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COMPUTER INTERFACED INSTRUMENTATION OF A ROTARY TABLET PRESS

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ABSTRACT

A 25 Station Manesty X-Press rotary tablet press was interfaced to a Hewlett-Packard 9825/T desktop computer. The tablet press was instrumented with three pairs of strain gauges to monitor pre-compression, compression and ejection forces. The ejection cam is of a special design, and calibrated under static conditions, such that the analog output signals can be converted into force or pressure units. The interface to the computer can simultaneously monitor all three pairs of strain gauges so that any selected station can be monitored for all three forces. The interfacing permits storage of data which can be analyzed later. The rate of data acquisition can be varied continuously up to one signal every 30 micro-seconds. The system was validated for sensitivity and reproducibility. Compression and ejection curves generated were of high quality with a low signal to noise ratio.

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INTRODUCTION

The instrumentation of pharmaceutical process equipment has attracted much attention in recent publications (1). However, this area of research and development has existed for over thirty years in the literature. Initially only single punch tablet presses were instrumented. Measurement of forces varied from upper punch, lower punch, and ejection forces to die wall forces. A wide variety of devices have been used to translate the tableting forces into a quantitative signal. These devices include piezoelectric transducers, telemetric and photoelastic systems, various load cells and strain gauges. The data obtained was treated in as many different ways. Much of previous research was based on photographic records of oscilloscope tracings of compression and ejection events (2). Some studies (3) attempt to mimic a production environment, however, studies of compression and ejection of tablets using a tablet press with one set of punches are obviously limited.

The purpose of the present research was to take a production model rotary tablet press and instrument it so that pre-compression, compression and ejection forces could be continuously monitored during tableting. This instrumentation was to be interfaced to a desk-top computer and high speed printer plotter. In this manner, large amounts of different types of data could be obtained and either examined or stored for later analysis. This system was designed not only as a research tool but also for the investigation of production problems. The system allows for high quality plotting of individual compression and ejection events or monitoring of an entire revolution of all the events. A link between the desktop computer and remote mainframe computer was established for greater storage and computational capacities.

INSTRUMENTATION

Tablet Press - Manesty Express X25; instrumented by Thomas Engineering with three sets of strain gauges. Pre-compression, compression and ejection forces were measured by placing strain gauges on the pre-compression roll assembly, on the tie rod and the specially designed ejection cam, respectively.[1]

Amplifier - Vishay Instruments 2100 Multichannel Signal Conditioner/Amplifier. This amplifier is a multi-channel plug-in module that provides bridge completion, bridge balance, amplification, excitation regulation and shunt calibration. The purpose of this amplifier was to accept the low level strain gauge signals from compression, pre-compression and ejection and amplify them into signals suitable for dynamic recording.[2]

Multiprogrammer - Hewlett Packard 6942A Multiprogrammer This Multiprogrammer has capabilities of a multiplexer to receive data from different sources and channel it at a slower rate to a computational device . The Multiprogrammer held high speed A/D converters, capable of 33,000 conversions/sec or one conversion every 30 milliseconds, a relay switching card, 4K memory cards and interfacing cards. Data from the amplifier were received, converted to digital signals and stored, for slower data transfer to the desk-top computer.[3]

Desk-Top Computer - Hewlett Packard 9825/T, 64K bytes memory This desk-top computer was the input-output device of the system. Commands for the format and sequencing of the data were entered, and an initialization signal was output from this computer. This computer has a single cassette tape drive for data storage, and is capable of performing limited calculations such as force to pressure conversions.[4]

Oscilloscope - Tektronix 564 Storage Oscilloscope
Amplified event signals could be displayed on this oscilloscope.[5]

High Speed Printer/Plotter - Hewlett-Packard 7245B continuous thermal paper feed high speed printer/plotter. The printer/plotter was used for plotting individual compression and ejection curves in great detail, or a series of curves, or for printing of individual peak pressures.[6]

Mainframe Computer - Digital Equipment Corporation PDP 1170
The Hewlett-Packard 9825/T desktop computer was linked with a communications cable and RS232 interface to a remote mainframe computer.[7]

Proximity Switch - Honeywell 1035R Micro Switch
A proximity switch was affixed to the tablet press to signal the Multiprogrammer to begin recording data points in memory. This is a magnetic position sensor, known as a Hall Effect Sensing element. The Hall Effect is used to differentiate between positive and negative charges with respect to their directions of movement. A small magnet is strategically placed on the turret of the tablet press. When the magnet passes the permanently positioned sensor, the magnetic flux turns on the sensor.[8]

