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Research and development of dosage devices for powdery products

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1. Introduction

Beam scales are not reliably precise, their application in automatic lines are complicated. It can be stated that those scales are obsolescent. New metrological requirements are much higher for precision and reliability and they force companies to renew their equipment by purchasing new electronic weighing machines or refurbishing their beam scales. Therefore in many companies old mechanical weighing machines are recently replaced by modern electronic machines.

Many various measuring operations can be performed in modern automated control systems. Data of measurements are transformed into forms suitable for acquisition, transferring, analysis and visualisation of measurements results. In this purpose, various sensors, controllers and computer aided systems are used for automation and in-situ control of technological processes.

Electronic weighing machines, used in high productive system of grains supply and dosage, are analysed in this article. Implementation of those machines was related with perfection of their design, aiming to increase their efficiency and precision [1-3].

2. Modernisation of powdery products dosage system

Constantly increasing requirements for production quality incites the modernisation of dosage systems [4-6], making them more precise and reliable. A powdery products (malt) dosage device has been designed and installed in joint-stock company Kalnapilis aiming to increase the precision of dosage.

Previously, a mechanical beam batcher was used in brewery for dosage of powdery products. However the characteristics of this batcher were unacceptable for increased requirements of production: mechanical scales were able to weigh doses of malt (depending on used receipt those doses can vary from 3000 to 3850 kg) with deviation of ± 100 kg. Usually scales were weighing large amount of malt, what influenced expenses of production and influenced quality of final product (beer).

A new automatic electronic tensometric scale (Fig. 1) has been designed and produced aiming to reduce expenses and improve quality of the products.

Operation of this new dosage system is given here. Product from container of malt is supplied by helical and tape transporters into transitional container. Grains from this container go through batcher of scales into the container of weighing. Once powdery product (malt), which spread evenly in the whole container of weighing, is weighed, this container is hanged on three supporting points – tensometric transducers SHBxR (*Revere Transducers Europe*, Holland). Those transducers have nominal metrological load of 50 kg. That gives relatively equal loads for each transducer. Analogical signals from transducers are transferred into signal acquisition device – controller. From this device signal is transferred into numerical indicator 1310 (*Avery Berkel*, Great Britain) which has the feature of programming and is connected with the main control board of the beer production control system. Weight of every dose, total weight of dosed powdery product and number of weighing are registered.

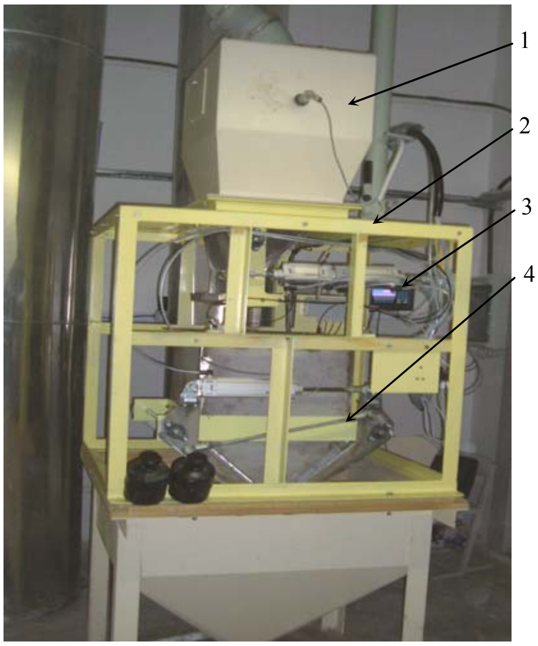

Fig. 1 New powdery product dosage device. Here *1* - transitional container, *2* - main frame of the devise, *3* - numerical indicator and *4* - container of weighting

This new dosage device contains weighing container with maximum capacity of 80 kg of malt, but regarding to the request of consumer, malt is measured in portions of 50 ± 0.02 kg. Accumulating malt required for beer brew, its amount is adjusted after every weighted dose and total deviation of the weight is less than ± 0.02 kg.

