DESIGN AND DEVELOPMENT OF V-BLENDER MACHINE, PART 1

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DESIGN AND DEVELOPMENT OF V-BLENDER MACHINE, PART 1

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ABSTRACT

V-blender is one of the tumbling type blender which widely used in many fields for powder mixing. This project objective is to design and develop a table top V-blender machine used for metal powder mixing. The main parameter to consider in the design and development of table top V-blender machine is the angle of the v-shell which is about 90^o and the mixing speed. The mixing speed in this machine is controlled by using a power window DC motor and a DC12V to DC40V motor speed controller. The mixing capability or performance of the machine is tested by using crushed plastic. From the testing, the machine able to properly mix the granules. The machine is equipped with a safety cover to prevent from any object accidently hit the canister or V-shell during the mixing process. The development of this V-blender can be very useful in UMP for small scale research that related to alloying components and powder metallurgy.

Keywords: V-blender machine, V-shell, mixing speed, small scale research

INTRODUCTION

Particles blending is important in ceramic, food, metallurgical, polymers, and pharmaceuticals industries [1-7]. The most important thing in compounding is the intimate blending of the components [8]. The fabrication of alloys by powder metallurgy requires diffusional homogenization of compacted blends of powder which achieved by blending [9-11]. V-blender is one of the common blender design to blend granular materials [12-15]. V blender machine perform blending process for mixing of dry powders homogeneously as the mixer revolves [8, 16]. There are numbers of researches on metal powder metallurgy was carried out by using V-blender as the mixer [17-21]. Besides mixing metal powders, V-blender also can be used to blend the mixture of metal powders and reinforced fibers [22]. V-blender also can be called as twin-shell blenders [23] have two cylindrical shells attached at an angle to form a V shape and for it to work properly, it should be filled on to the axis of rotation [24]. To design a V-shell for the V-blender machine, there are parameters that need to be considered. V-blender consist of two hollow cylindrical shells joint at 75^o to 90^o angle [25]. However, the angle range of 70^o to 90^o also been recommended [13]. Surface roughness also plays an important role in determining how an object interact with its environment and it is a good predictor of the performance [26, 27]. The segregation of granules in mixing can be due to device surface finish where rougher surface has less potential for segregation than smooth surface [28]. The velocity and kinetic energy of the mixture decreases when the fill level increases [29]. V shape feature will produce good quality of blending of granules in medium rpm movement.[29]. The V-blender operate intermittently combining splitting and merging making it has rapid mixing of granules mixture [2]. Understanding mixing mechanisms and identifying critical process and material parameters is one of the steps during process development [30]. Even the way that the powders been loaded into the blenders can changes the mixing time [3]. The operation process of V-blender involves intermittently, combining splitting and merging where the smaller particles will accumulate near the center of the v-shell [31, 32]. The blender volume normally in occupy 60% of V-shell volume where 40% is air volume to mix and flow [32, 33]. The fill level of 35% up to 65% and the rotational speed of 15, 30 and 45rpm was used for the research purpose [32, 34, 35]. Critical process control variables of blending operation are blender occupancy, blending time and RPM which affect blend uniformity [6, 36]. Alexander, Muzzio and Shinbrot research on effect of fill capacity and fill level beside the segregation patterns in V-blender by using the V-shell of the parameter shown in Figure 1 [12, 37].

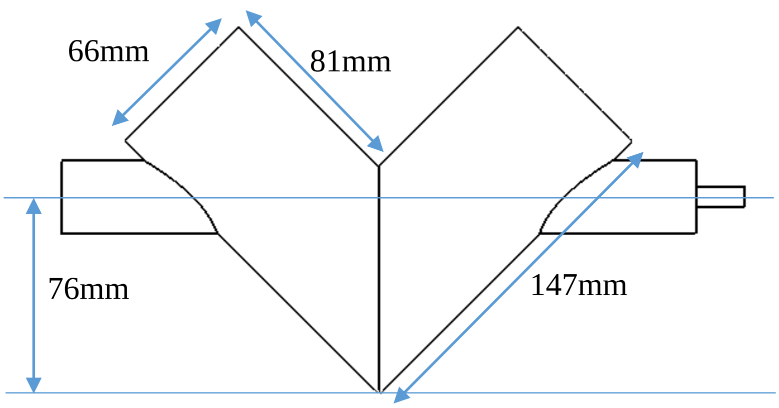

Figure 1. V-shell parameters (Alexander, et al, 2003)

