Setting Conversion with Experimental Validation from Semi Manual to Automatic Hydraulic Pressing Machine in Powder Foundation Formulation

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Abstract

Background: Different laboratories and production scale machine design for powder pressing inside the cosmetics manufacturer has been challenging when bringing semi-manual laboratories into the automatic production machine setting during the up-scaling process. At the same pressure given, the product can accept different forces and qualities in each machine. This study aimed to find the setting conversion between pressure and force using an experimental validation.
Methods: Measurements of pressure and force were carried out on three machines that were validated using standardized measuring instruments. Fixed factors including punch surface area (cm^2) and pressing time (second), and variable factors including pressure (psi) and force (Kgf) were determined. Compression load cell apparatus was used to obtain a correlation of pressure and force values from each machine. The method used was then validated with linearity and repeatability. Then the data is calculated using the CPK method.
Results: By using semi-manual hydraulic press machine (A), a powder foundation that has a pressure requirement of 1000 psi (with four cavity molds) to transfer 716 Kgf to each cavity, requires a pressure of 591 (with one cavity mold) in a Powder Press Automatic 7 Series 2 Kemwall machine (B), and a pressure of 635 psi (with one cavity mold) in a Powder Press Automatic 6 Series 6 Kemwall machine (C) by using the linear regression equation.
Conclusion: The applied force to determine the pressure to the Kemwall machines for the up-scaling process is the result of the conversion of its linear regression equation.
Keywords: Hydraulic pressing machine; Pressure; Force; Load cell; Conversion

Introduction

The compacting powder process is increasing daily with the improvement of techniques and technology. A flawless product will be obtained by involving many trials that are expected to cut production time and costs[1]. In pressing powder, the optimal pressure is required on a product. The pressure released varies by each press machine. If the pressure is too high, the product will be too hard, have a poor yield, and tend to glaze. Meanwhile, if the pressure is too low, the product will tend to be too soft, easily broken, and easy to peel off [2].

Different laboratories and production scale machine design for pressing powder inside the cosmetic manufacturer were common practice. It has been challenging when bringing manual laboratories into the automatic production machine setting during the up-scaling process. Pressure and force are important parameters that determine. At the same pressure released, the product can accept different forces, resulting in different qualities using a different machine design. It requires a long time to find and tune the production scale machines.

Hydraulic press machines use Pascal's law which states that when the intensity of pressure in a static liquid is transmitted through the piston, it will then move the punch in the same direction, resulting in friction between the punch and die and then inducing shear stress [3].

Pressure and force measurement is quite complex as each machine design has multi-factors that influence it. The compression load cell is an apparatus to convert pressure into an electrical signal in the form of force that can be measured and standardized. Pascal's formula, $P=F/A$ is used to predict the correlation of pressure and force values in each machine.

Force is a measure of the interaction between objects. The SI unit of force is Newton (N), which is the force that imparts a kilogram of mass to 1 meter per square second. Force measurement use a Load Cell[4]. In the load cell, the strain gauge component that will convert pressure into an electrical signal by detecting the force measured by strain [5].

The purpose of this study was to find the setting conversion between pressure and force using an experimental validation. This study would be a guidance for R&D and Engineer in the up-scaling process, and another benefit is decreasing the waste of setting time.

Materials and Methods

Materials

In this study, the materials used were load cell type of strain gauge with 10 Kgf capacity; three kinds of powder press machines, i.e., semi-manual hydraulic press machine (A), Powder Press Automatic 6 Series 6 Kemwall machine (B), Colour touch screen controls (unit); and Powder Press

Automatic 7 Series 2 Kemwall machine (C), with Reciprocating Hopper, size: 1979 x 1380 x 1780 mm (unit).

Methods

Force Measurement

Force measurement of each press machine was carried out 6 times using a load cell. This is to obtain data on the average stability of these components. When measuring, the load cell is placed under the punch of the press machine, then the punch is moved until it gives a load force to the load cell. Data reading is performed on the tool display. The input inserted into the press is in the form of pressure in units of psi. The amount of pressure applied to the press is in the range of 500 – 1800 psi with a data retrieval interval of every 100 psi.

