DRUG DEVELOPMENT AND INDUSTRIAL PHARMACY, 9(8), 1495-1505 (1983)

DIOSNA P25 HIGH-SPEED MIXER EQUIPPED WITH INSTRUMENTS FOR MEASURING THE RATE OF ROTATION OF THE MAIN IMPELLER MOTOR SHAFT

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ABSTRACT

An optical incremental encoder, combined with suitable electronic equipment of an analogue or digital type, proved to be a very sensitive instrument for obtaining measurements of the rate of rotation of the main impeller shaft.

The high sensitivity of the equipment could not be fully exploited, as the mains voltage fluctuation and the heat effects on the gear box caused some uncertainties in the measuring. When lactose was granulated with gelatin solution, impeller and chopper working at a high speed, the uncertainties were approximately ± 1-2%.

INTRODUCTION

The need for a reliable and reproducible technique for determining the end-point of granulation became especially obvious when high-speed mixers were introduced.

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 0363-9045/83/0908-1495$3.50/0

On the basis of observations of the current required during granulating experiments with a Lödige high-efficiency blender, it was decided that the granulation cycle was apparently capable of being instrumented. This relieved the operator of the necessity of determining the point of proper granulation (1). Diosna P600, equipped with amperemeters, indicated both the consumption of the impeller and that of the chopper (2). Systems based on current and power devices, or measurements of torque and mass temperature, were considered inconvenient. Therefore a system was constructed which made it possible to detect changes in momentum of granules moving in a constant velocity region of the mixer bowl (3). A way of determining the uncritical quantity of granulating liquid by means of power measurements on planetary mixers was also adopted, for use with intensive mixers (4,5). Measurements of the power input to the impeller and the chopper motor of Diosna P25 could be used in controlling the granulation process (6).

In different process-regulation techniques, the changes in the load of the machines are usually gauged by using optical incremental encoders, i.e. digital transducers. Digital measuring devices are especially suitable when the measurement quantities are to be processed in computers.

This study was performed to evaluate the use of an optical incremental encoder for measurements of the speed variation of the main impeller motor shaft of Diosna P25 during the agglomeration process.

EXPERIMENTAL

Mixer

The Diosna P25 high-speed mixer, with a bowl capacity of 25 l, had two 3-phase induction motors both with two fixed speeds. The shifting between speeds was carried out by means of shifting the number of poles in the motors. The impeller motor had a power capacity of 1.5 kW, and the idling speed of the impeller was 188 and 375 rpm, respectively. The power capacity for the chopper motor was 3.0 kW and the idling speed of the chopper was 2100 and 4200 rpm, respectively. These speeds were measured with a stroboscope[1].

Instrumentation

The capitals in parenthesis refer to Fig. 1. The main impeller motor was positioned vertically. The fan blade of the main impeller motor was removed from the end of the motor shaft. An adapter (A) was mounted on the shaft end. A distance piece (B) was attached to the lower edge of the motor (E) around the shaft. The optical incremental encoder[2] (C) was attached at the other end of the distance piece. The spindle of the encoder was connected to the adapter with a bellows clutch (D).

The transducer consisted of a slotted wheel and an optic pick-up containing a light source and a photo transistor. Each time a slot was passed the pick-up gave an impulse.

A phase-locked loop[3] (PLL) was connected to the optical incremental encoder, Fig. 2. The input frequency, F_I, from the transducer was received by the limiter which fed the signal to the phase comparator (PC). In the voltage-controlled oscillator (VCO), a signal of frequency F_O was simultaneously generated and also fed to the PC. The signals of the frequencies F_I and F_O met in the PC, where the sum and difference frequencies were obtained. An internal low pass filter removed the sum frequency component. The difference