DISCUSSION

The objective of the present study was to instrument a rotary tablet press such that pre-compression or compression and ejection events could be simultaneously recorded in a production situation. For satisfactory operation in the production environment, the instrumentation must be economical, portable, durable, and capable of withstanding a variety of environmental conditions. The Manesty Express X25 is available from Thomas Engineering pre-instrumented, as described. On receipt and closer examination of this unit, it was determined that the instrumented ejection cam, as supplied, was inadequate for sensitive and reproducible measurements of ejection force. Therefore, another design was developed for the ejection cam, fabricated, installed and instrumented.

The schematic of this design is represented in Figure 1. A section in the punch path on the ejection cam has been segmented. To replace this segment and maintain a smooth, continuous punch path, a cantilever beam was set in this segment. The cantilever was fabricated out of an oil hardened tool steel, Simonds flat ground Die Steel Rockwell Hardness 64C.

At the distant end of the cantilever, four 9.5 mm set pins anchored the beam firmly to the tablet press table surface. Four Constantan strain gauges were affixed to the cantilever beam. (Micro-Measurement Division, Measurements Group CEA-06-061WT-350). These gauges were selected for their strain sensitivity range of 5 percent, their stacked Rosette configuration and their integral solder tabs. One unit of two gauges, perpendicular to each other, was mounted on the upper surface of the cantilever surface.[4] This arrangement is referred to in the literature as the Poisson configuration.

The cantilever beam is deflected downwards in proportion to the force exerted by a lower punch as it ejects a

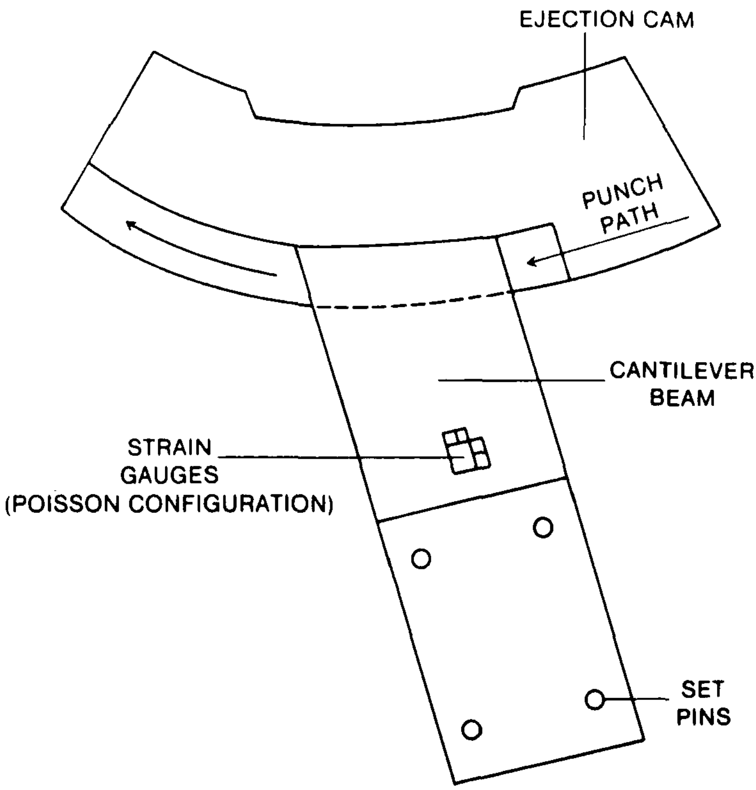

FIGURE 1

Schematic of instrumented ejection cam.

tablet. The cantilever was designed so that under a maximum applied force of 2000N, a maximum deflection of 0.38 mm was observed. This deformation is well within the elastic deformation range for tool steel. This cantilever measures the actual force needed to eject the tablet, and not the reactive force of the lower punch.

A reasonable analogy can be made between a strain gauge and a long, twisted coil of wire. As the long wire is placed in tension, or stretched, its length will increase and its diameter will decrease. Such a piece of wire is also a resistor, and must obey Ohm's Law (V=IxR).