Calculation of The Surface Area

The pressing surface area is calculated using formula $A = \frac{F}{(P*0.070307)}$. Where the pressure is multiplied by the multiplier factor which is the result of the conversion of units from psi to kg / cm^2. 1 psi = 0.070307 Kgf/cm^2.

Validation Method Measurement

To evaluate the performance of the press machine, validation was carried out on the measurement of experimental results. In this study, pressure and force were connected in the form of graphs, and calculated mathematically, through the parameters of linearity validation and repeatability.

Linearity

Linearity indicates the ability of an analytical method to obtain test results that correspond to the real force that the tool exerts on the product. The creation of a calibration curve of several sets of pressure will provide the highest and lowest ranges of the force. Furthermore, the value of the slope, the interception, its correlation coefficient (r), and the linear regression equation are determined. The linear regression equation will determine the minimum and maximum pressure limit ranges that can be used by each machine, to produce a force with a valid number, within the optimal pressure range used by production.

Repeatability

In addition to the system precision, this short-term variability includes the contributions from the test preparation, such as load cell positioning, needle positioning accuracy on the pressure gauge, time used, etc. Repeatability can be calculated using the equation below from a larger number of repeatedly prepared samples (at least 6).

$$s = \sum_{i=1}^{n} (x_i - \overline{x})^2 / (n - 1)$$

$$\%RSD = \frac{s}{\overline{x}} \cdot 100\%$$

Data Analysis

To describe reliability acceptance, the CPK method was used by determining these parameters first i.e., CPU, CPL, minimum specification value (LSL), and maximum specification value (USL).

CPK Method

The Process Capability Index (CPK) method was used to see the capabilities of a work process. The resulting numbers can provide an overview of the prediction of the stability of the process in the future. To determine the CPK value, here are the required components:

1. AVG, is the average value of a group of pressure data with the same engine pressure setting value.
2. S is the standard deviation value of a group of pressure data with the same engine pressure setting value.
3. USL is a specific value of the highest quality (upper limit) allowed in a work process.
4. LSL is the lowest quality specification value (upper limit) allowed in a work process.
5. CPU is a variable value formulated with ((USL – AVG)/(3*S)).
6. CPL is a variable value formulated with ((AVG – LSL)/(3*S)).
7. CPK, is a variable value that shows the capability of a process compared to its limitations and shows how its natural variability is. CPK is the lowest value between CPU and CPL.

Results

The results of force and repeatability measurements on all three machines are shown in tables 1, 2, and 3, respectively. The resulting force is linear with the pressure exerted. The higher the pressure, the higher the force value. Meanwhile, the results of the RSD that interpreted the repeatability, namely in the three machines with pressure variations, obtained a qualified RSD, where the RSD requirement for machine validation was $< 20\%$. The smaller the RSD value, the more appropriate the method used.

Table 1. Semi Manual Hydraulic Press Machine (A)

No	Pressure (psi)	Force (Kgf)							A (cm^2)	SD (Kgf)	RSD (%)	Mean±SD
		1	2	3	4	5	6	Mean (Kgf)				
1	500	992	995	993	992	994	994	993.3	28.3	1.2	0.12%	993.3±1.2
2	600	1337	1335	1337	1336	1335	1336	1336.0	31.7	0.9	0.07%	1336.0±0.9
3	700	1718	1712	1708	1715	1710	1712	1712.5	34.8	3.6	0.21%	1712.5±3.6
4	800	2084	2082	2076	2080	2078	2082	2080.3	37.0	2.9	0.14%	2080.3±2.9
5	900	2468	2467	2467	2468	2466	2467	2467.2	39.0	0.8	0.03%	2467.2±0.8
6	1000	2860	2866	2864	2864	2865	2866	2864.2	40.7	2.2	0.08%	2864.2±2.2
7	1100	3207	3201	3202	3202	3203	3203	3203.0	41.4	2.1	0.07%	3203.0±2.1
8	1200	3603	3600	3601	3600	3600	3601	3600.8	42.7	1.2	0.03%	3600.8±1.2
9	1300	3948	3949	3946	3949	3948	3948	3948.0	43.2	1.1	0.03%	3948.0±1.1
10	1400	4368	4364	4363	4365	4366	4365	4365.2	44.3	1.7	0.04%	4365.2±1.7
11	1500	4786	4785	4782	4785	4786	4784	4784.7	45.4	1.5	0.03%	4784.7±1.5
12	1600	5177	5173	5175	5174	5174	5175	5174.7	46.0	1.4	0.03%	5174.7±1.4
13	1700	5530	5530	5523	5528	5526	5530	5527.8	46.2	2.9	0.05%	5527.8±2.9
14	1800	5876	5870	5870	5870	5876	5871	5872.2	46.4	3.0	0.05%	5872.2±3.0