In industry scale, V-blender are permanently fixed to the blender shaft [14]. V-blender give slightly better mixing result compared to double cone blender [38]. Doucet and his team investigate the flow structure in 16 qt. V-blender with 50% fill level of 3mm glass beads [39]. In a metal powder metallurgy, a steel powder was mixed with a small amount of granular foaming agent for 75 min by using a V-blender and the mixing method was critical to achieve homogeneity [18]. Blending cycles can be in 15 minutes [40] to 30 minutes [41] or more which up to 20 hours [9, 10, 42, 43]. On the other hand, a research with the mixing of NiTi and NaCl powder with volume percentage of 60% and 40% is blended for 40 min [44]. On top of that, the Fe and Ni powder were mixed with V-blender for 2 hours in the study of microstructure on the mechanical properties of MIM Fe-Ni alloy steels [45].

Fabrication of the V-blender machine requires some consideration especially during drilling, metal shearing and spot welding. When drilling, there will be vibration which can be distinguished as low frequency vibrations associated with lobed holes and high frequency vibration (chatter) which caused the roundness problem [46]. In the shearing of sheet metal, clearance between punch and die play an important role [47]. During the operation of shearing machine, sheet metal subjected to shear stress developed between a punch and a die is called shearing. Shearing process usually starts with formation of cracks on both the top and bottom edges of the work piece where cracks meet each other and separation occurs.[48]. The tool positions must be adjust precisely when cutting the thin sheet metal in order to avoid develop clearance and effect cutting accuracy [49]. The spot welding process was used to spot weld between a sheet metal and a hinge. The spot welding of hinge and sheet metal is done with precaution as it subject to significant amount of peel force [50] when subject to the loading (safety cover). Spot weld diameter has significant effect on the fatigue life of the spot weld [51].

The dimension of the machine designed not more than 500 mm X 500 mm X 500 mm. Besides, the canister can detached from the machine and the machine can operate in variable rotational speed.

The objective of this project is to develop a table top v-blender machine that capable of performing powders mixing for powder metallurgy researches. The v-blender machine fabricated uses both electrical system and mechanical system. The electrical system is the system for the DC motor with controllable speed while the mechanical aspect is the design development of the machine body, frame and overall system. This machine uses aluminium profile as the frame, sheet metal as the body and acrylic as the safety guard.

METHODOLOGY

The design and development of V-blender will be divided into 4 stages. The stages are: (1) gathering of information, (2) concept generation, (3) fabrication, and (4) testing. The gathering information stage is the stage to gather all the related information such as the important of V-blender machine, the important design parameters and the fabrication methods to be used as described in literature review.

Concept Design

The design of the V-blender machine is made by using SolidWorks 2012. Few important parameters such as the motor minimum torque required and the equipment for rotation speed measurement is determined before the design is finalized as shown in Figure 2 and Figure 3. Figure 2 also shows the interior circuit and design of the machine with consist of a motor speed controller, power window DC motor, AC to DC converter, toggle switch and a push on switch by changing the body cover into transparent. Figure 3 on the other hand shows the complete design of the machine. The machine is designed to rotate only when the safety guard is closed and the main on off switch in the body panel is ‘ON’. Table 1 highlights the name and purpose of each important parts of this machine as labeled in the Figure 2 and Figure 3.

