

## Versatile Compression Force Measuring System for Rotary Tablet Presses

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### ABSTRACT

*Compression force has become more important in in-process quality control of tablet compression. In this study, two different designs of industrial rotary tablet presses were tested for versatility of the designed force measurement systems. Both presses were equipped with force measuring systems designed by using commercially-available equipment and instruments so that the procedure can be easily reproduced for commercial applications. A remote installation technique was used for installing an HBM® load cell at the compression roller's eyebolt. A bridge amplifier, analog to digital converter, and microcontroller from TSM® were used to determine the average maximum compression force, with the result displayed on a 4- digit LED display. C programming language was used to develop the program for the microcontroller. The calibration method was designed by installing a calibrated HBM® load cell on a modified lower punch, then manually pressing a modified upper punch onto the load cell with static force and collecting data for making the calibration curve. A linear relation between the punch's load cell and the data collected on the microcontroller resulted from both machines' calibrations. Testing the calibrated machine by applying static force comparable to the LED display was done to study the reliability of the calibrated force measuring system. Two direct compressible diluents, lactose and microcrystalline cellulose, were compressed into 12 mm, flat, bevel-edged tablets at the normal production speed of 400 tablets/minute at various compression forces on both calibrated tablet presses. Both the pressure-tensile strength profile and the pressure-tablet thickness profile were studied. The results were similar to work of other researchers while the tablet compression process was done according to industrial standards. This proved that the retrofitted machines could be used for both research work and industrial tablet compression.*

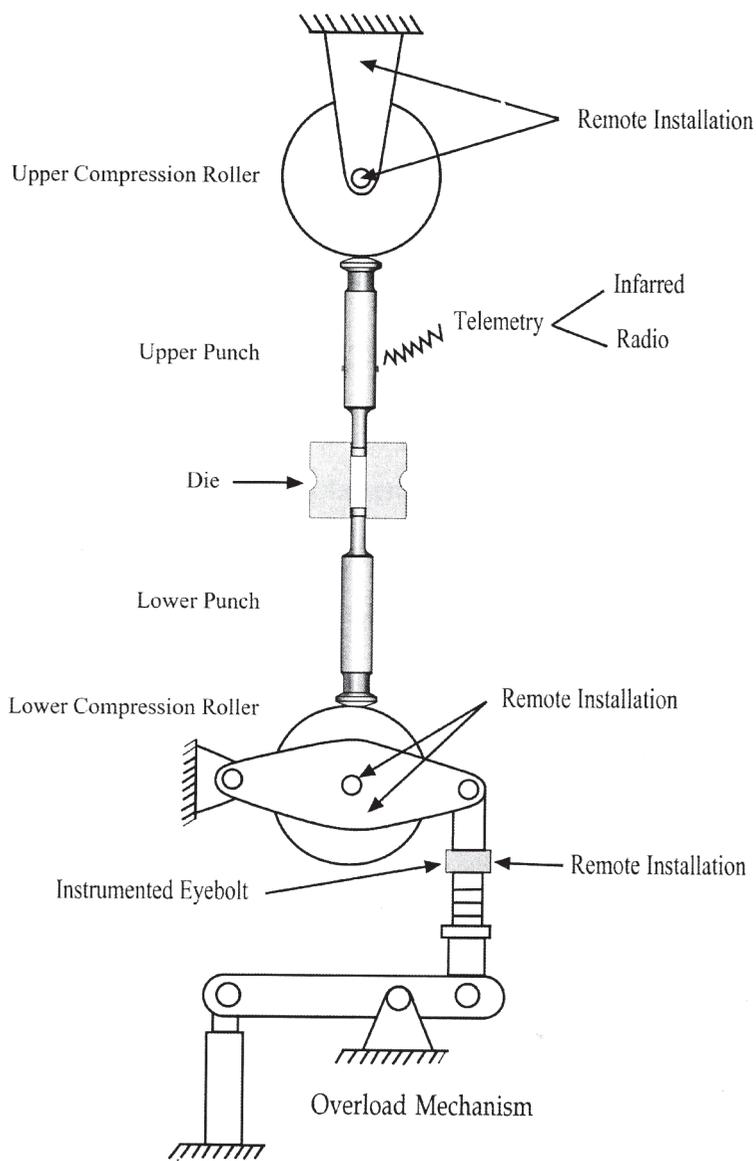
**Key words:** Compression Force, Rotary Tablet Press, Versatile

## INTRODUCTION

Rotary tablet presses are essential machines for pharmaceutical tablet production. They all provide basic functions and controls to make good tablets but the majority of them do not have a compression force measuring system. Compression force is an important parameter in determining the quality of tablets in a quality assurance process. The demand for such a system has been increasing but installation requires engineers with special skills in mechanical, electrical, and computer technology working together. Given this, the availability of this technology is limited and the price very high. With the Thai pharmaceutical industry currently employing many rotary tablet presses, the purpose of this study is to design a simple, versatile, compression force measuring system that can be retrofitted into these presses with proven versatility and reliability. This will help the Thai pharmaceutical industry elevate their quality assurance standards.