Note: A is pressing surface area; SD is standard deviation; RSD is the relative standard deviation

Table 2. Powder Press Automatic 7 Series 2 Kemwall Machine (B)

No	Pressure (psi)	Force (Kgf)							A (cm^2)	SD (Kgf)	RSD (%)	Mean ± SD
		1	2	3	4	5	6	Mean (Kgf)				
1	500	619	618	620	616	616	613	617	17.63	2.53	0.41%	619.7±3.67
2	600	698	698	697	699	700	696	698	16.96	1.41	0.20%	715.5±3.62
3	700	778	777	777	778	777	776	777.2	17.70	0.75	0.10%	871.0±4.82
4	800	858	857	858	858	858	854	857.2	17.84	1.60	0.19%	1003.7±5.54
5	900	940	940	937	937	938	937	938.2	18.35	1.47	0.16%	1161.3±4.27
6	1000	1029	1028	1027	1026	1028	1028	1027.7	17.93	1.03	0.10%	1260.5±5.36
7	1100	1114	1117	1114	1113	1112	1111	1113.5	18.60	2.07	0.19%	1438.5±4.85
8	1200	1207	1205	1207	1207	1206	1208	1206.7	18.30	1.03	0.09%	1544.0±5.55
9	1300	1306	1302	1303	1302	1300	1300	1302.2	18.58	2.23	0.17%	1698.3±6.50
10	1400	1392	1396	1396	1394	1394	1393	1394.2	18.77	1.60	0.11%	1847.5±5.50
11	1500	1491	1489	1488	1488	1488	1485	1488.2	19.03	1.94	0.13%	2006.5±3.83
12	1600	1581	1581	1583	1580	1579	1581	1580.8	19.17	1.33	0.08%	2156.2±3.71
13	1700	1677	1673	1671	1668	1670	1671	1671.7	19.06	3.08	0.18%	2277.5±2.17
14	1800	1768	1766	1766	1763	1767	1765	1765.8	19.01	1.72	0.10%	2405.8±2.86

Note: A is pressing surface area; SD is standard deviation; RSD is the relative standard deviation

Table 3. Powder Press Automatic 6 Series 6 Kemwall Machine (C)

No	Pressure (psi)	Force (Kgf)							A (cm^2)	SD (Kgf)	RSD (%)	Mean ± SD
		1	2	3	4	5	6	Mean (Kgf)				
1	500	619	618	620	616	616	613	617	17.55	2.53	0.41%	619.7±3.67
2	600	698	698	697	699	700	696	698	16.55	1.41	0.20%	715.5±3.62
3	700	778	777	777	778	777	776	777.2	15.79	0.75	0.10%	871.0±4.82
4	800	858	857	858	858	858	854	857.2	15.24	1.60	0.19%	1003.7±5.54
5	900	940	940	937	937	938	937	938.2	14.83	1.47	0.16%	1161.3±4.27
6	1000	1029	1028	1027	1026	1028	1028	1027.7	14.62	1.03	0.10%	1260.5±5.36
7	1100	1114	1117	1114	1113	1112	1111	1113.5	14.40	2.07	0.19%	1438.5±4.85
8	1200	1207	1205	1207	1207	1206	1208	1206.7	14.30	1.03	0.09%	1544.0±5.55
9	1300	1306	1302	1303	1302	1300	1300	1302.2	14.25	2.23	0.17%	1698.3±6.50
10	1400	1392	1396	1396	1394	1394	1393	1394.2	14.16	1.60	0.11%	1847.5±5.50
11	1500	1491	1489	1488	1488	1488	1485	1488.2	14.11	1.94	0.13%	2006.5±3.83
12	1600	1581	1581	1583	1580	1579	1581	1580.8	14.05	1.33	0.08%	2156.2±3.71
13	1700	1677	1673	1671	1668	1670	1671	1671.7	13.99	3.08	0.18%	2277.5±2.17
14	1800	1768	1766	1766	1763	1767	1765	1765.8	13.95	1.72	0.10%	2405.8±2.86