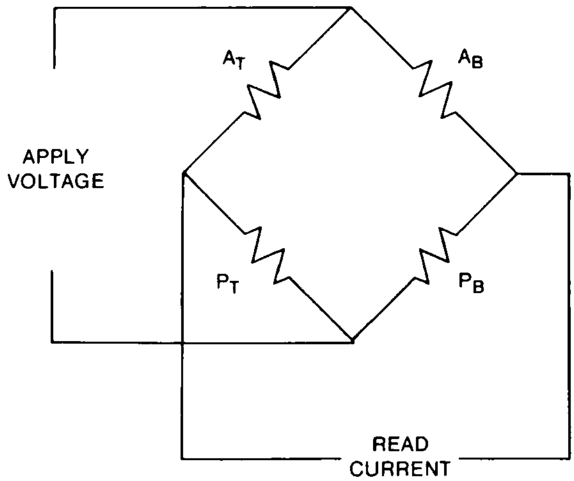

FIGURE 2

Schematic of instrumented ejection cam.

AT, PT = Resistances of Top Strain Gauges

AB, PB = Resistances of Bottom Strain Gauges

Under deflection AT is increased (stretching) and AB is decreased (compression)

As the length of the wire is increased, its inherent resistance also increases. By keeping the voltage applied to the system constant, such an increase in resistance will cause a reduction in the current through the wire. A deflection of a cantilever on which the strain gauges are mounted causes a tension on the gauge. The resistance of the gauge increases, and bending of the cantilever can be measured as a change in current.

The four strain gauges on the cantilever were wired in a Wheatstone Bridge configuration (Figure 2). An excitation voltage of 2.3 V is applied to the resistances of the two top gauges, axial and poisson. The subsequent

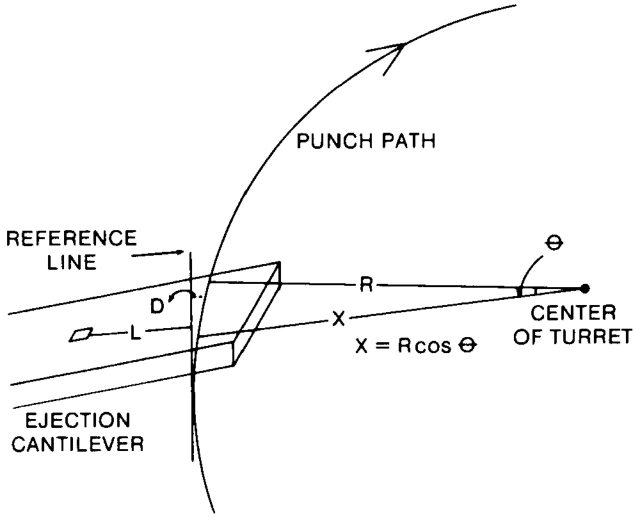

FIGURE 3

Geometric definition of lever arm distance -

Lever arm of Beam = L + D = LA

$D = R - X = R - R(\cos\theta) = Rx(1 - \cos\theta)$

$LA = L + Rx(1 - \cos\theta)$

change in current is measured across the resistances of the top and bottom lengthwise strain gauges, axial. This circuit (Figure 2) is in balance when there is no bending of the cantilever, and there will be no net current. Under the deflection caused by the ejection of a tablet, the resistance of the axial top strain gauge will increase as it undergoes stretching, and the resistance of the axial bottom strain gauge decreases, as it undergoes compression.

The cantilever beam was not mounted perpendicularly to the ejection cam. As the punch path has a certain degree of curvature, the lever arm distance for this system is not a fixed distance. For this purpose, the lever arm distance is defined as a function of an angle θ (Figure 3). Angle θ represents the deviation from the vertical normal force plane. The actual lever arm distance will be dependent on this deviation. From Figure 3, the lever arm will be defined as L+D or the actual distance between the punch head and the strain gauges. D is equal to (R-X) or the difference between the radius R of the punch path. By using a simple geometric definition, X is also equal to R times cosθ. Factorization of these expressions yields the final lever arm equation:

$$L+R \times (1-\cos\theta)$$

The strain gauge signal is proportional to both the force applied and the lever arm distance, or distance to which that force is applied. The total force is equal to a system constant multiplied by the strain gauge signal, divided by the total distance. To find the system constant, a static calibration of the ejection cantilever strain gauges was performed. A suspension bar was held in place across a punch by means of a set pin. The upper punch was in contact with a modified lower punch. Weights were then placed on the suspension bar. The net effect was that the strain gauges on the cantilever were subjected to a known weight. The calibration was performed at different positions across the cantilever using different weights. When applied force is plotted with respect to raw strain gauge signal, the result is a linear one, with a correlation coefficient greater than 0.999. This result clearly indicates a linear response of the strain gauges. By regression analysis of the applied force equation:

$$F = \frac{(K)\ (SAS)}{LA}$$

where K = system constant
SAS = raw strain gauge signal
LA = lever arm distance

K was determined to be 0.2968

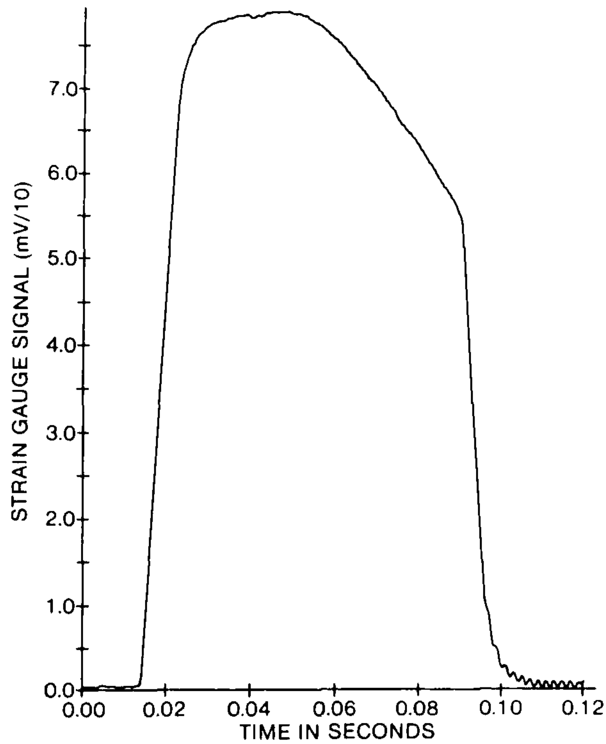

FIGURE 4

Ejection force as raw strain gauge signal.

Figure 4 is a plot of ejection force expressed as raw strain gauge signal. Figure 5 represents the calibration constant, or strain gauge output produced by the application of a constant known load to the system. Addition of these two curves produces Figure 6, which is ejection force normalized with respect to punch position. As anticipated, the peak strain gauge signal does not correspond to the peak ejection force.

The tie-rod compression strain gauges, supplied by Thomas Engineering, were not modified in any manner. A validation of the calibration supplied by Thomas Engineering was performed, utilizing an instrumented upper punch. Loads were applied to the instrumented punch, by placing the punch

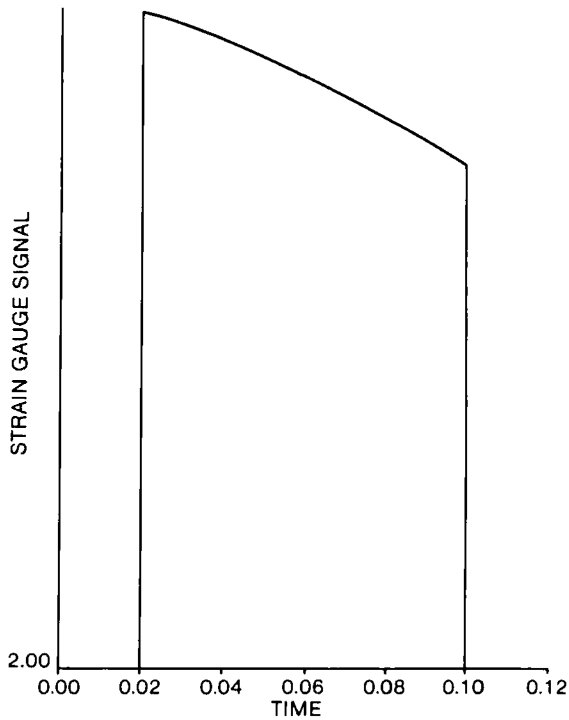

FIGURE 5

Calibration Constant Curve - strain gauge signal under constant load.

in an Instron tensile testing machine. The resultant strain gauge output signals were recorded, and a calibration constant was derived. This punch was then placed in the Manesty Express. The tie rod strain gauge signals were correlated with the instrumented punch strain gauge signals.