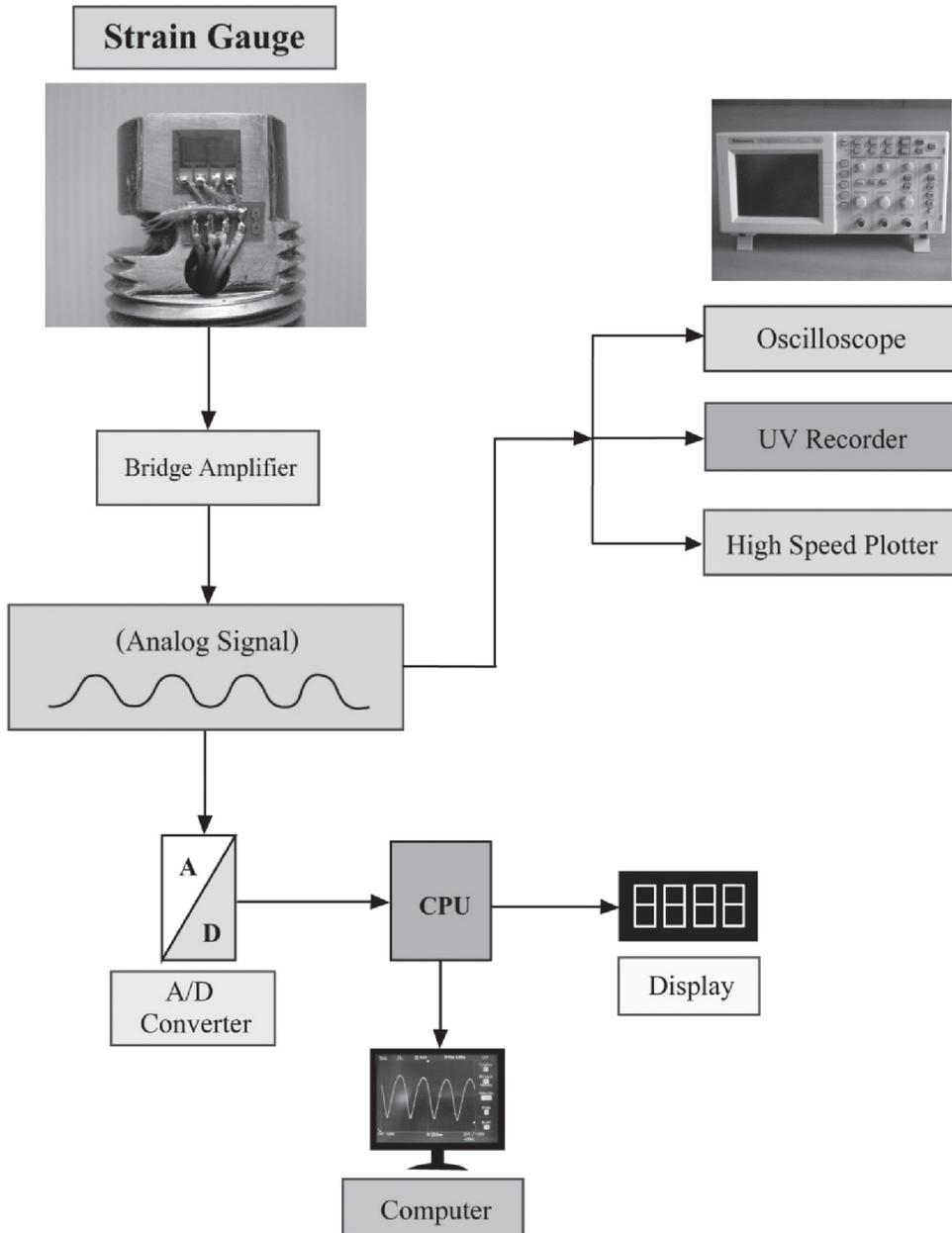
Higuchi et al., (1954) instrumented an eccentric tablet press and began the development of compression force measurement in 1954. In the early stages of development, most compression force measurements were done on eccentric presses because the instrumentation could be placed directly on the punch. Levin (2002) discussed the uses of instrumentation for formulation development but when products developed on eccentric presses were scaled-up in rotary presses, the results were different due to differences in compression and the feeding mechanism. In a rotary press, the punches are moving with the turret, making it more difficult to instrument. Watt (1988) described different ways of instrumentation of a rotary press. Shotton et al., (1963) instrumented upper and lower punches, then transmitted the signals via radio and recorded them on an ultraviolet recorder. Knoechel et al., (1967) instrumented a rotary press at a remote site and recorded it on an oscilloscope. Goodhart et al., (1968) compared various sites of remote installation in rotary presses. Patel et al., (2007) used infrared telemetry to transmit information from both upper and lower punches rotating on a turret. A summary of instrumentation of rotary tablet press is shown in Figure 1.

Researchers used different instrumentation techniques to measure compression force but all of them used a thin metal foil strain gauge to detect force by cementing it to the punches or remote parts through which the forces were transferred. This method was difficult to reproduce and maintain in an industrial application. Perry and Lissner (1962) stated the need to protect strain gauges from moisture and hazardous conditions that would change the characteristics of strain gauges. Watt (1988) discussed the advantage of using an industrial load cell that was well protected in a sealed case for easy maintenance and that could be easily changed if damaged. Industrial load cells became popular. They are widely used in electronic balances but rarely used for instrumentation of tablet presses because parts on the presses need to be modified to fit with the load cells.



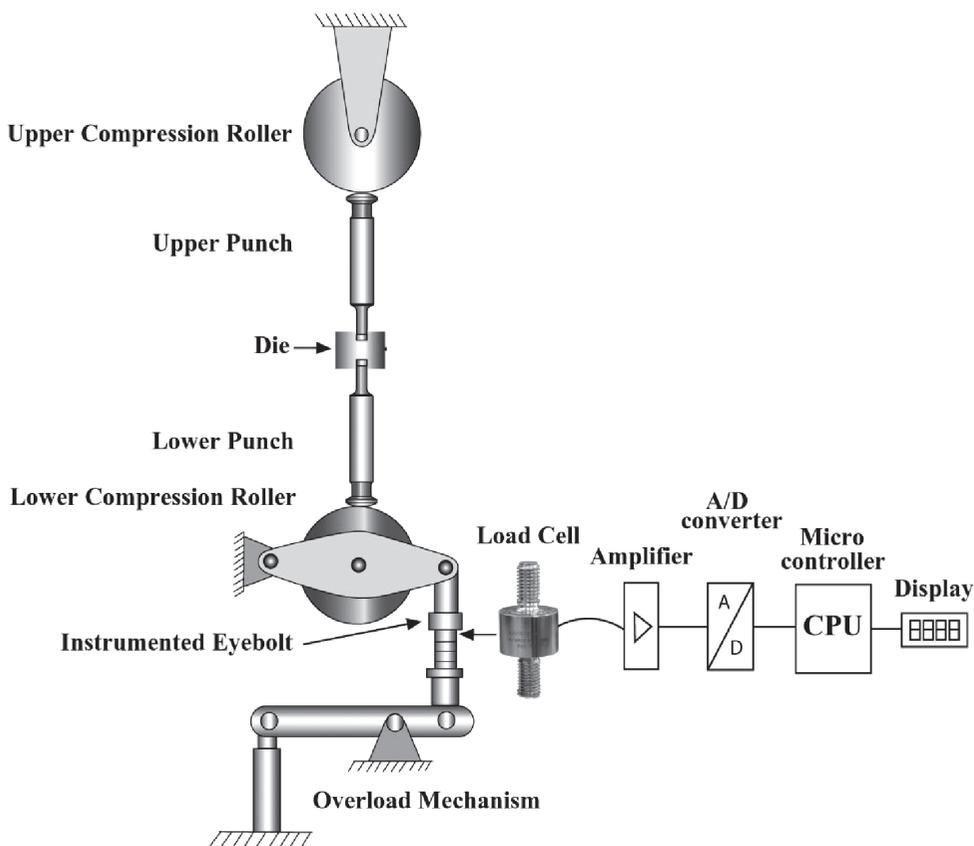
**Figure 1.** Instrumentation of a rotary tablet press

In 1984, Van Aerde (1984) published his work about instrumentation of compression force using microprocessor-based data acquisition and successfully used a computer to handle data for compression force measurement. This started a new era of using a microcontroller and computer in compression force measurement. Figure 2 shows different ways to display compression force.