3. Analysis of interaction between powdery product and automated dosing system

3.1 Analysis of scales dynamics

Mass of powdery product can be defined in static conditions when all required dose is collected or in dynamic conditions while the product is falling into the container of weighing. However there are moments in both methods when impact loads, vertical and horizontal vibrations of the scales are generated.

In the analysis of scales dynamics [7-9], a model of the system is composed using mass of the container and varying mass of powdery product connected with supports through elements of stiffness and damping. That allows stiffness evaluation of scale's structural elements and energy dissipation characteristics. Dynamic forces, generating vibrations of the scales, can have harmonic and impulse (impact) origin. Possible movements of the scales in direction of X coordinate axis can be linear motion and vibrations. Container of the scales, depending on accepted design, may be put (hanged) on two, three or four mass sensors.

The scales can weigh powdery products of mass $M(t)$ which can vary from 50 to 80 kg. Deviation of weighing is ± 0.02 kg.

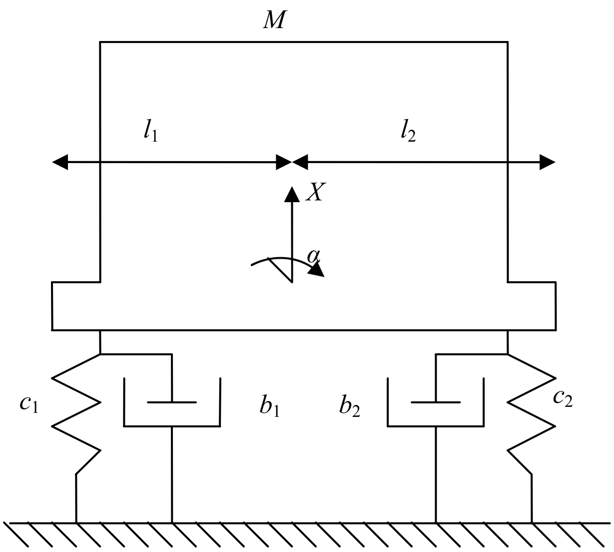

Fig. 2 Simplified dynamical model of the system

Simplified dynamical model (Fig. 2) can be given in a form of differential equations.

Equilibrium condition for forces affecting masses of the scales

$$\begin{cases} M(t)\ddot{x}+(b_1+b_2)\dot{x}+(c_1+c_2)x+(b_1l_1-b_2l_2)\dot{\alpha}+ \\ +(c_1l_1-c_2l_2)\alpha=F(t) \\ M(t)\rho^2\ddot{\alpha}+(b_1l_1^2+b_2l_2^2)\dot{\alpha}+(c_1l_1^2+c_2l_2^2)\alpha+ \\ +(b_1l_1-b_2l_2)\dot{x}+(c_1l_1-c_2l_2)x=0 \end{cases} \quad (1)$$

here $M(t)$ is the mass of powdery product and container (is given as M in further equations); x is motion of the scales in X direction; c_i is reduced coefficient of scale's stiffness; b_i is reduced coefficient of scale's damping; l_i is the distance from the centre of masses; α is the angle of scales turning; ρ is distance between centre of the mass and geometric centre of sensor's allocation, $F(t)$ is excitation force.

