Autotrickler for Powder Measurement

Allen Dominek

Abstract

Powder loading has become faster with digital scales. Manually loading with a digital scale may have some hysteresis when powder has to be removed from the pan. A trickler was built to automate powder loading and to remove potential error from powder removal. A strain gauge was instrumented with a Raspberry Pi and a display to sense the trickled powder amount. A control system was developed to accurately and repeatably dispense a desired load. This system is at least as accurate as digital powder scales. Some commercial scales provide .01 grain resolution but the use of these scales are not really necessary since many powder rods are of the order of .5 grains.

Keywords: recoil, powder loading, trickler, strain gauge

1. Introduction

Reloading requires careful and consistent powder measurements. Digital scales have made this process much more reliable and faster. However, it still is time consuming. An autotrickler to measure the powder can reduce the measurement time. There are autotrickler products on the market and internet references for do-it-yourself autotricklers.

This article examines the components and the performance for an autotrickler based upon the described autotrickler in [1]. There are three major components to an autotrickler. There are 1) a powder delivery system, 2) a scale and 3) a controller.

2. System Description

Figure 1 illustrates the major components of this autotrickler.

The powder delivery system is a RCBS trickler [2] that has a vibrating, 3 V motor attached to the delivery tube. The vibrating motor slightly shakes the delivery tube for the powder to be dispensed into the measuring pan. The motor vibration amount is controlled by supplying a square wave pulse width modulated (PWM) signal to it.

The scale consists of a load cell (TAL221) [4] and a 24 bit sigma-delta ADC (NAU7820) [5]. The measuring pan holder is attached to the load cell as a point load. The holder has a depression to retain the measuring pan in a stable, centered location. It is important for the pan to remain physically stable during the measurement cycle.

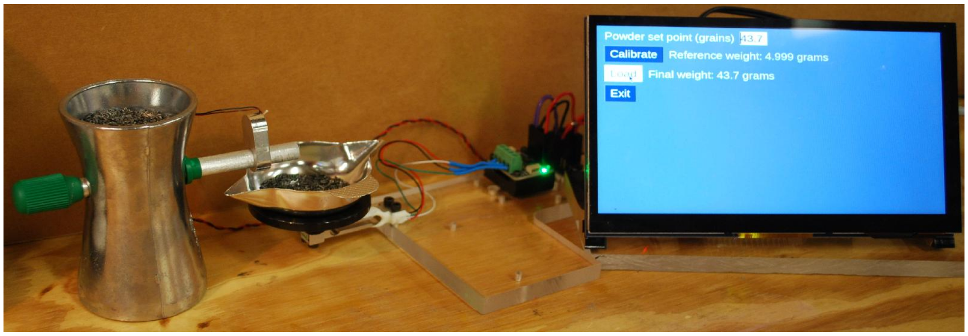

Figure 1: Illustration of autotrickler configuration.

The controller consisted of a Raspberry Pi 3 SBC with python modules to supply the vibrating motor with a PWM signal and to obtain the ADC output [5] to determine the dispensed powder weight.

A basic GUI was also generated to interface with the Raspberry Pi for the loading process using a touchscreen LCD as illustrated in Figure 2.