**Figure 2.** Different ways to display compression force

In this experiment, remote installation technique was used to instrument eyebolts of lower compression rollers with industrial load cells in two rotary tablet presses. A commercially-available bridge amplifier, analog to digital converter (A/D converter), microcontroller, and digital display were used to determine and display the compression force. The principle of the work is shown in Figure 3.



**Figure 3.** Principle to measure compression force in rotary tablet presses

### EXPERIMENTAL DESIGN

Two tablet presses, Manesty B3B (Manesty Machines Limited, Liverpool, England) and Narong NRIR13D (N.R. Industries Co., Ltd., Thailand), were selected for this study. Eyebolts of both machines were studied and redesigned to accommodate a force transducer with strain gauge (load cell) HBM® Model U9B 20 kN (Hottinger Balbwin Messtechnik GmbH, Germany). After installing the load cells, both of the eyebolts still had the same function as before, only that the load cells were acting as a part of them. The load cells could measure any force transferred from the compression rollers through these eyebolts. Bridge amplifiers and Analog to Digital converters (A/D converter) (ELZET TSM-LOADCELL®, ELZET80 Mikrocomputer GmbH & Co., KG, Germany), were used to amplify the load cells' signal and convert the force analog signal into digital data. Force

digital data were then interpreted and calculated by microcontroller (ELZET TSM-CPU® model 32 H2EA, ELZET80 Mikrocomputer GmbH & Co., KG, Germany). The average maximum force was displayed on a four-digit, serial LED display model SC4Dlite A (Silicon Craft Sdn. Bhd., Malaysia). The installation of this equipment is shown in Figure 3.

Compression of lubricated lactose SUPER TAB SD® (DMV – Fonterra Excipients GmbH & Co., KG, Germany), was performed on NRIR13D at a slow speed of 160 tablets/minute. An oscilloscope (Tektronix model TDS2012, Tektronix Inc., Oregon, USA) was used to study the waveform of the compression force and a photograph of the frozen waveform was taken. A C-language program was developed according to the result of the study of the waveform. The developed program was then downloaded to the TSM-CPU®.

The calibration method was designed by installing a calibrated 20 kN HBM® load cell on a modified lower punch, then manually pressing a modified upper punch onto the load cell to create static force. The modifications of the upper and lower punch are shown in Figure 4. The static force created at the punches was then detected at the load cell installed at the eyebolt. A measuring amplifier (model SCOUT55®, Hottinger Balwin Messtechnik GmbH, Germany) was used to read the static force on the calibrated load cell while the TSM-CPU® sent the digital data received from the load cell on the eyebolt. The principle of this calibration procedure is shown in Figure 5. The amplification factor of each machine was set up. An amplification factor of 20 kN to ¼-full scale of 0-4095 (12 bit) was set for the B3B press and an amplification factor of 20 kN to ½-full scale of 0-4095 (12 bit) was set for the NRIR13D press. The settings would allow the B3B press to measure up to a maximum force of about 80 kN (8 tons) and the NRIR13D press up to 40 kN (4 tons). This technique was prepared for adapting the compression force measuring system to fit with presses of various maximum compression forces.

Static forces of 1, 2, 3, 4, 5, 10, 15, and 20 kN were applied to the standard load cell. Readings from the SCOUT55® and the corresponding digital data received from the CPU were recorded. The force values were changed from kN to hN for plotting calibration curves of both machines. The slope and intersection point of each curve were used for calculating compression force in the C language programs written for the corresponding machine.

Two preparations, each of 5 kg, of direct compressible diluent, microcrystalline cellulose, MCC, (Comprecel® Mingtai Chemical Co., Ltd., Taiwan ROC) were prepared by adding and mixing 1% of magnesium stearate (UNION DERIVAN, SA (UNDESA), Spain). A dry blender (double cone dry blender model DB-15, N.R. Industries Co., Ltd., Thailand) was used for mixing the preparation for 5 min each. The same steps were carried out for lactose (SuperTab SD®, DMV – Fonterra Excipients GmbH & Co., KG., Germany).

Both calibrated machines, B3B and NRIR13D, were used to compress 560 mg. tablets of lubricated MCC and lactose with 12.0 mm flat bevel-edged punches and dies. The punches and dies for B3B were B type while for the NRIR13D were D type. Average compression forces of 4, 6, 8, 10, and 15 kN were applied