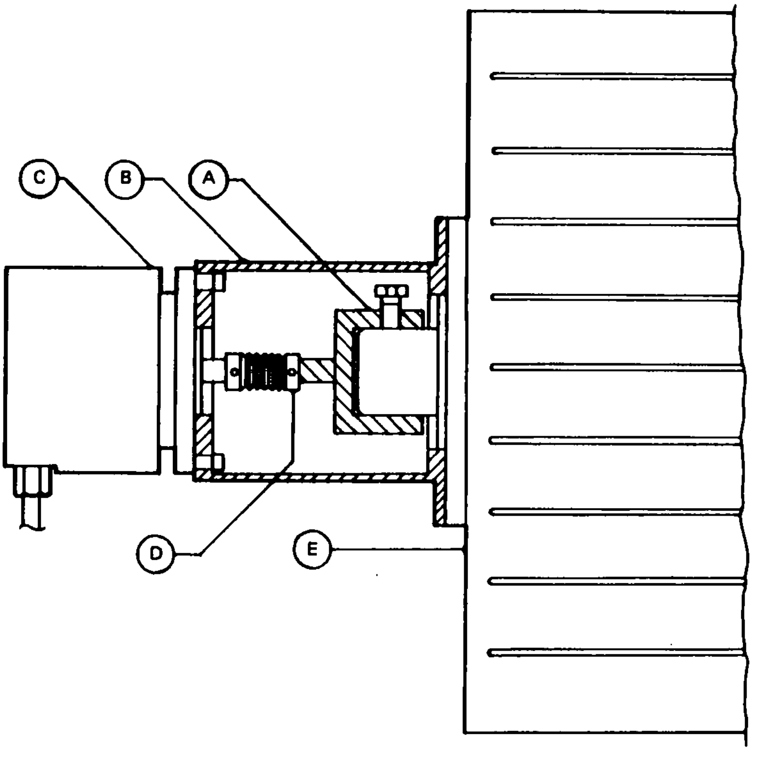

FIGURE 1

Principal sketch of instrumentation.

A Adapter

B Distance piece

C Optical incremental encoder

D Bellows clutch

E Lower edge of the impeller motor

frequency component, which was a DC voltage component, was amplified and fed back to the VCO. The DC signal, U_{corr}, was linearly related to F_I, i.e. the variation in motor shaft speed

$$U_{corr} = K^{-1}(F_I - F_O)$$

where K^{-1} was a constant. This voltage was filtered through a low pass filter and an offset adjustment de-

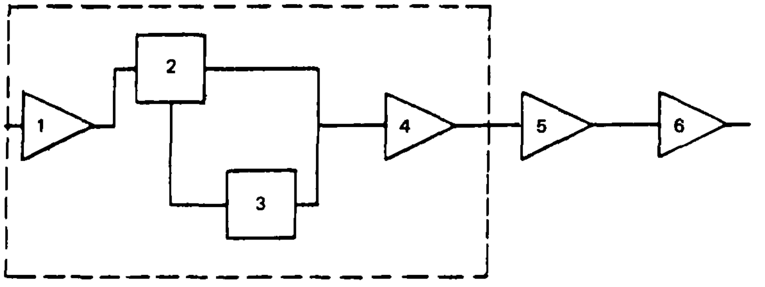

FIGURE 2

Block diagram of electronic equipment.
The phase-locked loop is symbolized by the rectangle of lines of short dashes.

1 Limiter
2 Phase comparator
3 Voltage controlled oscillator
4 Amplifier
5 Low pass filter
6 Offset adjustment device

vice and fed to a strip-chart recorder[4]. PLL and light source were supplied by 5V DC[5]. The offset adjustment device was supplied by 15 V DC[6].

Alternatively, the signals from the transducer were fed to a frequency counter[7] and interfaced to a computer[8] and a printer[9].

The impeller motor was cooled by letting compressed air into a jar in which the motor was partly contained.

Pump and nozzle

The granulating solution was added through a nozzle of the two-fluid type[10]. The air pressure was 69 kPa (10 lb/in^2). The solution was pumped through a peristaltic pump[11] with a variable flow rate through a tube of 8 mm inner diameter.