Strain gauges require some reference voltage to be applied, so that a change in current output can be measured. This reference voltage is known as an excitation voltage. The completed circuit of four strain gauges must generate no current when there is no stress on the circuit. To achieve this condition, the four strain gauges must be in balance. The Vishay Instruments amplifier performed these

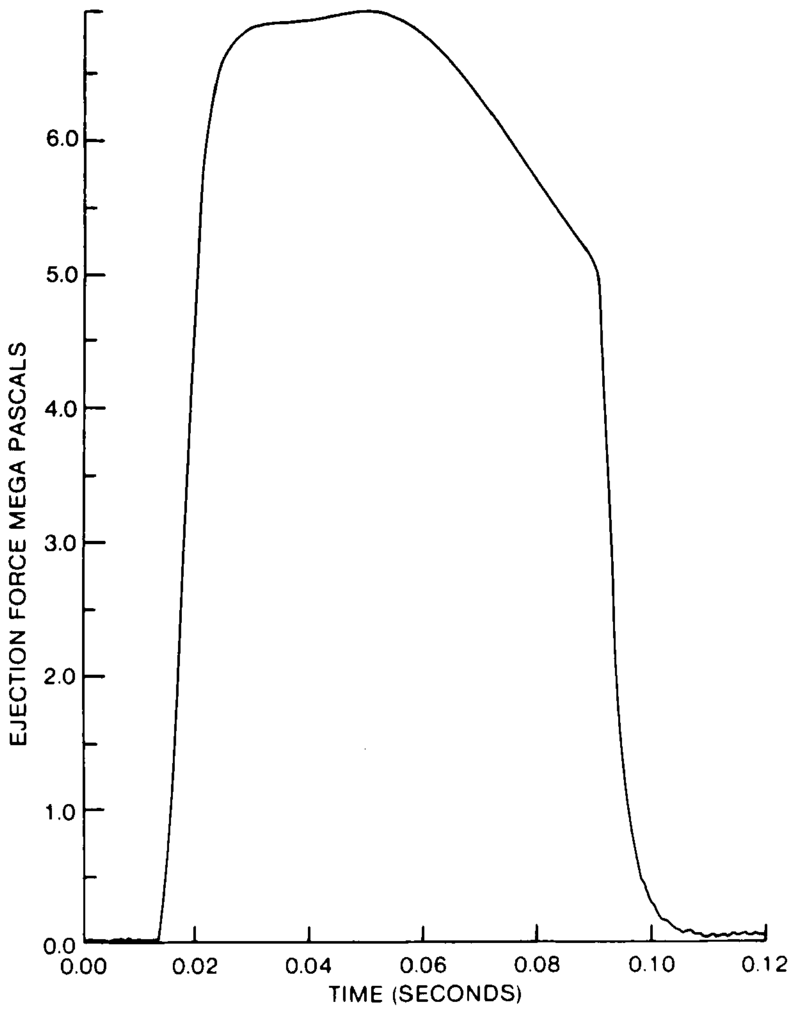

FIGURE 6

Normalized ejection force profile - addition of raw strain gauge signal and calibration constant curve.

two functions. A variable gain adjustment is incorporated in this amplifier, meaning that the raw strain gauge output can be magnified, if necessary. Some filtration of the signals occurs in this process, eliminating 60 cycle interference.

The amplified strain gauge signals from the compression and ejection events were entered into a Hewlett-Packard 6942A

Multiprogrammer. This Multiprogrammer functioned as an intelligent programmable multiplexer. This multiplexer performed three functions; A/D conversions of the data, temporary data storage and selection of which portions of data to accept. The proximity device, which was remote to the multiplexer, initiated the collection of data points, or strain gauge signals. After these signals were converted to digital values, they were stored in the Multiprogrammer memory capacity. The purpose of this multiplexer was to feed data for the desk-top computer at a controlled, pre-programmed rate, and in a particular sequence.

The computations to convert raw data into values of compression pressures and ejection pressures were handled by a Hewlett-Packard 9825T desk-top computer. Although this computer has 64 K-bytes of memory, only 23 K-bytes of memory were required to perform these calculations. The program to control the entire data acquisition was written and stored on a magnetic tape cassette. Similarly, output values could also be stored on these small cassettes for later evaluations. The desk-top computer was interfaced to a Digital Equipment Corporation PDP-1170 computer, which was not on-site. This interface was accomplished by means of an RS-232 communications cable. The remote DEC PDP-1170 computer was utilized for long term data storage or more sophisticated data manipulations. The type of calculations necessary to study and contrast the viscoelastic properties of tablets are outside the capabilities of this desk-top computer. The entire schematic of the data acquisition system is shown in Figure 7.