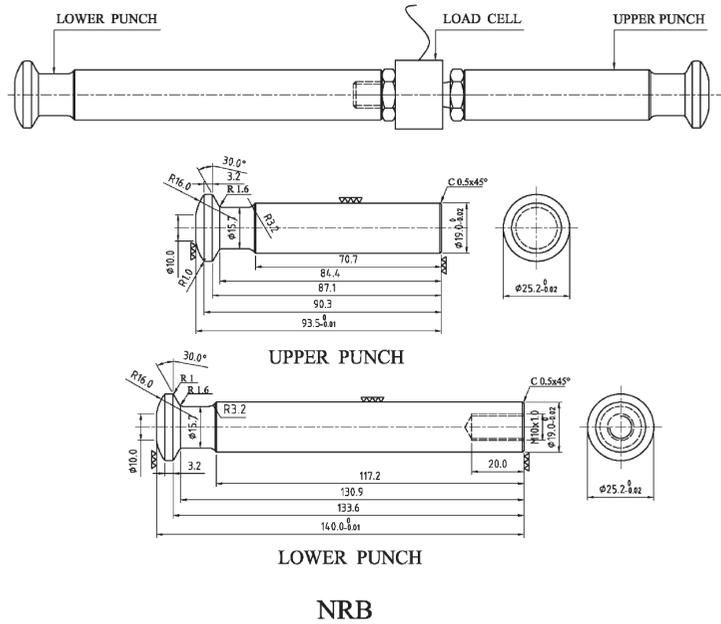


Figure 4. Modification of upper and lower punches for calibration

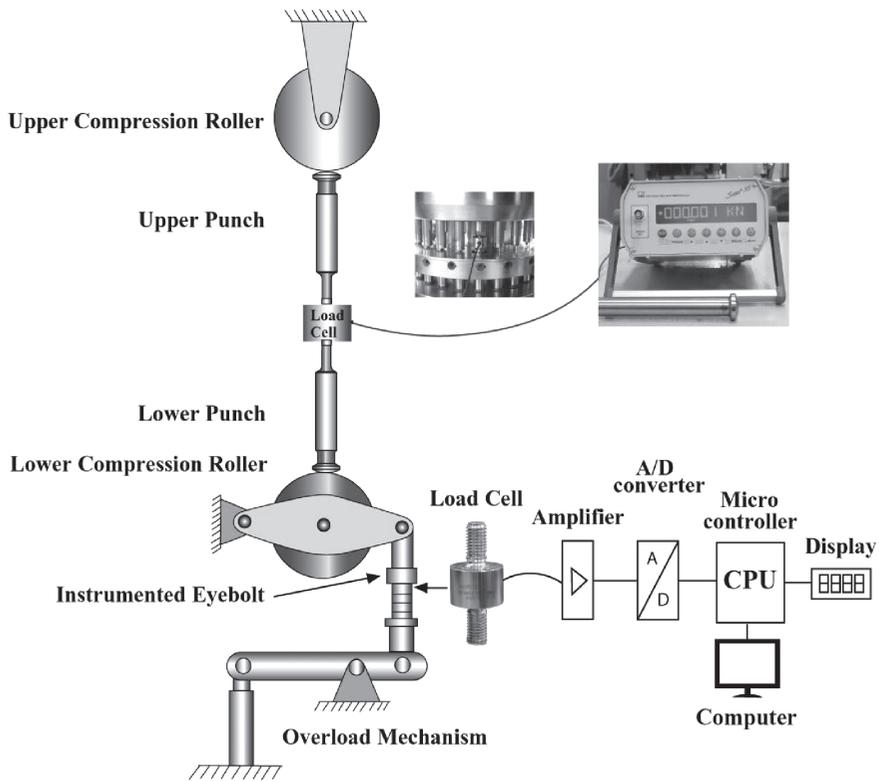
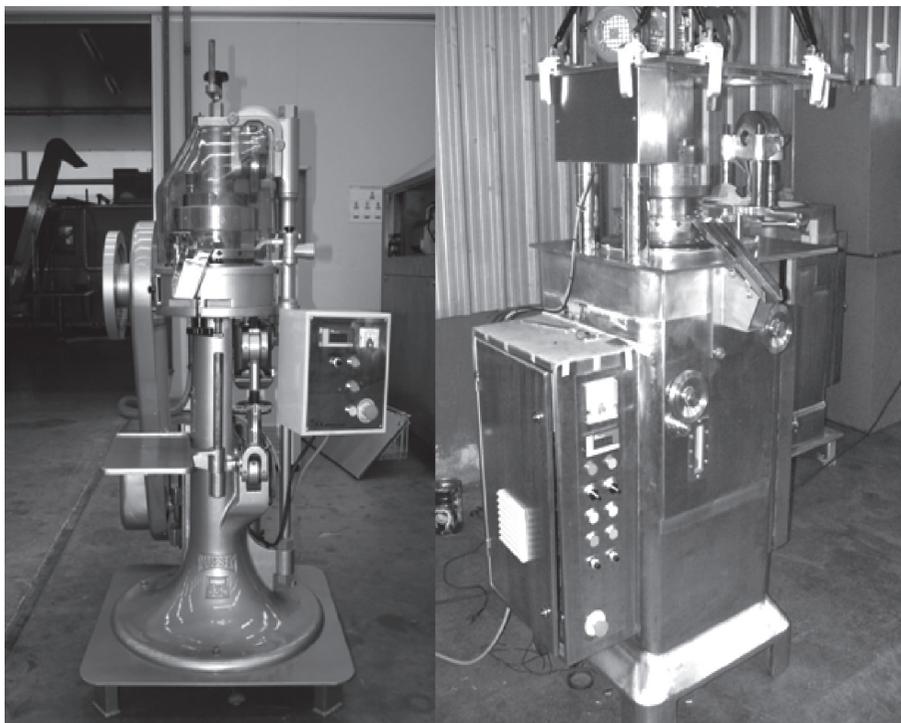


Figure 5. Principle of compression force calibration

for MCC tablets and average compression forces of 6, 8, 10, 15, 20, and 25 kN were applied for lactose tablets. Twenty sample tablets were collected at each compression force. A total of 200 tablets were collected for MCC and 240 tablets for lactose. Each tablet was weighed on an electronic balance (SARTORIUS® Model ED 323S, Satorius AG, Switzerland). The thickness of each tablet was measured with a digital vernier caliper (model BD-10, Baker Gauges India Pvt. Ltd., India). The hardness of the tablets was measured using a hardness tester (model 5Y, Dr. Schleuninger Pharmatron AG, Switzerland). Data from all the measurements were collected. Studies of tablets' weight variation, changes of thickness due to changes of compression pressure, and changes of tablets tensile strength due to changes of compression pressure were carried out.