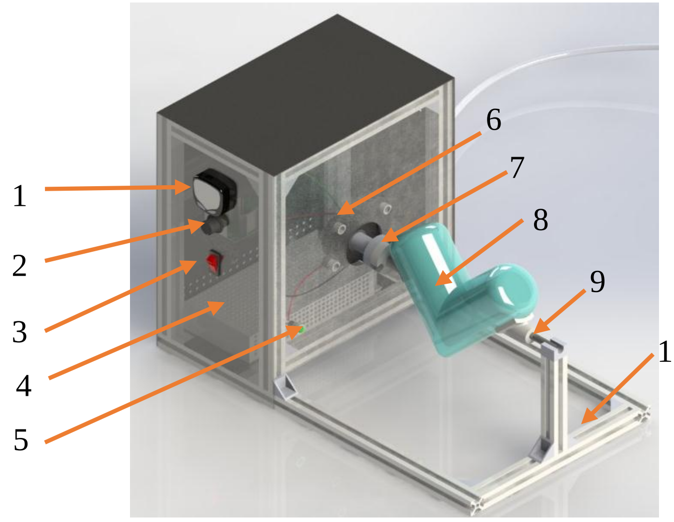

Figure 2. V-blender machine without safety guard

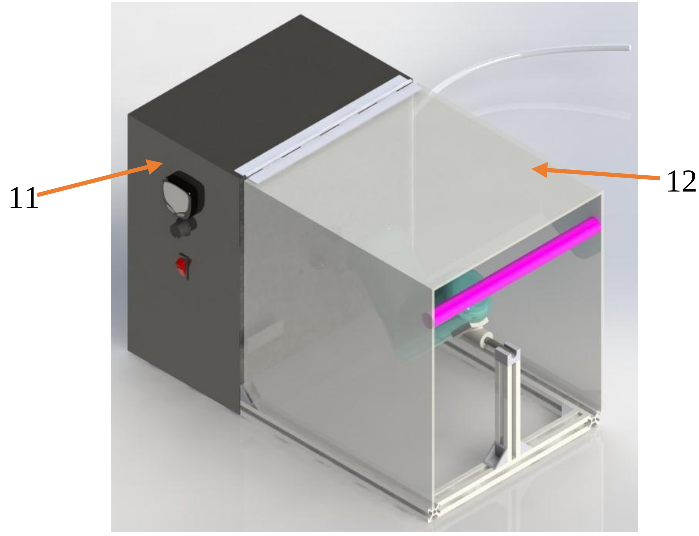

Figure 3. V-blender machine with safety guard

Table 1. Important parts of the V-Blender

Parts No.	Parts Name	Function
1	Speedometer	To display the rotation speed (RPM) of the V-Canister
2	Speed Controller	To allow the user to control the rotation speed of the V-Shell
3	ON/OFF button	To switch ON and OFF the machine.
4	AC to DC Converter	To convert AC to DC power supply and also to step down 240V to 12V so that the DC motor can operate.
5	Safety Switch	To make sure the safety guard is fully covers the rotating part before the operation starts.
6	DC Motor	To provide torque and continuous rotating force to the V-Shell.
7	Customised Hubbing	To bridge the DC motor and V-Shell through simple locking arrangement.

8	V-Shell	To contain and blend the mixture of the metal powders.
9	Support	To provide end support for the canister for stable rotating.
10	Aluminium Profile	To provide structural support for the whole construction.
11	Sheet Metal	To protects the internal component of the machine and to accommodate the Speedometer, Speed Controller and ON/OFF button
12	Safety Guard	To prevent the user to get injured due to the rotating parts.

The designed machine was analyzed for its displacement and factor of safety by using SolidWorks 2012 Simulation to perform the Finite Element Analysis (FEA). The load applied to the canister or V-shell was 2 kg and from the analysis as shown in Figure 4 and Figure 5, the maximum displacement for the canister when applied with 2 kg is 0.16 mm while the minimum FOS is 13. FOS of more than 2 is used in order to eliminate the potential of machine static failure due to the imperfection during fabrication process. Thus, it can be concluded that the design of the machine is safe and will not fail when fabricated according to the design.