Granulation

7 kg of lactose 350 mesh[12] was granulated with a 8.6 (w/w)% aqueous solution of gelatin at 45 - 50°C[13]. The granulating solution was added at a flow rate of 250 g/min, either with or without atomization. Before adding the solution, the powder was mixed for 3-4 min with the main impeller but without the chopper. When the granulating solution was added, the chopper was started immediately. Granulations were performed with high or low impeller speed, the chopper rate being high.

RESULTS AND DISCUSSION

Instrumentation

The accuracy of the transducer was ±0.014%, as the dividing fault which states the precision in the shaping of the slotted wheel was ±50 electric degrees[14] and one rotation was 360 000 electric degrees, i.e.

$$\pm \frac{50}{360\ 000} \simeq \pm 0.014\%$$

The linearity of the PLL was checked by an oscillator[15]. The output signal from the PLL versus the frequency within the range 17 - 27 kHz for low impeller rate (center frequency approximately 25 kHz) and 42 - 65 kHz for high impeller speed (center frequency approximately 50 kHz) was linear, the correlation coefficient being r = 1.00.

The interferences from the 5V DC source affecting PLL and light source were negligible, about 0.02%.

As the reference signal to the offset adjusting device came via the 15 V DC source, variations in the DC voltage might produce variations of the reference signal. However, the interferences from the 15 V DC source were also negligible.

When the signal from the PLL was fed to the recorder without filtration, very strong fluctuations were recorded during granulation. By connecting a second-order Butterworth filter of 5, 0.5 and finally 0.1 Hz cut-off frequency, a satisfying attenuation of the fluctuations was obtained. The filter eliminated distortion signals with higher frequencies. This was obvious from Fig. 3, where the recorded curve for output signals from PLL was compared to data from the printer plotted on the same scale. The signal from the frequency counter did not pass any filter. The great fluctuations of the frequency counter signal were due to interference from the chopper during mixing and granulation.

When the mixer was started for the day, there was a successive increase of the speed before the oil in the gear box became warmed up. Where the low impeller rate was concerned this meant that the idling speed was 1495 - 1497 rpm; the figures for the high impeller speed were 2986 - 2988 rpm.

During no-load operation, there were minor fluctuations of the impeller rate irrespective of the temperature of the gear box. The fluctuations were approximately $\pm$ 3 mV or $\pm$ 0.5 rpm at low impeller speed and about $\pm$ 1.5 mV or $\pm$ 0.8 rpm at high impeller rate. It is clear from Table 1 when changes on the recorded curves of voltage versus added liquid corresponding to S-limits (4) occurred. The uncertainty when measuring a predetermined speed corresponding to S_3, i.e. the ratio of the fluctuation (mV or rpm) to the difference between S_3 and idling, would be approximately $\pm$7% for low impeller rate and about $\pm$2% for high impeller speed. With regard to S_4 the corresponding uncertainties would be approximately $\pm$4 and $\pm$1% respectively.

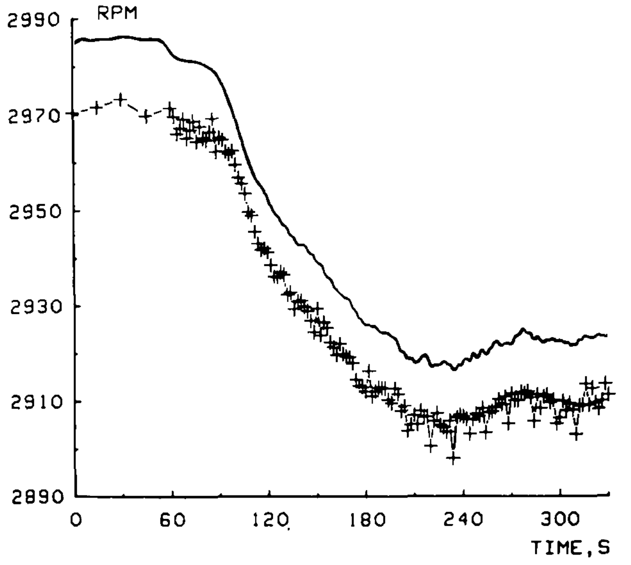

FIGURE 3

Relation between rotation rate of main impeller motor shaft, from recorder curve (continuous curve) or printer data (crosses), and time. Printer data are plotted on the same scale as the recorder curve. The recorder curve is moved along the Y-axis to facilitate the observations. Graduation of Y-axis refers to printer data.