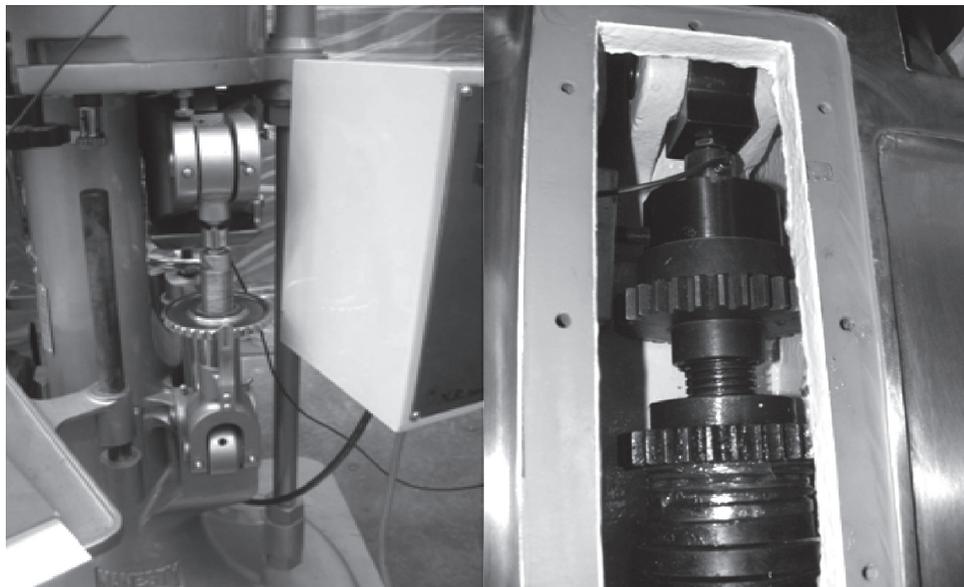
## RESULTS AND DISCUSSION

The two tablet presses, as shown in Figure 6, were selected to represent the tablet presses used in the Thai pharmaceutical industry. Their designs are different. The Manesty B3B machine has a unique lower compression roller eyebolt built outside of the machine's main frame while the Narong NRIR13D has its lower compression roller eyebolt built inside the machine's frame. The B3B represents tablet presses from Manesty, England; Stroke, USA; Cadmach, India, and some manufacturers from China. The NRIR13D represents the presses Kilian, Korsch, and Fette, Germany; Jen Chiang, Taiwan; and many manufacturers from China. Both of them use a spring for overload protection but with different mechanisms of tablet thickness adjustment. The differences of the two machines potentiate the versatility of the force measurement system designed in this study. The other important difference of the two is the tableting tool (American Pharmaceutical Association, 1995). The B3B uses B type tooling while the NRIR13D uses D type tooling. The head flat, the flat part of a punch head, of D type tooling is 15 mm. in diameter while the B type is 10.0 mm. During the compression cycle, D type tooling will have a 50% longer dwell time than the B type. This enhanced the value of this study because the effect of dwell time on a tablet's properties could also be studied. One other difference of design is that the two machines use different granule feeding systems. The B3B uses a gravity feed shoe while NRIR13D uses a forced feeder. A weight variation study was carried out to prove that the differences in the feeding systems did not effect tablet weight variation.



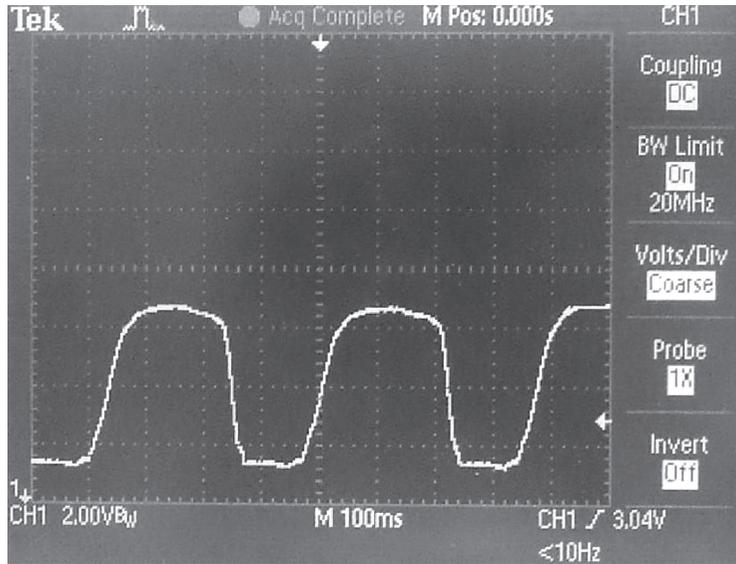
**Figure 6.** Tablet presses – Manesty B3B (left) and Narong NRIR13D (right)

Many researchers have used metal-foil resistance strain gauges for measuring tablet compression force. Its advantage is that it can be cemented to the part nearest to the force origin for precise force measurement. However, the procedure to cement the metal-foil to the part needs competent, skillful, and very fine workmanship. Reproducibility of the work is not very likely because it depends very much on skill. In this experiment, a remote installation method was selected for installation of the force transducer. An industrial load cell was selected for force transducer instead of a metal-foil resistance strain gauge because it has some advantages over metal-foil. Watt (1988) described the advantages of load cells for industrial uses in that the device was sealed for protection from dust and moisture and can be replaced easily when damaged. Its other advantage is that the elasticity of the load cell is tested from the factory and the linearity of it must be confirmed. The disadvantage of the load cell is its large size. It needs more space than a metal-foil strain gauge. Due to its large size, installation directly at the punch is not possible. In this experiment, eyebolts of both machines were redesigned so that they were separated into two pieces to accommodate the load cells, HBM® Model U9B 20 kN, in the middle. The screws on each side of the load cells were tightened to each piece of the eyebolt to make the completed eyebolts similar to the original eyebolt in terms of length and their application. The only difference was that the new ones, shown in Figure 7, have the load cells installed in the middle to detect forces transferred through them.



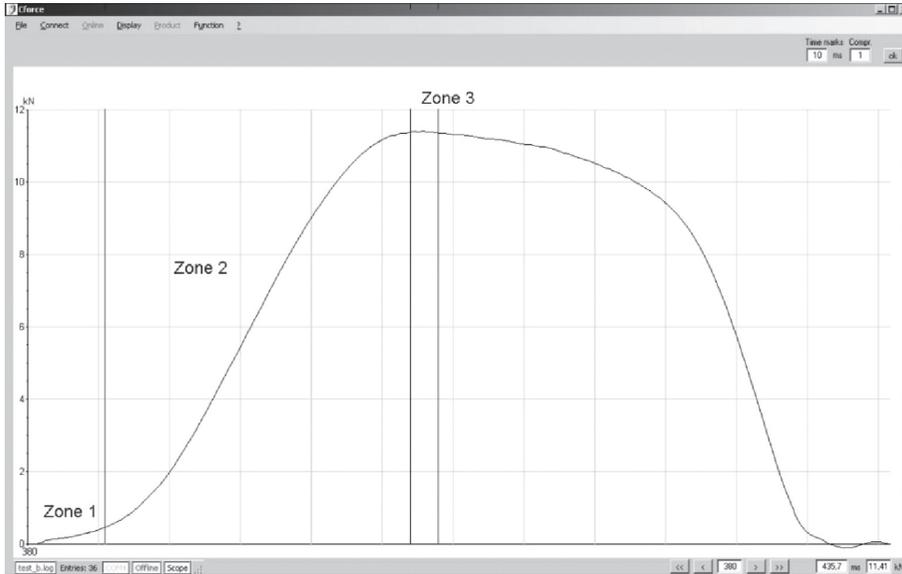
**Figure 7.** The load cell installed on the Manesty B3B (left) and Narong NRIR13D (right)

The compression force waveform of NRIR13D is shown in Figure 8. The compression speed was 160 tablets/minute. The cycle time of one compression cycle was about 380 ms of which the compression duty time was about 270 ms and the remaining idle time was about 110 ms. Van Aerde et al., (1984) used a 12-bit A/D converter with the sampling time adjustable from 600  $\mu$ s to 16 s. The average sampling rate of the microprocessor was 500 samples per channel per compression cycle and the data collected gave very fine waveform plotting for compression force study. In this experiment, the A/D converter (ELZET80<sup>®</sup> Mikrocomputer GmbH & Co., Germany using microchip MAX197<sup>®</sup>, Maxim Integrated Products, USA) could convert analog signal into 12 bit (0-4095) digital data with the conversion time of 6  $\mu$ s. The microcontroller used in this experiment was an ELZET TSM-CPU 32 H2EA (ELZET80 Mikrocomputer GmbH & Co., Germany), with a sampling rate every 100  $\mu$ s. When the tablet press was running at 400 tablets/minute, the total number of samples per cycle was about 1,500 samples. From the study of the waveform, it could be concluded the performance of the data collecting system exceeded that needed to properly measure compression force for either industrial or research applications.