If $l_1=l_2=l$

$$\begin{cases} M\ddot{x}+(b_1+b_2)\dot{x}+(c_1+c_2)x+(b_1-b_2)l\dot{\alpha}+ \\ +(c_1-c_2)l\alpha=F(t) \\ M\rho^2\ddot{\alpha}+(b_1+b_2)l^2\dot{\alpha}+(c_1+c_2)l^2\alpha+ \\ +(b_1-b_2)l\dot{x}+(c_1-c_2)lx=0 \end{cases} \quad (2)$$

Dividing equations of the system by M and ρ gives

$$\begin{cases} \ddot{x}+2(h_1+h_2)\dot{x}+(\omega_{01}+\omega_{02})x+2(h_1-h_2)l\dot{\alpha}+ \\ +(\omega_{01}{}^2-\omega_{02}{}^2)l\alpha=\frac{1}{M}F(t) \\ \ddot{\alpha}+\frac{2l^2}{\rho^2}(h_1+h_2)\dot{\alpha}+(\omega_{01}+\omega_{02})\frac{l^2}{\rho^2}\alpha+ \\ +\frac{2l}{\rho^2}(h_1-h_2)\dot{x}+(\omega_{01}{}^2-\omega_{02}{}^2)\frac{l}{\rho^2}x=0 \end{cases} \quad (3)$$

where $h_i=\frac{b}{2M}, \omega_{0i}=\sqrt{\frac{c}{M}}$.

If α = 0, the second equation of the system is

$$\frac{2l}{\rho^2}(h_1-h_2)\dot{x}+(\omega_{01}{}^2-\omega_{02}{}^2)\frac{l}{\rho^2}x=0 \quad (4)$$

This condition is satisfied when

$$h_1=h_2=\frac{h}{2};\omega_{01}{}^2=\omega_{02}{}^2=\frac{\omega_0{}^2}{2}$$

If $F(t)=F_0\, sin\omega t$, it can be written

$$x(t)=\frac{F_0}{M\omega_0{}^2}\Big\{-2h\omega\cos\omega t+(\omega_0{}^2+\omega^2)\sin\omega t- \\ +e^{-ht}\left[-2h\omega\cos\omega_h t+\left(h^2+\omega\frac{\omega_h{}^2-\omega^2}{\omega_h}\right)\sin\omega_h t\right]\Big\} \quad (5)$$

where $\omega_h=\sqrt{\omega_0^2-h^2}$.

Spectrum of the system forced vibrations should be considered in analytical and numerical calculations of the system parameters. It means that frequencies of vibrations corresponding to the highest amplitudes should differ from the system's own frequencies as much as possible.

3.2 Experimental research

One of the most reliable methods to improve the results of supplied powdery product (malt) and the scale interaction is experimental research. Impact forces are affecting scales and mass sensors during the supply of powdery product and moments of valves opening and closing.

Installing of the new design dosing system in the automated production line was followed by several problems. First of all the initial design of the system was not rigid enough, that caused large amplitude scales movements and relatively long period of time for reduction of the system's free vibrations. Too large amplitude of scale motion caused breakage of the sensors and long period of vibrations reduction disturbs weighing of the product and gives unsatisfactory results or even can terminate this process.

Therefore experimental research of the scales dynamics was carried out. Main aims of experiments was the determination of sources of the mentioned problems (high amplitudes of vibrations and long periods of vibration's reduction time) applying methods of vibrodiagnostics as well as evaluation and improvement of dosage system condition based on those experimental results.

Experiments were carried out using computer based analyser of vibrations: portable personal computer with special software for vibrations analysis, two channel signal converter (PICO ADC - 212, Great Britain) and two mechanical sensors of vibrations (KV - 12, Germany).

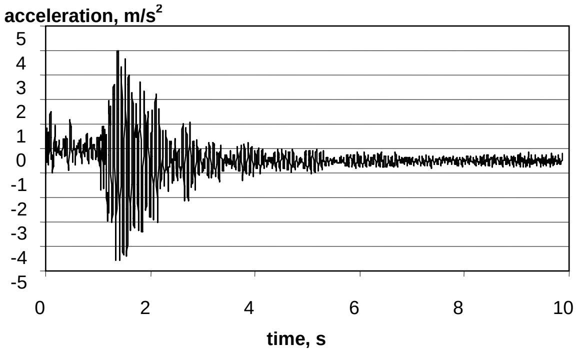

Fig. 3 Time-frequency characteristic of the initial design system

Results of free vibrations measurements of initial design system (with low rigidity) are given in Fig. 3. This picture shows that the period of vibrations reduction is quite long. It takes about 1.5 - 5.0 s and is too long for a dosage system. New cycle of weighing process after removing of the collected amount of the product from weighing container should start after 2 seconds. Besides, pulsations of vibrations can be highlighted, that shows reducing vibrations of the system consist of two modes similar resonance frequencies.