Note: A is pressing surface area; SD is standard deviation; RSD is the relative standard deviation

The linearity parameter on all three machines are indicated by the regression curves in figures 1, 2, and 3, respectively. A linear correlation between the pressure and the resulting force is obtained. The linear equation can be determined from the created regression curve.

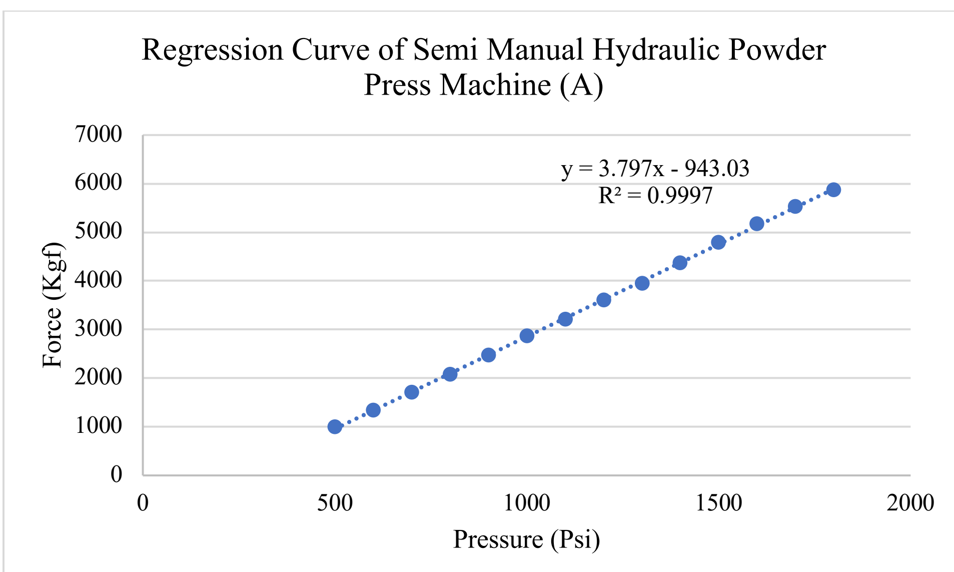

Figure 1. Regression Curve of Semi Manual Hydraulic Powder Press Machine (A)