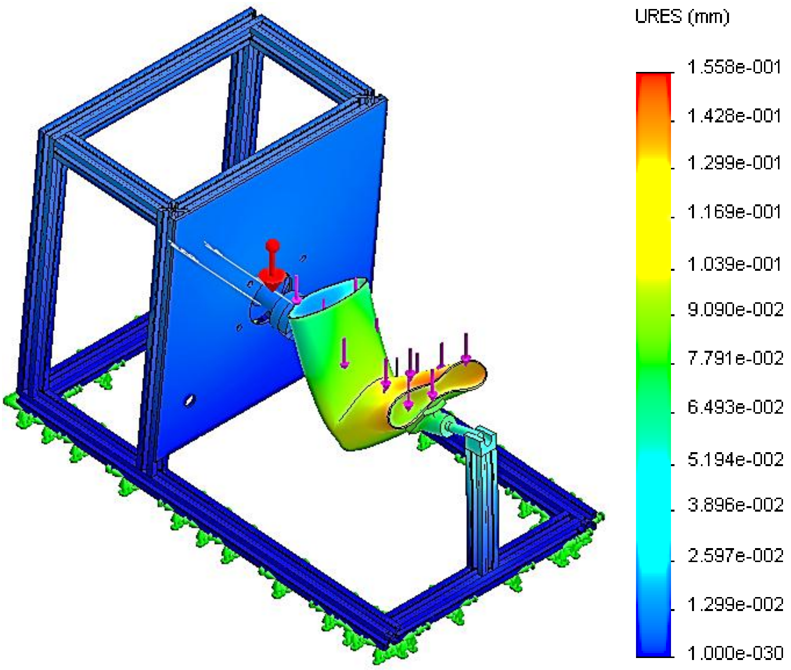

Figure 4. Resultant Displacement of the V-blender machine

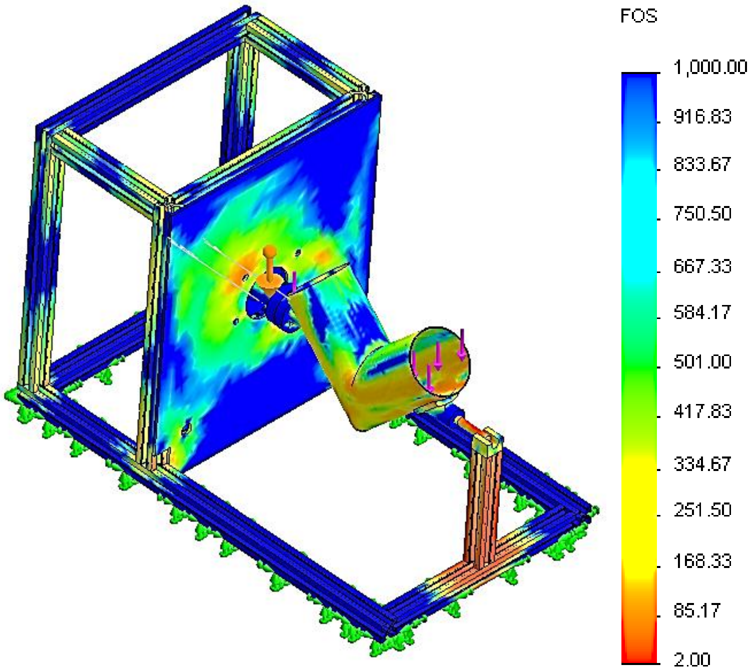

Figure 5. FOS of the V-blender machine

The simulation result shows that the maximum displacement occurs at the canister region while minimum FOC occurs at the end support region which in red colour. The displacement of the canister is the maximum due to the force applied on it besides the material itself. This is because the material of the canister is Polyethylene terephthalate (PET) which is significantly less strength compared to other parts which made of aluminium, galvanized iron and stainless steel. On the other hand, the minimum FOC is at the end support as shown in Figure 5 as the reaction force of the load applied in the canister is directly acted on the support and at the same time, it has a small diameter in size, 5mm.

Torque Calculation

The torque required to rotate the v-shell is calculated as below by using the v-shell parameter as shown in Figure 6. The dimensions used in Figure 6 is according to the maximum v-shell size can be allocated in the machine. The total weight of the v-shell together with metal powder is taken to be 2.563kg. From the calculation below, the minimum motor torque required is 0.528N.m.