Spectrum of low rigidity system's vibrations is given in Fig. 4.

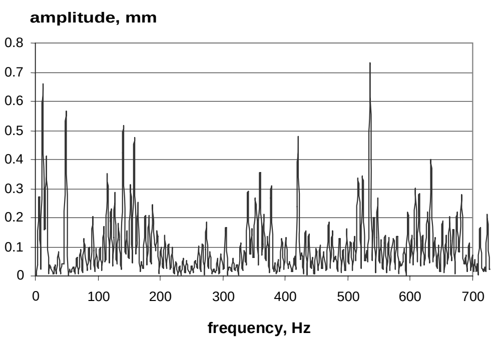

Fig. 4 Amplitude-frequency characteristic of the low rigidity system's vibrations

Analysis shows that the main source of problems is low stiffness of the machine's frame transversal beams, which are supporting tensometric transducers. This insufficient stiffness of the frame caused long period of scales vibrations, overdue of supply valve's opening and overloading of the container with powdery product. Overloading of collecting container caused that level sensor of the container was sending signal to the main control system to stop malt supply (weighing process). Once all beer production line is fully automated, that caused many problems of production, operators of the systems had to remove collected malt by hands, etc.

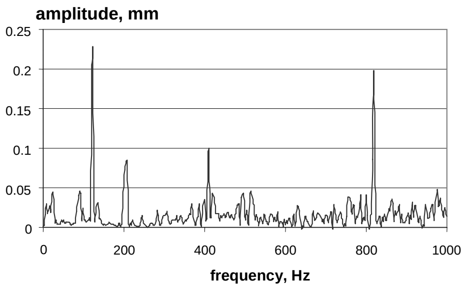

Fig. 5 Amplitude-frequency characteristic of the improved system vibrations

Increasing stiffness of the scale frame and transversal beam for fixture of tensometric transducers solved those problems. Process of weighing could go without unpredicted stopping and better precision of the product dose mass was achieved. Amplitude-frequency characteristic of the improved system vibrations is given in Fig. 5 and amplitudes of vibrations during one operation cycle of the dosing system are given in Fig. 6.

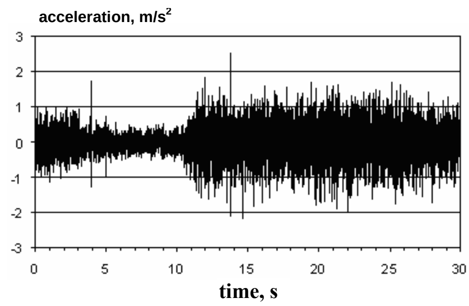

Fig. 6 Amplitudes of vibrations during one operation cycle of the dosing system

Fig. 6 shows, that the length of one malt dosing cycle is 30 seconds. Measurements of the collected mass are running between the 3rd and 4th second. Opening and closing of pouring out valve, it means pouring out of the collected dose of malt takes 4 - 5 seconds. After removal of the powdery product, the system waits between the 5th and 11th second before supply of grains will start again. Malt supply to the weighing container takes about 22 seconds.