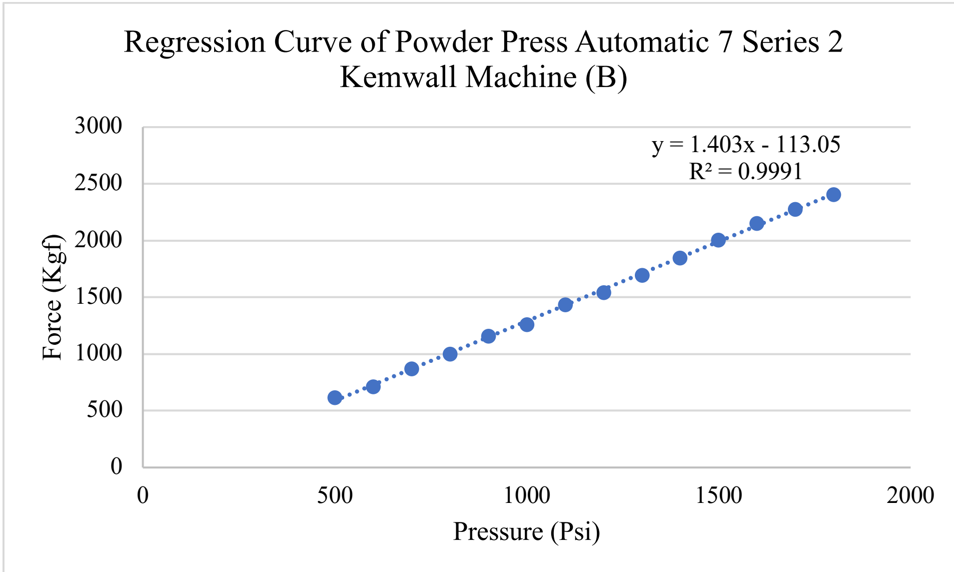

Figure 2. Regression Curve of Powder Press Automatic 7 Series 2 Kemwall Machine (B)

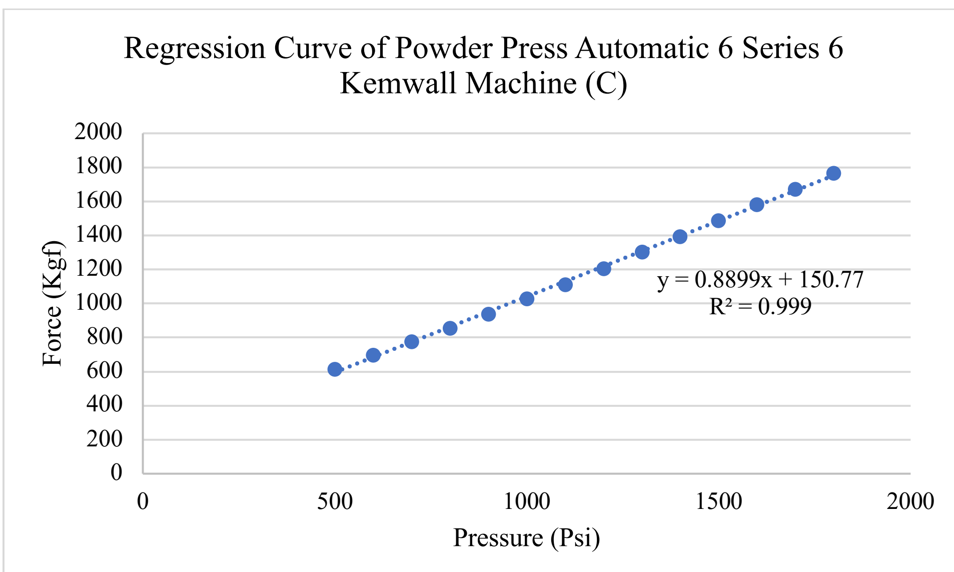

Figure 3. Regression Curve of Powder Press Automatic 6 Series 6 Kemwall Machine (C)