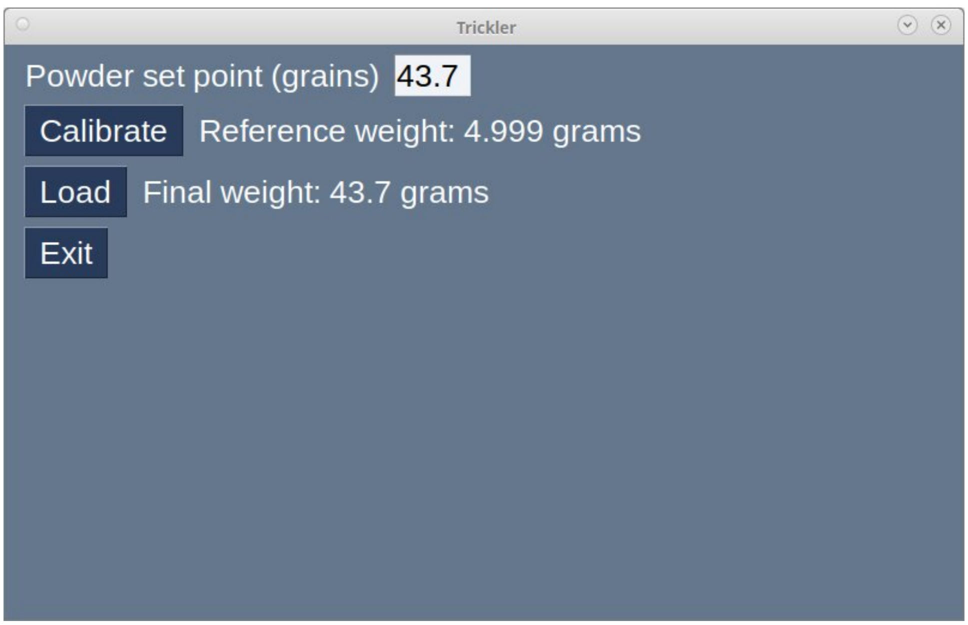

Figure 2: Illustration of touchscreen GUI.

2.1. Powder Delivery System

The powder delivery system is fairly simple. An aluminum holder was made to retain the vibrating motor and to allow attachment to the feeding stem. This holder was machined but it could have been made using a 3D printer. No issues were observed for the powder not being consistently feed through the feeding tube. No additional guides were used to exit the powder from the feeding tube. The location of the vibrating motor along the feeding tube was not critical.

An important parameter to be aware of is the rate of powder that the delivery system can dispense per second. It is important to know this parameter to use the proper ADC sampling rate and controller design. Figure 3 illustrates the characteristics for this powder delivery system. The powder used here is IMR 4350. Each rod has an average weight of .042 grains. This powder delivery system has linear rates depending upon how fast the vibrating motor vibrates.

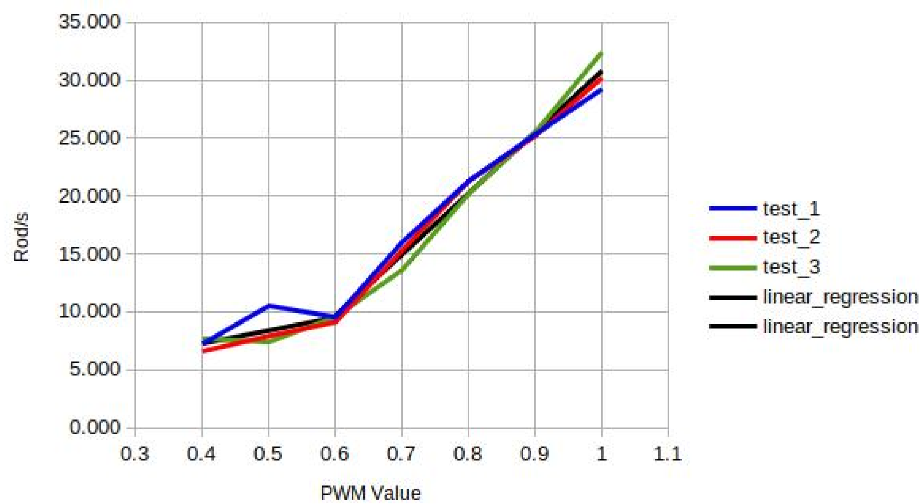

Figure 3: Rod rate as function of PWM.

For PWM levels less than 60%, the dispensed rod rate is

$$\text{Rod Rate} = 11.21 * \text{PWM} + 2.789 \tag{1}$$

and for PWM levels greater than 60%, the dispensed rod rate is

$$\text{Rod Rate} = 52.81 * \text{PWM} - 21.99 \tag{2}$$

2.2. Scale

A low cost load cell (TAL221) was used which had a measured load capacity of 100 grams. A higher precision load cell could be desirable with better performance specifications. It was observed that both the RCBS 2000 digital scale and the US Solid 100 gram scale [9] had a 300 gram load cell. It was decided to use a 100 gram load cell since my powder measurements would typically be less than 5 grams ($\sim$ 77 grains). Using a larger capacity load cell would decrease the measurement resolution although the 300 gram capacity load cell had better load sensitivities (typically 1mv/V compared to the .6mv/V for the TAL221 load cell).

The analog digital convertor (ADC) (NAU7802) used most likely had the same performance as the ADC 24 bit ADC's in the referenced RCSB and US Solid scales. The performance of the NAU7802 was evaluated against the Analog Device's AD7191 24 bit sigma-delta ADC which was designed for weighing scales. Both had comparable performance characteristics.