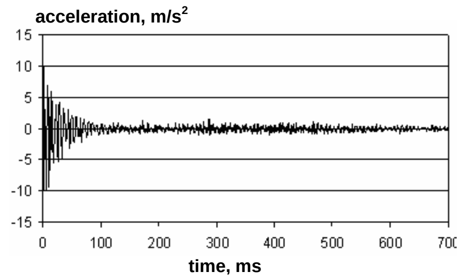

Fig. 7 Amplitudes of vibrations of the dosing system with increased rigidity

Besides, this graph shows that the amplitude of vibrations (external noise) during the state of waiting is 0.3 m/s^2. The amplitude of vibration during the opening of removal valve is about 1.8 m/s^2 and during its closing about 1.1 m/s^2. The amplitude of vibrations during supply of grain is from 2.1 m/s^2 to 1.0 m/s^2 (average is 1.5 m/s^2).

Period of the dosage system settling down is about 0.25 - 0.26 s.

Characteristic of increased rigidity system vibrations (Fig. 7) shows that vibrations are reduced in 150 ms. That is enough for continuous and precise operation of the automated powdery product dosage system.

4. Conclusions

1. Dosage system ensures the collection of powdery product (malt) dose with total mass precision of ± 0.02 kg. Therefore it can be stated that weighing of powdery product is very precise.

2. This batcher can be successfully used for any dosage of any powdery products into bags, big containers in automated production processes.

References

1. **Dambrauskas A.** Automatinių valdymo sistemų optimizavimas .-Vilnius: Technika, 2003.-304p.
2. **Bansevičius R., Giniotis V.** Mechatronic means for machine accuracy improvement.-Mechatronics, 2002, 12, p.1133-1143.
3. **Mitchell, John S.** Introduction to Machinery Analysis And Monitoring.-Tusla: Penn Well Books, 1993.-230p.
4. **Bubulis A.** Preciziniai vibraciniai įrenginiai skysčiams ir birioms medžiagoms dozuoti. -Kaunas: Technologija, 1999.-159p.
5. http://www.usda.gov/gipsa/reference-library/vrml/scale1.htm
6. http://www.intersystems-inc.com/prime/html/products/bulk_weighing.htm
7. Вибрации в технике: справочник. -Москва: Машиностроение, 1978, т-1.-352с.
8. Вибрации в технике: справочник.-Москва: Машиностроение, 1980, т-3.-544с.
9. **Žiliukas P., Barauskas R.** Mechaniniai virpesiai. -Kaunas: Technologija, 2001.-309p.

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BIRIŲ PRODUKTŲ DOZAVIMO ĮRENGINIŲ TYRIMAS IR TOBULINIMAS

R e z i u m ė

Straipsnyje nagrinėjamos automatizuotos elektroninės svarstyklės, įrengtos AB „Kalnapilis“ didelio našumo automatinėje grūdų tiekimo linijoje. Patobulinus svarstyklių konstrukciją gerokai padidėjo linijos našumas ir tikslumas. Modernizuota svarstyklių dozavimo sistema užtikrina biraus produkto – salyklo dozavimą ±0,02 kg tikslumu.

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RESEARCH AND DEVELOPMENT OF DOSAGE DEVICES FOR POWDERY PRODUCTS

S u m m a r y

In this article automatic electronic scales, which are installed in supply – dosage line of malt in “Kalnapilis” company are analysed. Some improvements in construction (increasing of rigidity) of weighing machine have been made during installing of the scales into automatic production line. As a consequence of these changes, an increase in productivity and precision of the scale has been obtained. Dosing system ensures the total weight of powdery products (malts) with precision ± 0.02 kg.

А. Бубулис, В. Юренас, R. Кранчюкас

ИССЛЕДОВАНИЕ И МОДЕРНИЗАЦИЯ УСТРОЙСТВА ДОЗИРОВКИ СЫПУЧИХ МАТЕРИАЛОВ

Р е з ю м е

В статье рассматриваются автоматизированные электронные весы, работающие в линии подачи сыпучих материалов на предприятии АО „Kalnapilis”.

Приведены исследования повышения точности динамических характеристик процесса дозировки, определены основные параметры, влияющие на точность и быстродействие дозировки, что позволило повысить точность дозировки до ± 0,02 кг.

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