Detailed plots of individual or multiple compression and ejection profiles were obtained with a Hewlett-Packard

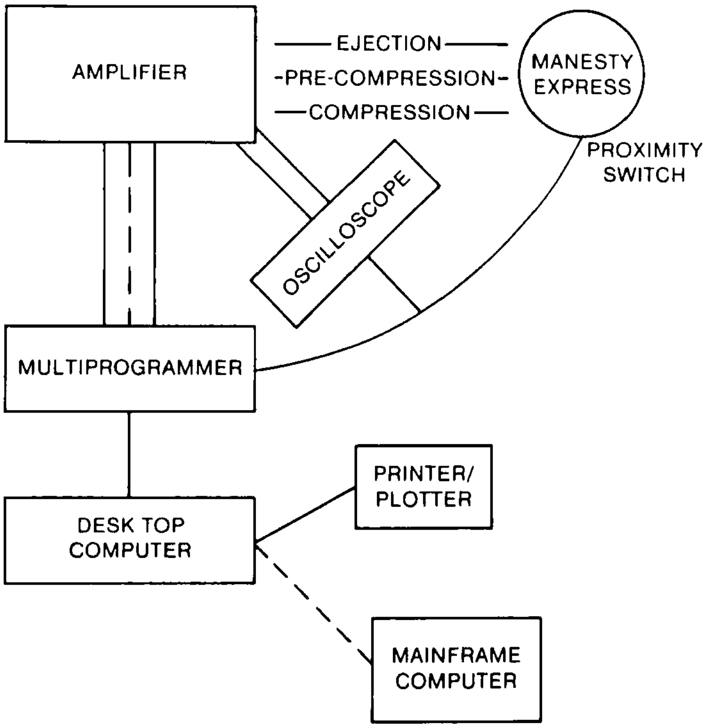

FIGURE 7

Data acquisition system.

7245B printer/plotter. Examples of single profiles (Figures 6 and 8) show compression and ejection pressure as a function of Mega Pascals versus time in seconds. Electrical and mechanical noise have been eliminated from these profiles by shielding the data cables and grounding several points on the entire system. The resultant profiles are smooth and have no discontinuation.

By slowing the rate of data acquisition, more events can be captured with a small loss in detail. Figure 9 depicits twelve compression curves. Variations in peak height can show differentials in punch length or die fill weight.