There are usually a number of user controlled parameters to consider with load cells and ADC's. These parameters impact the measurement accuracy. One is the excitation voltage of the load cell. 4.5 V was used in this case. The higher the voltage, the greater voltage separation for each quantization level in the ADC. This is important since all measurements have noise and since small weight differences are desired in the application, having the largest excitation voltage was desirable.

The other parameter of interest is the ADC sampling rate. The sampling rate has to be sufficiently large to account for the amount of powder being dispensed during the measurement cycle. ADC's of this class typically have rates of 10 sps (samples per second) and upward. As the sampling rate increases, so does the measurement noise. This noise can be characterized by the standard deviation in a measured weight. Shown in Figures 4 through 7 are the measured distributions when no weight on the scale at sampling rates of 10, 20 and 80 sps based upon 1000 samples.

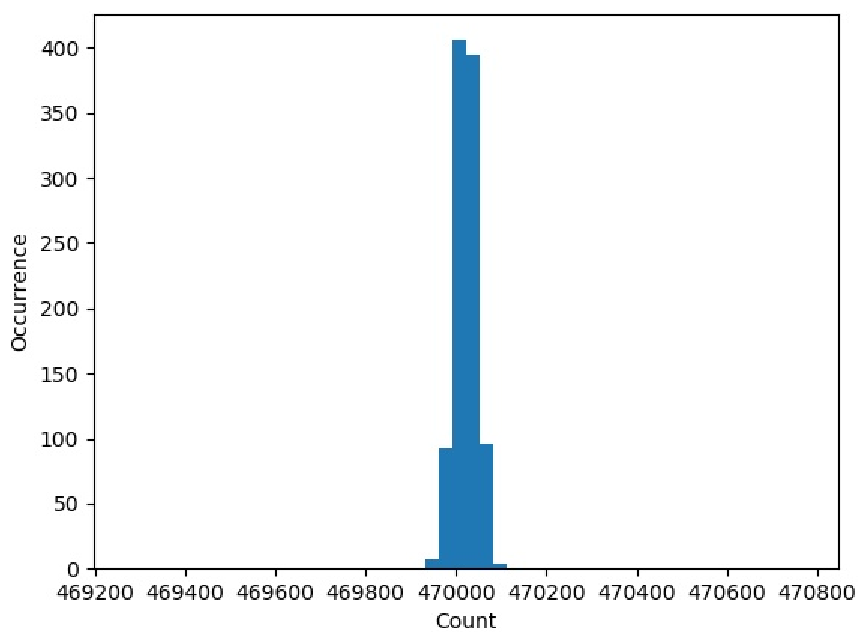

Figure 4: Count distribution with a 10 sps rate.

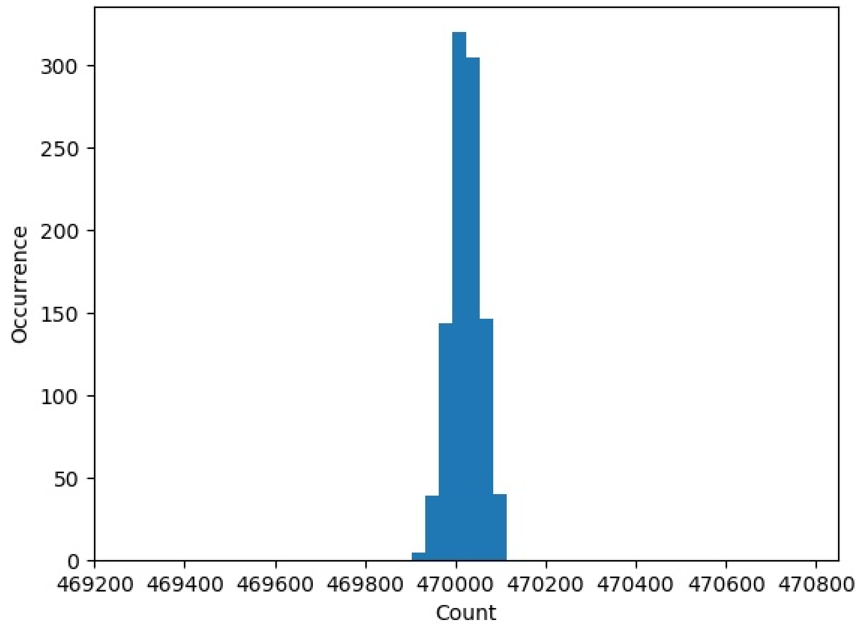

Figure 5: Count distribution with a 20 sps rate.