**Figure 8.** Compression force waveform of NRIR13D

Computer programs were developed using C programming language to monitor the presses and compression force. Modular programming (Hanly and Koffman, 2001) was used so that the high-speed tasks and the administrative tasks were separated for better performance. The high-speed task consisted primarily of the maximum forces detection. This part starts from receiving a trigger pulse from the mCAT (Mocom Software GmbH & CO KG., 2006), the operating system used in the ELZET TSM-CPU 32 H2EA, every 100  $\mu$ s. Then it gets data from the A/D converter and analyzes the data to find the maximum point. In order to reduce the CPU occupied time, the compression wave was divided into 3 zones as shown in Figure 9. In rising zone 1, the data received from the A/D converter kept on increasing 50 times, confirming that the compression force was on the rising edge and started zone 2. The program started comparing new data with previous data, the higher value was stored in the maximum value variable until the highest value was reached. The zone 3 started when the program would count the number of data that decreased from the maximum points for 50 times, then sending the maximum value to the main program and stopped to wait for zone 1 of next wave. In the event that zone 3 did not occur within 3 sec (during calibration with the static force), the program would send out the current existing value.

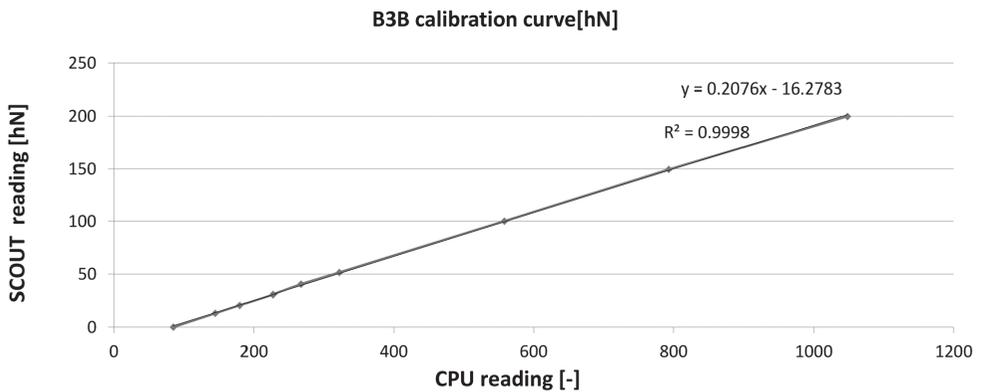


**Figure 9.** Compression wave divided into 3 zones

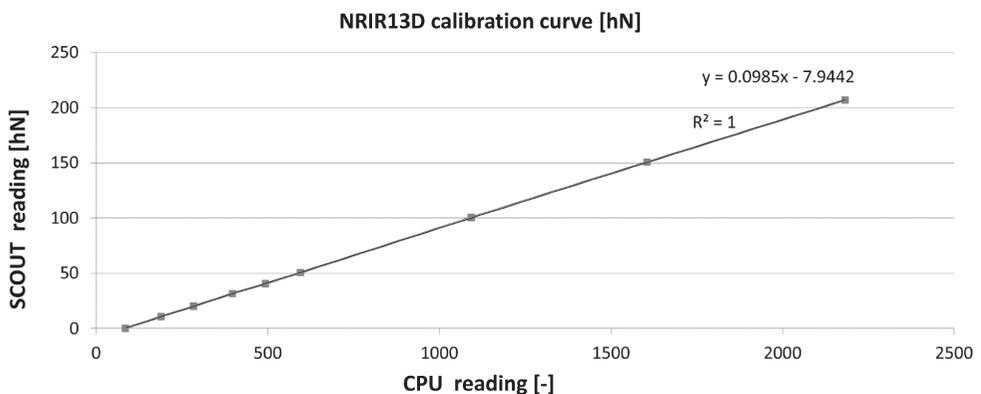
When the presses started, the computer program managing the administrative task would look for the proximity signal from punch number one on the press to come in and would synchronize the data table with the punch number of the press. This occurred with every turn of the turret to ensure the punch number and data were always synchronized. This routine began when the maximum value was sent from the high-speed task. The calculation of absolute compression force was done using the slope and intersection from the calibration curve discussed in the next paragraph. Programs for both machines were the same except for the constants used in the force calculation equation. The programs were written using event-driven programming (Ferg, 2006) techniques so that the program would stay idle unless the event it was waiting for occurred. For the high-speed task, the event was the trigger signal from mCAT. For the administrative tasks/program, the events were the proximity signal from punch number one (only one time per round) and the maximum value from the high-speed task, which occurred once each compression cycle. This technique reduced the processing time of the CPU to keep its performance at maximum. The average of maximum force was displayed in kN with an accuracy of 0.1 kN.

To reduce the data processing and transfer time between the CPU and the LED display, another technique was developed. If the value was sent in kN, then it had to be transferred in floating point which took much longer than data transferred in integer. In this experiment, the average of maximum force was sent in hN (equal to 0.1 kN) to a 4-digit LED display via RS232. The display was configured to display a decimal point in between the third and the last digit. This way, the result was automatically converted back in kN with the accuracy of  $\pm 0.1$ , while the data processing and transfer were done in integer to save the processing time.

Since the compression force was measured from a remote site, a calibration procedure had to be developed to compare the force at the punches and the value received at the CPU. The procedure for calibrating the force measuring system was similar to that developed by Sirithunyalug et al., (1999). The results of the calibration are shown in calibration curve in Figures 10 and 11. The slope and intersection for B3B was determined as:  $Y = 0.2076 X - 16.2783$  (Coefficient of determination  $R^2 = 0.999$ ). The slope and intersection for NRIR13D was determined as:  $Y = 0.0985 X - 7.9442$  (Coefficient of determination  $R^2 = 1.000$ ).



**Figure 10.** Calibration slope and intersection of the Manesty B3B press



**Figure 11.** Calibration slope and intersection of the Narong NRIR13D press

The linearity of both curves was very good due to the linear elasticity of the load cell. The intersections of the curves were not at the 0,0 point because the weight of the compression rollers and accessories were always pressing on the measuring load cells at zero punch force. The slope and intersection obtained from the calibration curves were used by the CPU to calculate compression force. Even though the amplification factors of both presses were different, the calibrations of both presses were linear. The setting of 20 kN to ¼ full scale of 0 - 4095 (12 bit) was for B3B while the NRIR13D was set to ½ full scale of 0 - 4095 (12 bit) at 20 kN. The settings allowed the B3B press to measure up to a maximum force of about 80 kN (8 Tons) and the NRIR13D press up to 40 kN (4Tons). This technique allowed for adapting the compression force measuring system to fit presses of various maximum compression forces.