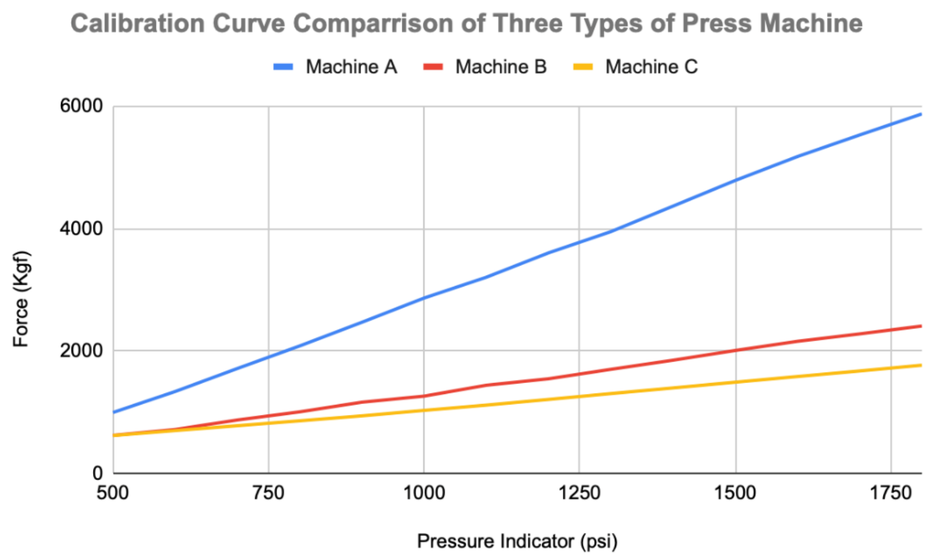

Figure 4. Calibration Curve Comparison of Three Types of Press Machine

Figure 4 shows that when the same pressure is released can cause machine A produces a greater force when compared to automatic machines (machine B and machine C). The regression equation of the three machines shows that the value of b as a slope expresses the degree of sensitivity of a method. The slope on machine A, namely 3.8, has a sensitivity of 2.7 times compared to the machine B engine (slope = 1.4), and 4.3 times compared to the machine C engine (slope = 0.88).

The compression process is influenced by the number of cavities used. The force received is divided evenly based on the number of cavities used. Based on the machine used, Semi Manual Hydraulic Press Machine (A) uses four cavities while the other two machines use a single cavity. This will give a difference in the force required during the compression process. The compression process with an increasing number of cavities requires a greater force because each cavity must receive the same force from one machine to another. Based on the regression curve generated from data collection, to produce the same force at 716.1 Kgf, the pressure value required for each machine is attached in Table 4.

Table 4. Pressure Conversion of Powder Foundation in Three Types of Press Machine

No	Machine Type	Pressure Needed (psi)	Number of Cavity Mold	Force Needed (Kgf)	Force Needed/Cavity (Kgf)
1	Semi Manual Hydraulic Press Machine (A)	1000	4	2864.2	716.1
2	Powder Press Automatic 6 Series 6 Kemwall Machine (B)	591	1	716.1	716.1
3	Powder Press Automatic 7 Series 2 Kemwall Machine	635	1	716.1	716.1

Note: Calculation of the required pressure, using the linear regression equation of each machine.

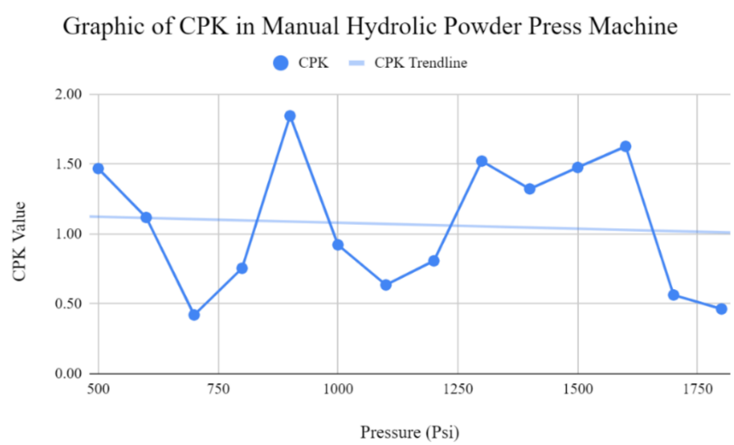

Figure 5. Graphic of CPK value results in Semi Manual Hydraulic Powder Press Machine (A)

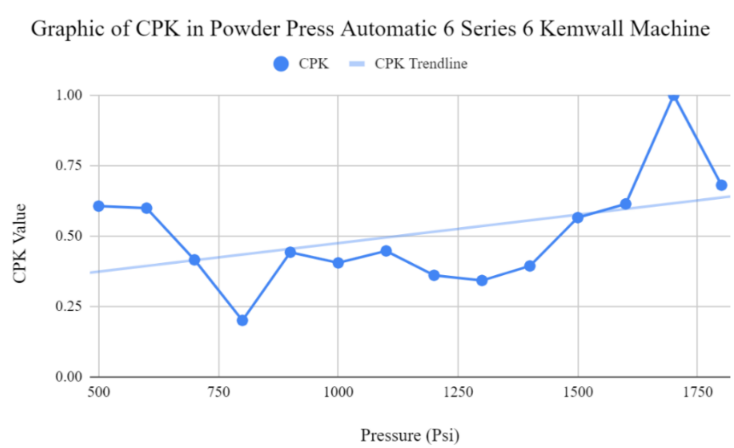

Figure 6. Graphic of CPK value results in Powder Press Automatic 7 Series 2 Kemwall Machine (B)