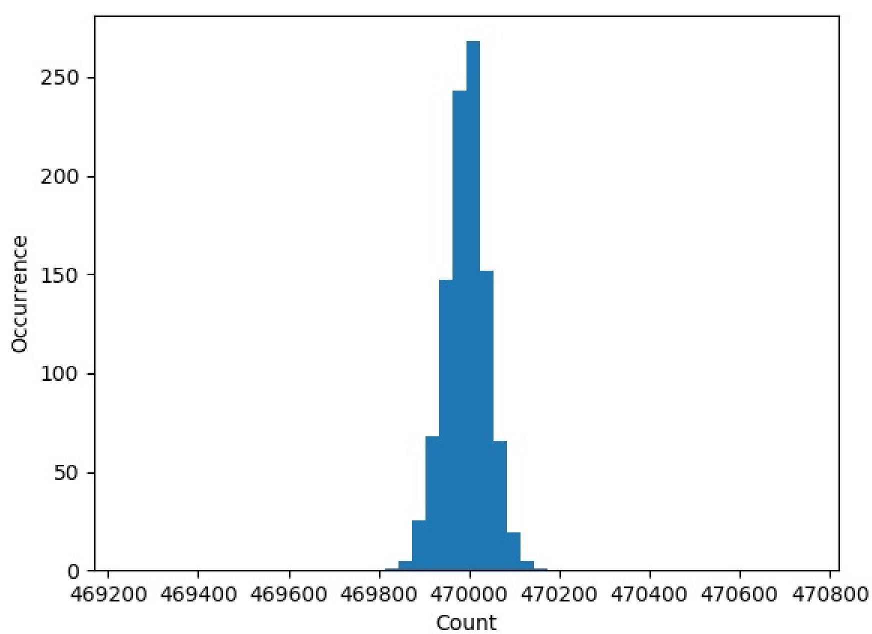

Figure 6: Count distribution with a 40 sps rate.

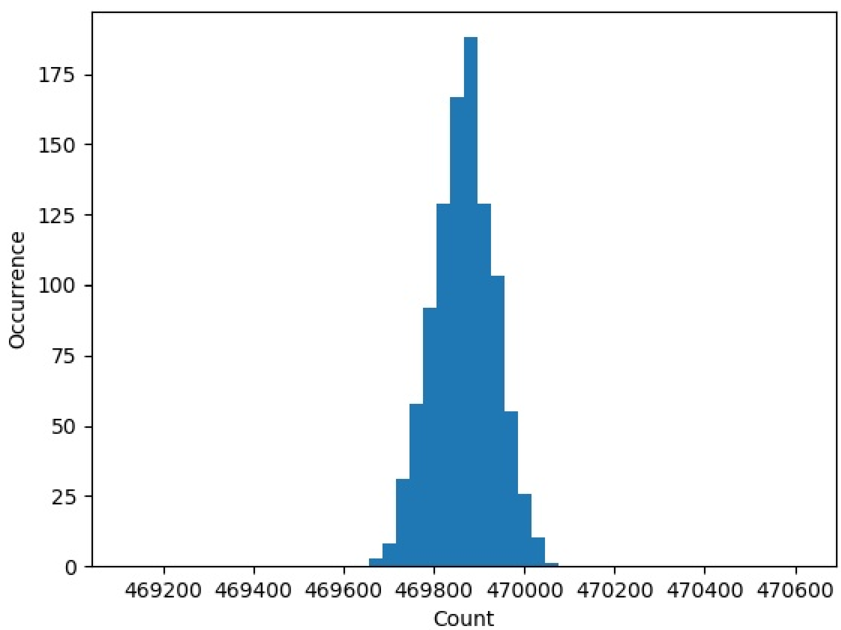

Figure 7: Count distribution with a 80 sps rate.

Table 1 contains the standard deviation of the digital output (measured voltage scaled to 2^{24} quantization levels) for various ADC sampling rates based upon 1000 samples.