After the calibration processes were completed, the machines were tested again with the same standard load cell and amplifier to compare the reading with the compression force read at the LED display of the systems. The results of these comparisons are shown in Tables 1 and 2. The average error of the reading is 0.47% for both machines with a maximum error of 1.06% for the B3B press and 1.01% for the NRIR13D press.

**Table 1.** Comparing the standard load cell with LED display value of Manesty B3B

Check the calibration of Manesty B3B

Scout reading (Master) [kN]	Force Display (on LED) [kN]	Error [%]
0.0017	0.0	0.00
5.1396	5.1	0.77
10.2734	10.3	-0.26
15.3217	15.2	0.79
20.2145	20.0	1.06
Average error		0.47

**Table 2.** Comparing the standard load cell with LED display value of Narong NRIR13D

Check the calibration of NRIR13D

Scout reading (Master) [kN]	Force Display (on LED) [kN]	Error [%]
0.0012	2	0.00
5.0435	5.0	0.86
10.1644	10.2	-0.35
15.4278	15.3	0.83
20.1034	19.9	1.01
Average error		0.47

Most researchers send their instrumented parts to be calibrated by a calibrating machine before installing on the tablet presses. The calibration technique developed in this experiment was different in that the instrumented parts could be calibrated when on the press. This is very important because Good Manufacturing Practice (GMP) regulations require all equipment to be validated before releasing for use in production or R&D. Calibration, which is a part of the validation process, must be performed annually to ensure that parameters affecting the quality of products are well controlled. The calibration process designed in this experiment makes it possible to fulfill the GMP regulation requirements.

Two commonly used, direct-compressible diluents, MCC and lactose, were used to make tablets at various compression forces. The forces were then converted into pressure, based on the punch diameter of 12.00 mm. Hardness of tablets also was converted into tensile strength, using the equation proposed by Haririan and Newton (1999) for flat round tablets:

$T = 2P / (\pi D t)$ , where T = Tensile strength, P = Fracture load, D = Diameter, and t = Thickness

In this experiment, after setting the weight and compression force, tablets were collected. The thickness of tablets was kept constant throughout each compression pressure. When thickness is kept constant, weight variation of the tablets plays a major role in variation of compression pressure, resulting in uncertainty of other tablet properties. Because the two tablet presses had different granule feeding systems – the B3B press used a gravity feed shoe and the NRIR13D press used a forced feeder – the variation in tablet weights was measured to check that both machines were within normal limit. A summary of the weight variation study is shown in Table 3. British Pharmacopeia (2004) defined the acceptable limit of weight variation in uncoated and film-coated tablets as:

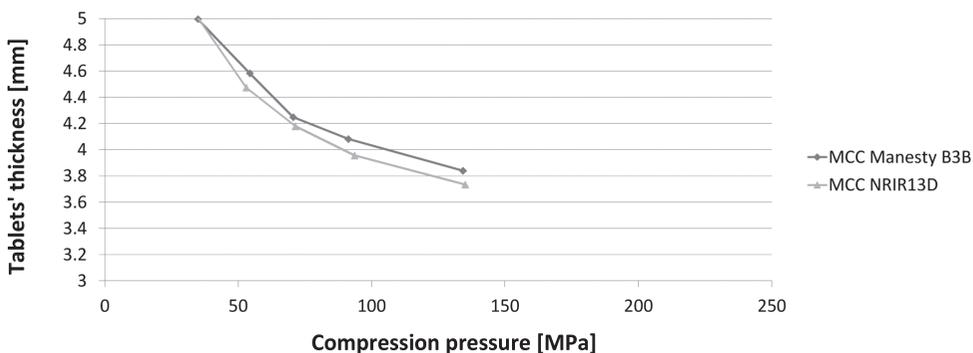
Tablets 80 mg or less	Percentage Deviation 10%
Tablets more than 80 and less than 250 mg	Percentage Deviation 7.5%
Tablets more than 250 mg	Percentage Deviation 5%

**Table 3.** Summary of tablet weight variation

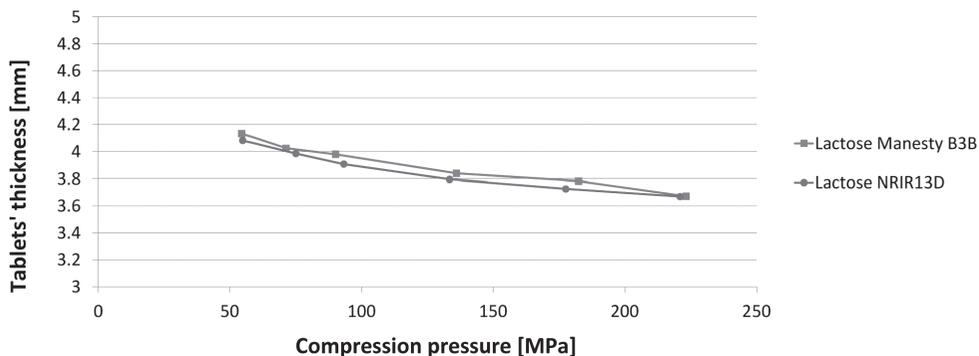
Standard deviation, average weight, relative standard deviation						
	Manesty B3B			Narong NRIR13D		
	SD	A.W.	RSD	SD	A.W.	RSD
4 kN MCC	2.51	<b>549.10</b>	0.46	5.31	566.65	0.94
6 kN MCC	2.98	564.70	0.53	4.89	568.10	0.86
8 kN MCC	<b>1.93</b>	559.15	<b>0.35</b>	<b>2.94</b>	563.75	<b>0.52</b>
10 kN MCC	2.32	560.30	0.41	3.25	564.50	0.58
15 kN MCC	1.97	560.90	<b>0.35</b>	3.57	<b>562.30</b>	0.63
6 kN Lactose	2.31	562.20	0.41	4.99	564.15	0.88
8 kN Lactose	3.71	561.70	0.66	<b>6.01</b>	566.00	<b>1.06</b>
10 kN Lactose	3.57	561.10	0.64	4.52	<b>567.85</b>	0.80
15 kN Lactose	6.44	559.80	1.15	4.99	563.55	0.89
20 kN Lactose	4.32	<b>563.55</b>	0.77	3.43	567.55	0.60
25 kN Lactose	<b>7.05</b>	552.25	<b>1.28</b>	3.51	567.10	0.62
<b>Average</b>	<b>3.56</b>	<b>559.43</b>	<b>0.64</b>	<b>4.31</b>	<b>565.59</b>	<b>0.76</b>

In this experiment, average tablet weight of all the tablets compressed in the Manesty B3B press was 559.43 mg and 565.59 in the Narong NRIR13D press. The control value was 560 mg. The highest standard deviation in the B3B machine was 7.05, which was equivalent to a relative standard deviation of 1.28%. The highest standard deviation in the NRIR13D machine was 6.01, which was equivalent to a relative standard deviation of 1.06%. The highest tablet average weight was 568.1 mg (+1.45%) in 6 kN MCC tablets made in the NRIR13D press and the lowest was 549.1 mg (-1.95%) in 4 kN MCC tablets made in the B3B machine. The weight variation was well controlled in this experiment.