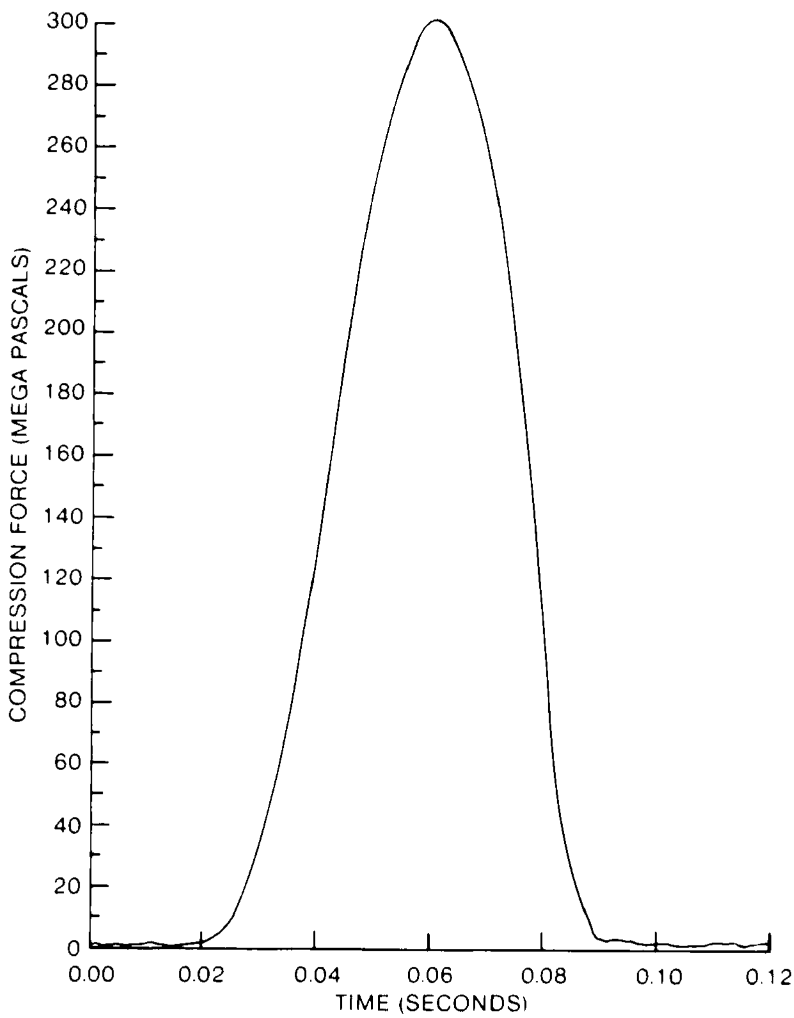

FIGURE 8

Compression pressure profile.

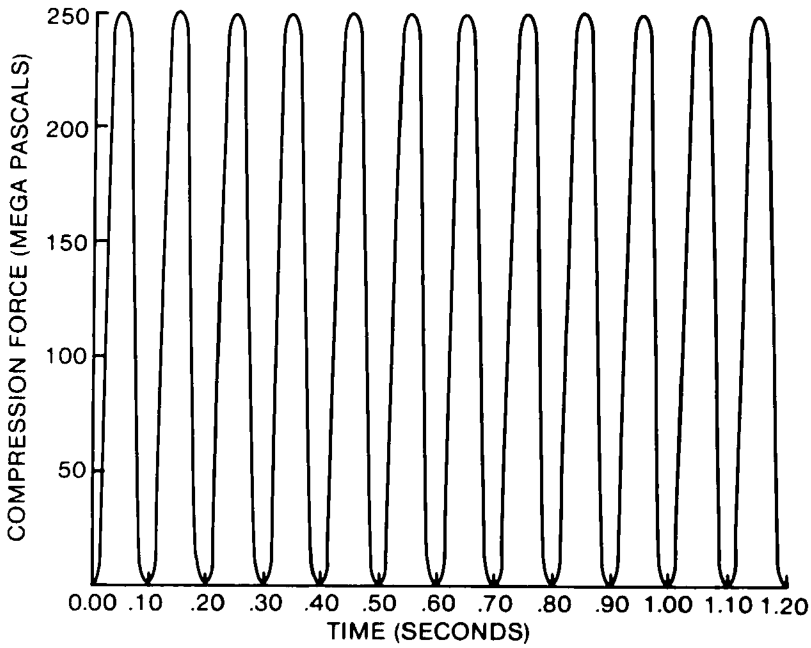

FIGURE 9

Multiple compression pressure profiles.

This type of configuration has many advantages. The need for an oscilloscope and digitizer has been eliminated. Raw data can either be stored on magnetic cassettes or remote computer. The calibration, analysis and plotting of data can be completed almost instantaneously by the desk-top computer. This system is extremely versatile and can be applied to many types of formulation studies or the trouble shooting of production problems in a realistic manner. Because the rate of data acquisition is variable, the press can be run with any number of sets of tooling. The use of only one set enables the researcher to hand fill the dies for absolute control of the fill weight. Since recorded values of compression pressure are very sensitive to changes in die fill weight, this type of control is necessary for detailed formulation studies. The production environment can be replicated by running the press with a full hopper for a longer period of time. Sequential changes in compression and ejection pressures can be evaluated as they vary over time. Because the pressure units have been selected for output rather than simple force units, any size or shape of tooling can be used, without distorting the data recorded. The speed of tableting can also be varied. This instrumented Manesty Express has been used specifically and successfully for excipient evaluation, optimization of formulation and lubrication, tooling evaluation and troubleshooting compression and ejection production problems. These case histories will be the subject of a separate publication.

FOOTNOTES

[1] Instrumented Manesty Express X 25, Thomas Engineering, Hoffman Estates, IL

[2] Vishay Instruments 2100 Amplifier, Measurements, Inc., Frazer, PA

[3] 6942A Multiprogrammer, Hewlett-Packard, Paramus, NJ

[4] 9825/T Desk-Top Computer, Hewlett Packard, Paramus, NJ

[5] 564 Storage Oscilloscope, Tektronix, Inc., Beaverton, OR

[6] 7245B Printer/Plotter, Hewlett Packard, Paramus, NJ

[7] PDP 1170 Minicomputer, Digital Equipment Corporation, Piscataway, NJ

[8] Honeywell 1035R MicrcSwitch, State Electronics, East Hanover, NJ

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