Table 1:
ADC Characteristics for 1000 Samples

SPS	Average Count	Standard Deviation
10	469997	25
20	469906	35
40	469907	50
80	469983	65
320	469976	280

The above graphs and table provide important information regarding the accuracy of the measured powder load. The measured quantization levels for a 5 gram weight is 65958 for this system. If .1 grain resolution is desired, the system has to be able to resolve between a quantization difference of 85 quantization levels (.1 grain = .00647989 gram and 65958∗.00647989/5 = 85). It is desirable to use a sampling rate that is at least as fast as the rod dispensing rate shown in Figure 3.

Finally, the load cell was calibrated using reference weights of 0 and 5 grams. It was felt that no benefit is realized with using a larger dynamic range since my measured weights of interest are less than 5 grams. Load cells are fairly linear but not perfect. There is no reason to calibrated to 50 or 100 grams if measurements are not going to be required in this range. A two point calibration (no weight and 5 grams) was used for calibration since the load cell is probably sufficiently linear in this range.

2.3. Controller

A Raspberry Pi was chosen to control the measurement process. A touchscreen interface with a GUI was also built to facilitate the loading process. The python based program was written to control the process. The gpiozero module was used to generate a pulse width waveform to drive the vibrating motor. The pulse width varied between 30% to 100%. The electrical interface to the vibrating motor is shown in Figure 8. The resistor value of 2000 ohms was experimentally determined to have the best PWM performance with 2N5449 transistor. Many NPN transistors can be used but care has to be used to insure the most appropriate base resistor is used. Appropriate means that the vibrating motor is responsive with the change of the PWM value.

A PID controller [8] was initially used to determined the PWM level. The PWM level characteristics were analyzed and replaced with a simple control function. The acronym "PID" refers to controller's *proportional*, *integral* and

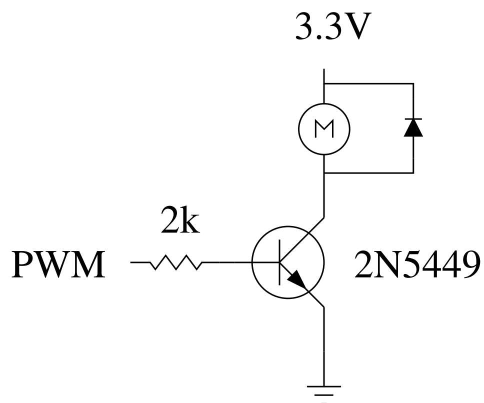

Figure 8: Transistor driver circuit for the vibrating motor.

derivative response to the input signal. This response was examined for this system.

With a set point of 43.7 grains of IMR 4350 powder, the PID parameters were changed independently as shown in Figures 9 and 10. The nomenclature in the graphs contains three numbers refering to the PID constants used. The numbers are the weights for the proportional, integral and derivative components (commonly referred to as the K_p, K_i and K_d constants). The value for the derivative component was always set to zero since the changing measured powder weight was not smooth enough for the first order derivative in the PID formulation to yield a useful result.

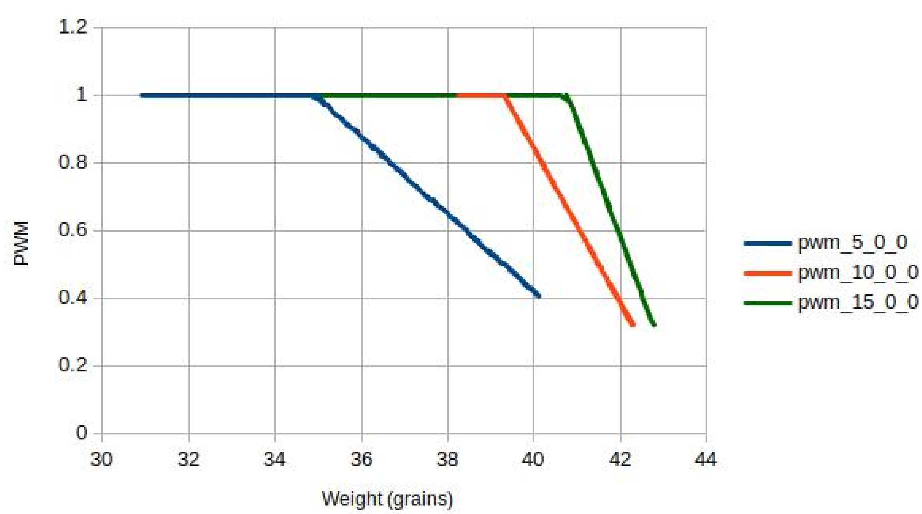

Figure 9: PWM characteristics with PID controller. "Proportional" control only.

