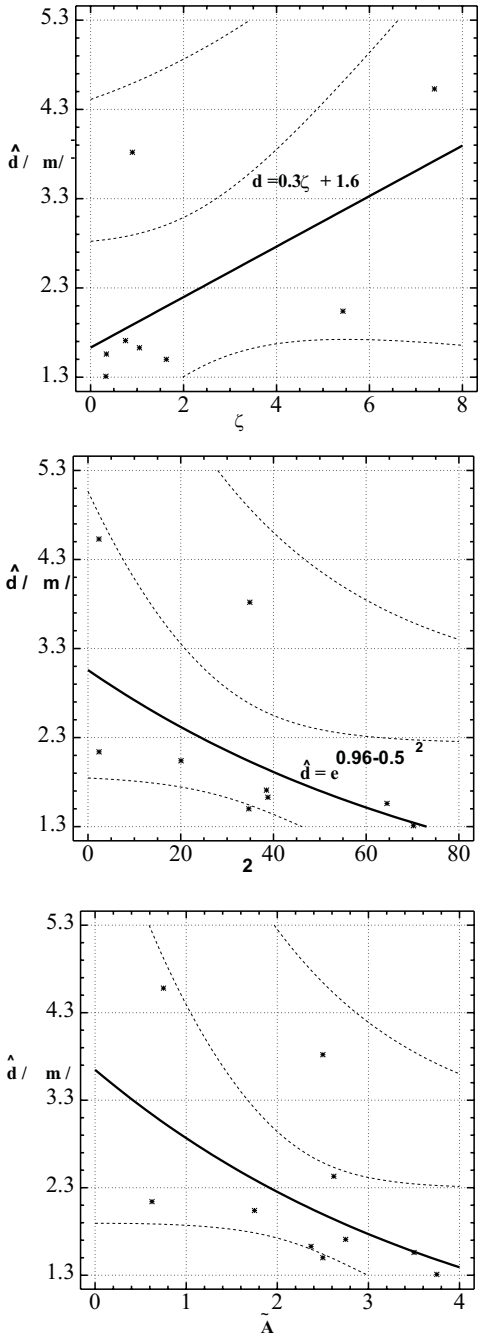

Fig. 4. Regression curves.

T a b l e 1. Results of the inter-relationships of the variables

Relationship	Correlation coefficient r	r significance level	Determination coefficient (%)	Regression model	a significance level	b significance level
A – d	- 0.60	0.05	36.1	$d = e^{1.3-0.2A}$	0.01	0.06
σ^2 – d	- 0.47	0.07	22.2	$d=e^{0.96-0.5\sigma 2}$	0.01	0.10
ζ - d	0.62	0.02	38.7	d=0.3ζ+1.6	0.09	0.02

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