The pressure-thickness profile of the tablets produced was studied and the results are shown in Figures 12 and 13. Changes in thickness due to the pressure of the two diluents were clearly different. MCC tablets decreased more in thickness with increasing compression pressure while lactose showed a much lower relative response. The results were similar to that of Palanuphap (1995) and Tye et al., (2005). The differences in the deformation mechanisms could explain this. Lactose undergoes fragmentation under compression while MCC undergoes plastic deformation. Under compression force, lactose fragmented before it could consolidate to form a tablet, the void space was reduced significantly before it could convert compression energy into compaction bonding to form a solid tablet. At the pressure at which it could form a solid tablet, the void space was already greatly reduced. MCC, on the other hand, formed hard tablets at lower pressure because plastic deformation and bonding at points of contact occurred together with materials of plastic deformation under compression. At the pressure that MCC formed a tablet, the deformation was still far from completion, resulting in much higher void space than lactose at low compression force. In this experiment, MCC were compressed only up to 15 kN of compression force because the hardness of the tablets was already higher than 400 N at 15 kN. The maximum hardness that the hardness tester could test was 450 N, so for MCC, the maximum force was set at 15 kN.



**Figure 12.** Pressure-thickness profile of MCC tablets



**Figure 13.** Pressure-thickness profile of lactose tablets

The effect of dwell time on tablet thickness was observed in this experiment. The NRIR13D press used D type tooling which had a higher dwell time than the B type tooling used in the B3B press. The effect of dwell time on changes of thickness was shown on both MCC and lactose; the higher the dwell time, the lower the thickness of tablets. The effect was more pronounced in MCC than in lactose. More interesting was that at high compression pressure of about 220 MPa, the thickness of lactose tablets was the same on both machines because the tablets had reached true density (void space became zero).

Tye et al., (2005) expressed tableability in terms of a pressure-tensile strength profile. It indicates the capability of a powder to be transformed into a tablet of specified strength under the effect of compaction pressure. In this experiment, a pressure-tensile strength study was conducted on the sample tablets with the results shown in Figure 14. Tableability of MCC was much higher than that of lactose, which was similar to results found by Palanuphap (1995) and Tye et al., (2005). MCC is well known for its superiority to other diluents in terms of tableability and is the first choice for use to increase tablet hardness. The effect of dwell time on tableability was also observed. Narang et al., (2010) did an experiment on lactose and MCC mixture and found that dwell time had effect on tableability. Rees and Rue (1978) found that dwell time had more effect on lactose than MCC. Tye et al., (2005) stated that MCC was independent of compression speed (dwell time) and there was a minor effect on lactose. The results from this study showed similar results with dwell time having no effect on MCC tableability but a more pronounced effect on lactose, especially at high compression pressure.

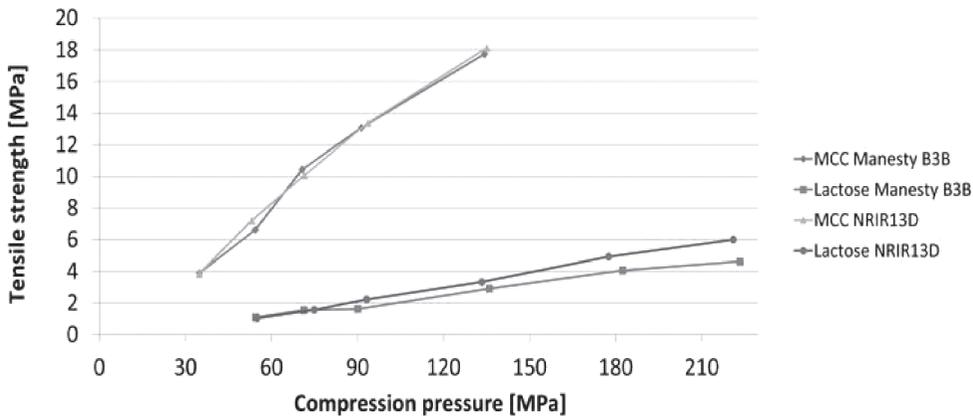


Figure 14. Pressure-tensile strength profile of the tablets

## CONCLUSION

Two different types of rotary tablet presses were instrumented with compression force measuring systems that had been specifically design to be fitted to them. Instrumentation of the presses was done at a remote site. Industrial load cells were used for detecting compression force to avoid complication in the instrumentation process and also for easy maintenance in industrial use. The compression force waveform was studied using an oscilloscope to determine the performance of the force measuring system needed to detect the wave. Commercially available bridge amplifiers, A/D converters, and microcontrollers were used in this study. The computer program was developed in C language to match the mCAT operating system used on the microcontroller. The cycle time of each data collection point from the system was 100  $\mu$ s, resulting in fine measurement of the waveform. The average of the maximum compression force was calculated and displayed on a 4-digit LED display. Different amplification factors were set for the two presses; the B3B press was set at  $\frac{1}{4}$  full scale and the NRIR13D press was set at  $\frac{1}{2}$  full scale for a compression force of 20kN. The calibration tools and method were designed to perform calibration directly at the press. The result of calibration on both presses showed a linear relationship between the compression force on the punch and the value read at the CPU. System reliability was checked by comparing the force shown on the standard load cell and the value of the LED display, which differed at an average of 0.47%. After calibrating, lactose and MCC tablets were compressed at a rate of 400 tablets/minute on both machines. Twenty tablets from each compression force were collected. Studies on weight variation, the pressure-thickness profile, and the pressure-tensile strength of the tablets were carried out. The results were similar to what others had found in prior research. These results proved that the instrumented machines could be used for both research and commercial production of tablets. In addition, the system was versatile, as it could be adapted to different types of presses for use at different amplification factors and for different types of applications. The designed system could be easily reproduced for commercial application with a calibration method that meets GMP regulations.

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