As can be seen, there is a linear variation in the PWM signal when the set point weight is approached. The allowed PWM values were between .3 and 1. Both the proportional and integral constants impacted when the PWM signal differed from 1. Using only a proportional control drove the PWM

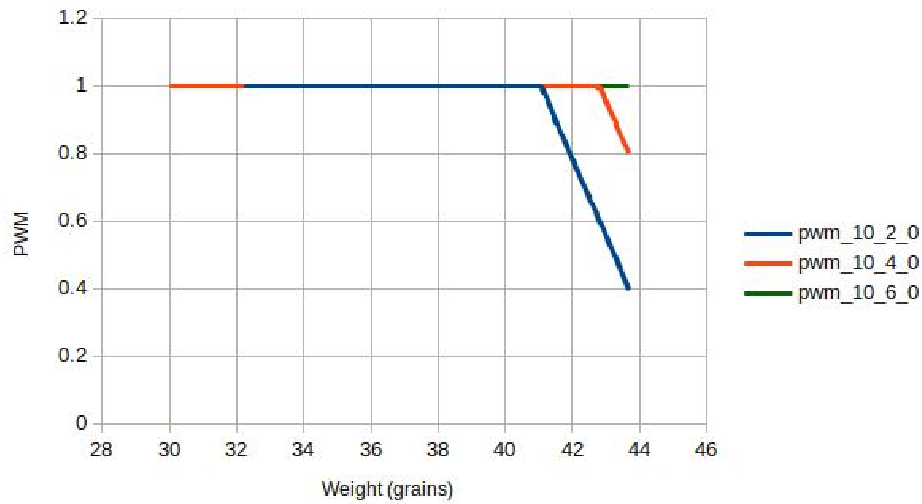

Figure 10: PWM characteristics with PID controller. Fixed "Proportional" value with "integral" variation.

value close to .3 when the dispensed powder neared the set point resulting in no powder being delivered in a timely manner. Including an integral component controlled the PWM value when the dispensed powder neared the set point.

The PID constants do not have have a direct physical interperation of how the PWM values are set. Two alternate controllers are proposed and implemented.

The design considerations for a controller are two. Firstly, to deliver the powder in the shortest time which implies to have the motor vibrate as long as possible at the fastest speed and secondly, to have the motor vibrate at a low speed near the target weight for the ADC to accurately measure the dispensed weight so when the target weight has been achieved, the motor can be shut off without additional powder dispensing. It is not necessary to accurately measure the dispensed powder weight unitl the motor vibration has been reduced near the set point.

There are two simple approaches to achieve these design constraints. The simplest one is to drive the vibrating motor at its fastest rate until some weight value, w_i has been achieved and then to drop the motor vibration to a slow and final rate, PWM_f to accurately measure the dispensed powder weight and to shut the motor off when the final, set point weight w_t has been achieved.

The other approach is to linearly vary the motor vibration between its fastest rate at w_i to the final rate PWM_f at w_f. The equation for the PWM value as a function of measured weight w is

$$\mathrm{PWM} = 1 + \frac{\mathrm{PWM}_f - \mathrm{PWM}_i}{\mathrm{w}_f - \mathrm{w}_i} * (\mathrm{w} - \mathrm{w}_i) \tag{3}$$

Figure 11 illustrates the graphical representation of the linear and step controllers. Note that the step controller is a special case of this controller.