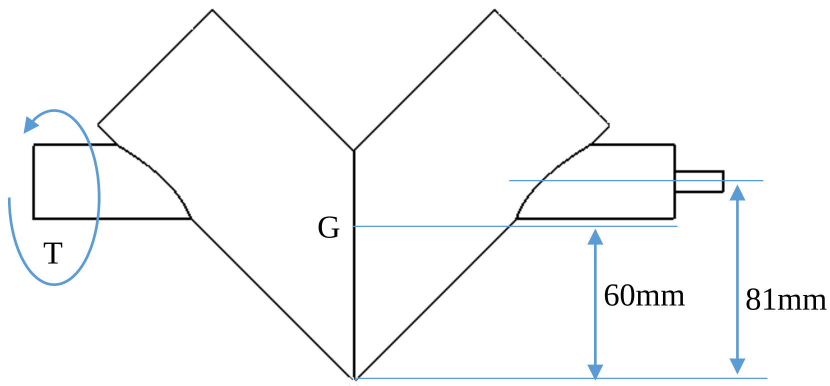

Figure 6. V-shell dimensions for torque calculation

$$d = 81 - 60 = 21mm$$
$$w = 2.563 \times 9.81 = 25.143N$$
$$T = Fd$$
$$T = 25.143 \times 0.021 = 0.528N.m$$

Bicycle Speedometer Speed Conversion

The bicycle speedometer is an equipment used to measure the speed of the bicycle either in km/h or m/h. However, in order to use this speedometer to determine the rotational speed of the motor shaft, there is some conversion of input need to make.

$$88ft/\min = 1m/h$$
$$88ft = 26.8224m = 26822.4mm$$

As shown above, there value of 88ft in mm contain five main digits but the input of the wheel circumference in speedometer only can reach to four digits. Thus, it should be divided by ten and the value for the wheel circumference is taken to be 2682mm. Putting this value during the speedometer set up, it will give out the value of the rotation speed (unit in mph) when times with ten. For example, when the speedometer display 6.5mph is also indicate the motor shaft rotate in 65 rpm.

Fabrication

The design and development of V-blender will be divided into 4 stages. The stages are: (1) gathering of information, (2) concept generation, (3) fabrication, and (4) testing. The gathering information stage is where all the information about the standard specification regarding the dimension, variation of speed and duration of blending.

The second stage is the concept generation stage. At this stage, a design of the machine is generated base on the standard information obtained in the information gathered and the components been purchased. Basic calculation on torque required and the dimension of the whole arrangement has been made. The electrical components such as the DC motor, AC to DC converter, motor speed controller and switches to be used also been determined. The important electrical components been purchased for the use in the machine are as shown in Table 2.

Table 2. Electrical component purchased

Electrical Component	**Features**
DC motor	Voltage Rating: 12VDC
	Rated Speed: 60 ± 15RPM
	Rated Torque: 30Kg.cm (2.9N.m)
Motor speed controller	DC12V-DC40V
	Control Power: 0.01-400W
AC to DC converter	Output voltage: 12VDC single output
	Output current: 8.5A
	Output power: 102W

The electrical circuit for activating the V-Blender is designed as shown in the Figure 7 after every components purchased. The schematic diagram clearly shows that there are 3 components namely AC to DC Converter, Motor Speed Controlled and Normally Open Pushbutton is installed in between the power source and the load which is DC Motor. The AC to DC Converter is installed in order to step down the 240VAC to 12VDC which is to match the voltage rating of the DC Motor. Motor Speed Controller is a device that allows the user to control the voltage being supplied to the DC motor to manipulate the rotational speed (RPM) of the V-shell. The Normally Open Pushbutton is installed in such way where the safety guard must be closed completely to connect the circuit. This approach adds the safety features to make sure the user's body parts does not engage to the rotating parts.