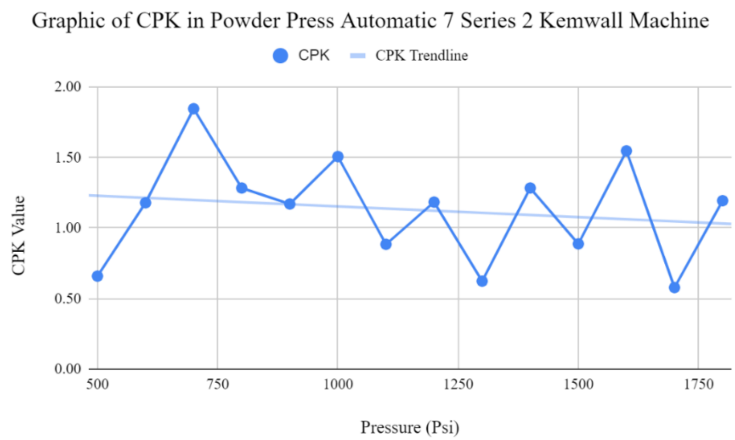

Figure 7. Graphic of CPK method value in Powder Press Automatic 6 Series 6 Kemwall Machine (C)

CPK method result from each machine is shown in Figures 5, 6, and 7, respectively. A CPK value equal to 1 indicates a perfectly centralized data variation. The greater the CPK value, the less likely it is that the future process value will fall out of the USL and LSL limits. Of the three machines, only machine B with a pressure of 1700 psi has a CPK value equal to 1, so it is concluded that machine B with a pressure of 1700 psi has good repeatability.

The CPK trendline is shown in the figure above. Machine B has a trendline that tends to go up. Meanwhile, machine A and C have a trendline that tends to fall. However, in both machines, several pressures have a CPK value greater than 1, which is still better when compared to other machines that have a CPK value less than 1. Machine B will be of better use to products that require high pressure, which is indicated by the increment of the CPK value trendline. However, the limitations of this machine are not known yet in what pressure this machine works properly for pressing products.

Discussion

The method of measuring force using the load cell apparatus in this study was validated with linearity and repeatability parameters. The measured force is the value with Kgf units because the machine used uses these units. The selection of pressure between 500 to 1800 psi is carried out because, in his daily life in the field, the production of press cosmetics uses this range of pressure.

The initial hypothesis of this study is that the results are expected to be in line with Pascal's law, but the results show that it is not in line with the law because the A value in the variation of the pressure exerted is not constant. Therefore, further research will be carried out based on the Laws of Impulse and Momentum (time & speed). As for the non-constant A value, it is necessary to conduct further research on the influence of the surface area of the compressive cross-section on each machine.

In this study, the initial force for the product was determined through the linear regression equation of machine A in the lab by inputting the pressure into the equation. For the up-scaling process, the conversion is done by inputting the initial force to the linear regression equation of machine B and machine C to get the pressure needed by each machine. With this conversion, setting time in the production machine can be reduced and the production lead-time can be more efficient.

Another benefit is that it can be a guideline to determine specifications when buying a new press machine, either when adding a new machine due to increasing production capacity, or if there are new product requirements that require force outside the existing press machine specification range. Besides that, the reliability of the machine can also be used for maintenance and or calibration indicators. When the machine reliability value is not by the standard, then the machine maintenance and or calibration period can be designed. In addition, the results of this study are useful in the process of determining the grouping of formula types that can be pressed. Having the pressure specifications of product will allow adjustment of the production machine to be used.

Conclusion

This paper discusses the basic knowledge related to force measuring instruments and force realization systems. In the future, the converter can be used as a solution to determine which machine to use for up-scaling and production processes that ensure the same force value with the lab scale machine, by entering an existing linear regression equation and to achieve an efficient setting time of the pressing process.

Acknowledgments

The authors would like to thank the contribution of Nur Afifah Pulungan, Sri Intan Zakaria, and Paragon Technology and Innovation towards this research.

Conflict of Interest Statement

NONE.

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