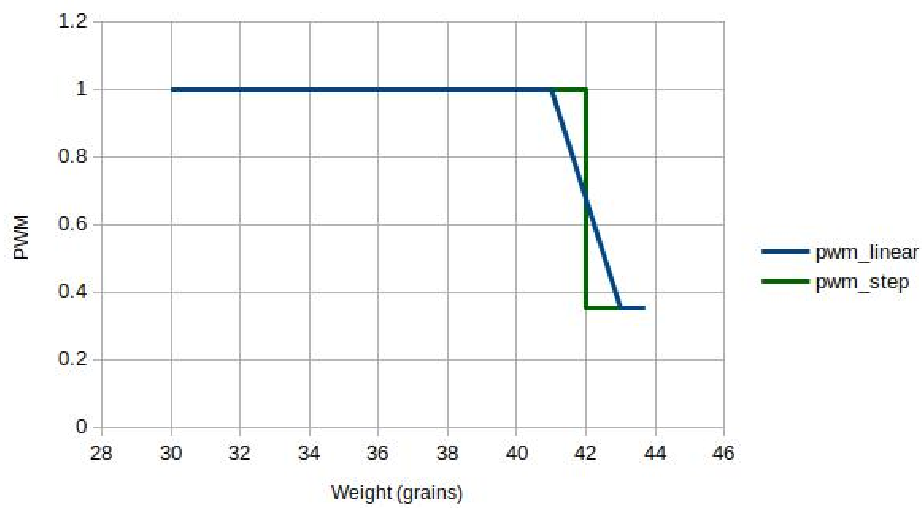

Figure 11: The PWM function for the linear and step controller. Target weight of w_t = 43.7 grains, w_i = 41.0 grains, w_f = 43.0 grains for the linear controller. The step controller with a PWM transition at a powder weight of w_i = 42.0 grains.

3. Evaluation

The proposed linear controllers were evaluated with $w_t = w_f = 43.7$ grains, $w_i = 41.7$ grains and $PWM_f = .35$ for the linear controller and $w_i = 42.2$ grains and $PWM_f = .4$ for the step controller. The powder pan was preloaded with about 40 grains for powder (IMR 4350) to minimize the amount of loading time. It took about 8 seconds to achieve the desired powder weight with a sps rate of 20. Tables 2 and 3 illustrate the weight comparison between the scales.

Excellent weight agreement is obtained between the powder loads for this autotrickler and the RBCS 2000 scale [3] and US Solid scale, model JFDBS00046 [9]. The "step" controller was not as consistent as the "linear" controller but the w_i and PWM_f values were slightly different too. It was observed that the RCSB 2000 scale sometimes produces a slightly higher reading when the measured powder was poured into the measuring pan. Lifting the pan from the scale and placing back produced a lower reading. Sometimes during manual powder measurements with the RCSB 2000 scale, a hysteretic behavior has been observed. Removing some rods of powder may not always register the anticipated reading for the number of rods removed. It is believed that a more consistent amount of powder is dispensed when mechanically dispensed and always adding to the total amount powder and not removing any powder rods during the measurement process.

Table 2:
Weight Comparison between Scales (grains)
$w_i = 41.7$ grains, $w_t = w_f = 43.7$ grains and $PWM_f = .35$

	Autotrickler (linear)	RCSB 2000	US Solid
1	43.73	43.7	43.689
2	43.76	43.7	43.750
3	43.75	43.7	43.704
4	43.75	43.7	43.766
5	43.77	43.7	43.689
6	43.73	43.8/43.7	43.704
7	43.75	43.7	43.719
8	43.72	43.8	43.735
9	43.73	43.7	43.719
10	43.80	43.8	43.766

Table 3:
Weight Comparison between Scales (grains)
$w_i = 42.2$ grains and $PWM_f = .4$

	Autotrickler (step)	RCSB 2000	US Solid
1	43.75	43.7	43.704
2	43.78	43.8	43.812
3	43.80	43.7	43.735
4	43.68	43.7	43.689
5	43.73	43.7	43.735
6	43.75	43.8	43.812
7	43.69	43.6	43.658
8	43.77	43.7	43.719
9	43.77	43.8/43.7	43.766
10	43.71	43.7	43.704

4. Conclusion

Presented is a discussion on the components for a powder autotrickler and its design. Its performance is excellent and at least as good to that of manually using a digital scale. The benefit of autotrickleling is the speed at which a powder load can be measured compared to manually measuring. Additionally, alternative controller methodologies are presented. These alternate controllers have a direct physical interpertation of the PWM control parameters which the PID K_p, K_i and K_d control constants do not provide.

Both alternate controllers have the potential to have comparable performance, however, the "linear" controller was slightly better for the constants used. It is important, at least for this powder delivery system and scale, as the target weight is approached, the dispensing powder rate is small (small PWM value). This insures that the powder dispensing can be terminated when the target weight is achieved with no additional powder contributions.

Commercially available scales with serial interfaces are available to use instead of the discrete load cell and ADC module. The US Solid scale, model JFDBS00046 does have a serial interface but its sample rate is slow and has a long settling time. Other much more expensive scales such as the FX-120i [10] have been used in autotrickling powder which has a magnetic damping feature and serial interface.

No performance comparisons were made to commercially available autotricklers.

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