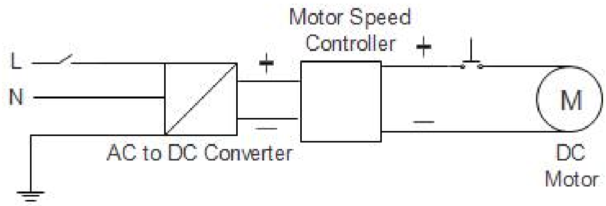

Figure 7. The schematic diagram of the V-Blender electrical system

The first step in the V-blender fabrication process is the fabrication of the machine frame by using a 20 X 20 mm aluminium profile which been cut by using disc cutting machine. After that, the V-shell or canister also been fabricated by cutting two tumbler at 45 degree angle and joined together by using epoxy adhesive. The tumblers were cut by using a saw and guided by a 3D printed jig. After the machine frame is fabricated, the dimension of the frame is re-measured before the sheet metals for the body covers were cut by using shearing machine. Two types of sheet metal thicknesses are used: 1mm mild steel sheet metal and 3mm galvanized iron sheet metal. To cut the 3mm sheet metal, the rake angle of 3 is used while rake angle of 1 is used to cut 1mm sheet metal by using the shearing machine. After the sheet metals been shear, holes for parts and components placement were drilled by using drill press. The hole to pass through the power window motor was drilled by using a 50mm hole saw. After the drilling process was done and tested by assembling the components and test run the machine to determine its functionality, the mild steel sheet metals were sand blasted to remove the rust before proceed with spraying.

RESULTS AND DISCUSSION

After all the sheet metal been sprayed, all the components are reassembled and the V-shell or canister also been attached as shown in Figure 8.

Figure 8. Complete assembly of v-blender machine

Numbers of holes also been drilled at the body panel as shown in Figure 9 which is at the back cover and left side cover. These holes are drilled to allow air ventilation as heat losses need to be transferred from the source of generation in order to not allow the temperature in the machine exceed the operating temperature [52]. The main reason is due to the long operating hours of the machine to blend metal powders. This machine utilized natural convection where the fluid motion is due entirely to buoyancy forces arising from density variations in the fluid [53] in order to save the power consumption and cost from installing fan for forced convection.

(a) (b)

Figure 9. Machine view (a) back view and (b) left side view of v-blender machine

The machine also been test run by using crushed plastic in the plastic lab to determine its reliability. As been stated in the literature study, the canister for v-blender consist of two hollow cylindrical shells joint at 75^o to 90^o angle [25]. The angle of 90^o is used in this project for fabrication simplicity and testing purposes. Few configuration such as left right filling, front behind filling and top bottom filling has been conducted by McCarthy, et al. [3] were used to test the overall performance of the machine. Thus, in this machine testing, the crushed plastic filling configuration used is left right filling, front behind filling and top bottom filling. Figure 10 shows the left right filling configuration with its post-mixing result, Figure 11 shows the front behind filling configuration with its post-mixing result, and Figure 12 shows the top bottom filling and its post-mixing result.

(a) (b)

Figure 10. Machine testing (a) left right filling and (b) post-mixing result

(a) (b)

Figure 11. Machine testing (a) front behind filling and (b) post-mixing result

(a) (b)

Figure 12. Machine testing (a) Top bottom filling and (b) post-mixing result

From the testing conducted, the machine that been fabricated is workable and able to deliver the expected result of mixing capability. The crushed plastic able mix together and from the visual inspection of the color distribution, the mixing is homogenous and it is achieved within minutes. However, the effectiveness in mixing of the metal powder is unknown due to unavailable metal powder supply for testing. According to the past researcher, the mixing of metal powder can be from 30 minutes up to hours. Thus, it is expected that the machine capable to deliver the mixing capability from the crushed plastic mixing result obtained. This is because the size of particles affect the particles dynamics where larger particles travel faster in the blender canister at the same rotation speed and same canister size [54].

This machine possess many advantages in terms of workability and user friendliness. This machine includes very simple operating procedure and does not require any manual to learn how to operate this machine. Apart from that, the V-shell unit is designed in such way that can be easily assemble and disassemble from the rotating compartment which helps to save the set up time. Note that the V-shell is fabricated by using transparent material and this approach allows the user to have visual check during the blending operation. This machine also includes a safety guard to prevent the user to get injured due to the rotating parts. The safety guard works together with a switch whereby the machine will completely stop if the user accidentally open the safety guard during the operation. This machine is lightweight, small in dimension and portable which able the user to easily shift the machine whenever he or she intended.