0 - 60 s	Dry mixing
60 - 210 s	Fluid addition
210 - 330 s	Wet massing

TABLE 1

Lactose granulated with gelatin solution.
Voltage signal at S-limits (4).

S-limit:		Idling		S_3		S_4	
Signal	Impeller rate:	Low	High	Low	High	Low	High
mV		0	0	40	70	70	104
rpm		1497	2986	1486	2930	1480	2898

The minor fluctuations during idling were caused by mains voltage variations which were about 0.4%. The influence of mains voltage variations on the output signal during no-load operation and mixing was studied by simultaneous measurements of the voltage between each of the three phases and earth, using high-accuracy digital voltmeters[16]. The mains voltage variations appeared simultaneously with the minor fluctuations during no-load operation; this occurred with both low and high impeller speed.

There were no differences when the rotation rate of the impeller motor shaft was measured from the recorder, i.e. via PLL, or from the printer, i.e. via the frequency counter.

In spite of the high accuracy of the transducer, mains voltage variations and heating effects on gear box oil will influence the accuracy when measuring for instance a predetermined main impeller motor shaft speed, disturbing the result. However, these inconveniences affect other methods too, e.g. electric input power to the motor.

Granulation

The variations in the rotation speed of the impeller shaft during the granulation of lactose with a gelatin solution at a high impeller rate are very clear, Fig. 3. Both the recorder curve and the computer data are plotted in the same figure on the same scale.

ACKNOWLEDGEMENTS

We wish to thank P.G. Nilsson, Department of Industrial Electrical Engineering, Institute of Technology, University of Lund, for valuable discussions and for the loan of some equipment.

FOOTNOTES

1. Model 1545, General Radio, West Concord, USA
2. Model 58 with pulse number (periods/revolution) 1000, Leine & Linde AB, Eskilstunavägen 6, S-152 00 Strängnäs
3. SE/NE 564 Signetics, ELCOMA, Lidingövägen 50, S-115 84, Stockholm, Sweden
4. Servogor 210, BBC Goerz, Vienna, Austria
5. PE 1535 DC power supply, Philips, Eindhoven, The Netherlands
6. Home-made DC voltage supply unit
7. Model 5316A universal counter with HP-IB interface output, Hewlett-Packard
8. Model HP-85 personal computer with 82937A HP-IB interface, Hewlett-Packard.
9. 82905 A printer, Hewlett-Packard.
10. Body assembly 1/4 JN, Air cap 14011110, fluid cap 40100, spraying angle approximately 20°, Spraying Systems, Wheaton, USA
11. Flow inducer type MHRE 200, Watson Marlow Ltd., Falmouth, UK
12. DMV, Veghel, The Netherlands
13. Density 1010 kg/m^3
14. One period was equivalent to 360 electrical degrees. There were 1000 periods/revolution which made the figure 360 000
15. Model 7060 function generator, Exact, Scandia Metric AB, Box 1307, S-17125 Solna, Sweden
16. Model 177 microvolt four-digit digital multimeter, Keithley, Ohio, USA, and Model 3490A five-digit digital multimeter, Hewlett-Packard

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3. D. Kay and P.C. Record, Mfg. Chemist 49(9), 45 (1978).

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6. N.-O. Lindberg and H. Helgesen, The Swedish Academy of Pharmaceutical Sciences, Annual Congress. Proceedings, 6-7 October 1980, p.66.