This machine also fabricated with the capability of providing variable mixing speed by using a DC12V-DC40V motor speed controller whilst output the rotation speed by using a bicycle speedometer and the method to read the speedometer is as explained above. However, there is a drawback of the bicycle speedometer where it is not able to output the canister rotation speed of under 30 RPM. Thus, a way to overcome the problem is to provide a reading scale from 0 RPM until 30 RPM at the motor speed controller knob thus allowing the user to adjust the speed of below 30 RPM. However, for the rotational speed of above 30 RPM, the speedometer able to deliver the accurate and precise rotation speed reading. Another drawback of this machine is the initial rotation speed directly depend on the weight applied in the canister. The heavier the mixture, the higher the initial rotation speed needed for the motor to rotate the canister. This can be due to the power itself. The power of a rotating shaft can be equate as in Equation (1) [55] and as the higher the weight or load in the canister, the higher the torque needed this increases the power needed for the rotation.

$$P_{rot} = 2\pi NT \tag{1}$$

On the other hand, the power supply to the motor can be calculated by using Equation (2) and as the motor speed controller controlled the voltage output, thus, the higher the voltage, the higher the power which result in higher motor speed.

$$P = IV \tag{2}$$

Thus, from both Equation (1) and Equation (2), we can form a relation where, the higher the load of the mixture in canister, the higher the speed of rotation needed in order to start the rotation.

CONCLUSION

This project was attempted to develop a v-blender machine that can be used for powder metallurgy research. The machine and its component connections were designed by using SolidWorks 2012 and the stress analysis has been performed to determine the reliability of the design. The simulation shows that the design is safe and will not fail when subjected to 2 kg of powder. After design and simulation, the machine was fabricated which consist both mechanical structures and electrical connection. From the testing been conducted, the machine is workable and able to deliver the expected result with minor errors in speedometer reading below 30 RPM. In overall, this project achieved the objective to develop a table top V-blender machine that capable of performing powders mixing for powder metallurgy researches.

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APPENDIX 1

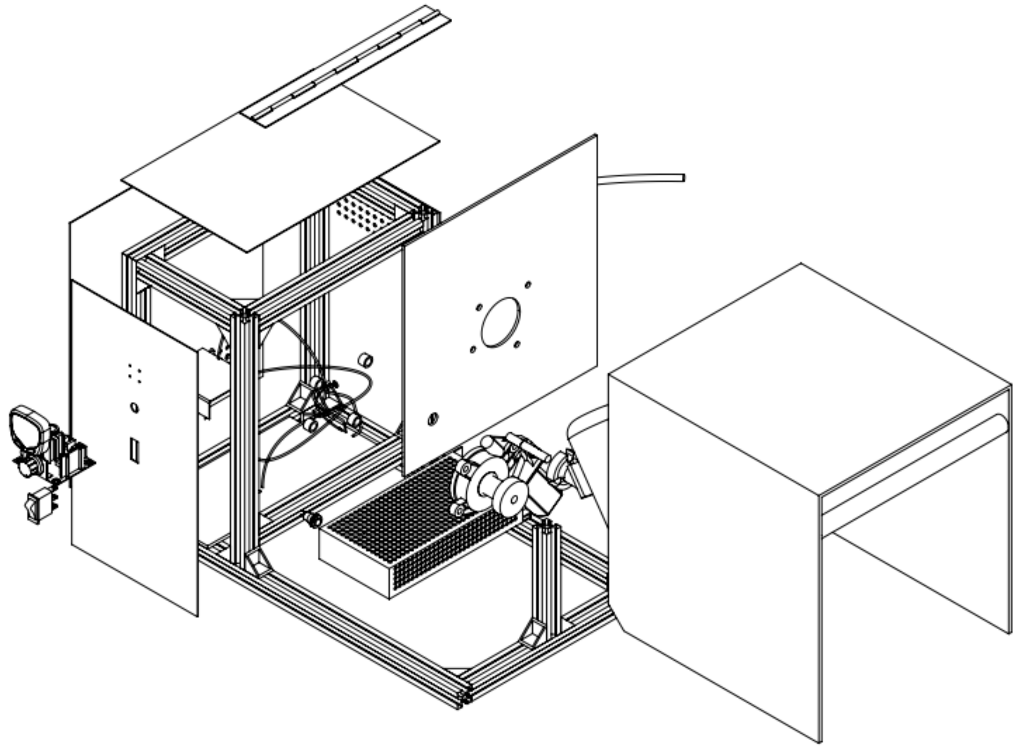

Figure 13. Exploded view of the v-blender machine