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Design and Development of a Cyclone Separator and Blower Unit for a Mini Dal Mill

Anjali Khuntia*, Anup Behera, Abhishek Das, Manoj Kumar Panda and Rabindra Sahoo

Department of Agriculture Processing and Food Engineering, College of Agricultural Engineering and Technology, Bhubaneswar, Odisha, India

**Corresponding author*

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A B S T R A C T

Pulses are the integral part of the Indian diet and also cultivated in many rural areas. So, in this context, a low cost, untroubled some mini dal mill which is operated by a 1 HP electric motor that is easily accessible will be very helpful. Through the addition of a cyclone separator and blower unit, a mini dal mill that had already existed was modified. This modification was useful for separating the milled dal from its husk which was lacking in the unmodified dal mill. For this, the terminal velocity was measured for green gram. An existing high capacity dal mill was regarded as a reference for designing and developing of present blower and cyclone separator unit. Finally the developed unit was tested and cleaned milled dal from the husk was successfully separated.

Introduction

Pulses are basically grain legumes. They occupy an important place in human nutrition due to their high protein content than cereal grains. In Indian dietary regime it occupies an important place. Since majority of Indians are vegetarians, they depend largely on grain legumes (pulses) for their dietary protein (Mangaraj *et al.*, 2013). Legumes contribute a major portion of lysine in the vegetarian diet. They are also a fairly good source of vitamins like thiamine, niacin, riboflavin and much needed iron (Sadan *et al.*, 2008). India is the world's largest producers (25% of global production), consumers (27% of global consumption) and importers of pulses (14%). Pulses account for about 20% of the food grain area and account for about 7-10 % of the total food grain production in the world. While pulses are grown in both Kharif and Rabi seasons, Rabi pulses account for more than 60% of total production (Anon., 2020a). In the country, pulses are mainly consumed in form of dal, dehusked and split kernel. Almost 75% of the total output of legumes is transformed into dal (Singh, 2017). Milling is the most important operation of postharvest handling of pulses. The removal of seed coat is very important because it is indigestible and bitter. The processes of milling differ greatly from place to place. Therefore the recovery of dal varied between 60-75% depends on the pulse type, techniques and mills type. Many agricultural universities, ICAR institutions in the country have developed modern improved dal mills like PKV Akola, CFTRI- Mysore, GBPUAT- Panthnagar, CIAE- Bhopal, IIPR-Kanpur, TNAU- Coimbatore and IARI- New Delhi. However, all have used more than 2 HP electric motor for the operation of the dal mill. According to a Government of India report, the pulse production in Odisha is 4.09 lakh ha in 2016-17 (Anon., 2020b) with majority of green gram and black gram. However, there is very negligible amount of dal milling in Odisha because of unavailability of power for agriculture operations. During last 5 years, farmers are utilizing 1 HP motor for pumping water and operating small thresher. For that reason, OUAT, Bhubaneswar has developed a mini dal mill which is operated by 1 HP electric motor with an output capacity of 35-40 kg/ha and milling efficiency of 80%. However, it has a disadvantage that milled dal with huskwas exit from the main outlet. So, in the present study, a cyclone separator and blower were designed and developed for this mini dal mill which will run using the existing power source. This will help to separate the milled dal from the husk which will improve the value of the end product and efficiency of the developed mill.

Materials and Methods

Description of mini dal mill

The developed dal mill as shown in Fig. 1, consisted of a main frame, feed hopper, feed hopper gate, tapered roller assembly and a stationery perforated tapered cage. The tapered roller coated with emery paste and surface finish with carborundum layer surrounded by stationery perforated tapered cage through which the husk was discharged. The length of the roller was 400 mm and smaller and bigger end diameters of the roller were 165 mm and 200 mm, respectively. The concave clearance was made adjustable and maximum efficiency was found to be achieved at 14 mm clearance for green gram and black gram. The dal mill was successfully operated using a 1 HP single phase electric motor with an output capacity of 35-40 kg/ha and milling efficiency of 80%. Dry method of milling for processing of dal was used in this dal mill. To clean the milled dal i.e. separating the clean dal from husk, a cyclone separator with a blower unit was designed and developed which is discussed in the following sections.

Measurement of terminal velocity of green gram

The velocity at which a falling body moves through a medium, as air, when the force of resistance of the medium is equal in magnitude and opposite in direction to the force of gravity is called as terminal velocity. This physical property played a very important role for designing a separator unit for the developed dal mill. Terminal velocity of raw dal, oil treated dal, milled dal and husk was measured using a terminal velocity apparatus, which had a blower unit. 10-20 gram of each sample was placed on the bed of the apparatus and air was introduced by use of the blower. The velocity was increased by an electric resistance type variac unit (Fig. 2) and the velocity of air was measured by a digital anemometer by placing it on the top of the apparatus (Fig. 3). By increasing the air velocity, the sample started jumping at a particular velocity and they got fluidized which was known as terminal velocity and velocity at that point was measured by the digital anemometer.

Working principle of the separation unit

A 1 HP motor was used to provide power to a blower through required sizes of belt and pulley to achieve the designed RPM of the blower. The blower unit helped to suck the husks materials along with the air from the feed hopper of the separation unit and the clean dal fell down through gravity. The husks were then allowed to move to the cyclone separator through flexible pipe. In cyclone separator the husks were removed by cyclone effect. The RPM of blower was such that, it sucked only the husk materials not the clean milled dal.

Design of the blower unit

An impeller was designed which was attached with the shaft which rotated by a 1HP electric motor by belt and pulley arrangement according to the designed RPM. It was placed inside a centrifuged type casing. The blades of the impeller were welded with a bush and angle between each blade was 60^0. One part of the casing was detachable which was bolted with the casing. For the design of impeller, the dimensions of the impeller blade of a high capacity dal mill were measured, and the dimension of the blade for developed mill was decided using proportionality method. The distance of the cover from the center of the existing dal mill was measured at 12 different angles i.e. at 0°, 30°, 60°, 90°, 120°, 150°, 180°, 210°, 240°, 270°, 300°, 330° and then, the radius of the impeller from those distances was subtracted to obtain the clearance. Then a graph was plotted between the clearances and their corresponding angles to get a relation between these two parameters. From that, the clearance at those 12 angles was obtained for the developed blower.

Design of cyclone separator

The outlet diameter, inlet diameter, outlet velocity of cyclone separator of the existing dal mill was measured and from that the air flow rate and the capacity of the separator unit was calculated. Then by proportioning all these, the dimensions of inlet, outlet, and air flow rate, and capacity of the new separator unit was decided. Other design dimensions were calculated by using the standard table for cyclone separator design, which is given in Table 1.

Results and Discussion

Terminal velocity of samples

The terminal velocity of green gram at different conditions i.e. raw green gram, pre-treated green gram, milled green gram and also the husk material was measured using a terminal velocity apparatus. The results are shown in Fig. 4.

From this figure, it can be noticed that the terminal velocity of raw green gram was highest followed by pre-treated green gram, milled green gram and husk material at all the three test condition. Velocity at which the sample started lifting from the bed surface called as fluidized terminal velocity. The other two velocities were measured when the sample reached at 10 cm and 24 cm height from the bed surface. The terminal velocity was found to be increased when the test condition was changed from fluidized condition to 24 cm height for all the four type of samples.

From the test, the terminal velocity of the milled dal and husk material was found i.e. 3.7 m/s and 2.2 m/s, respectively, which was used for the design of blower and cyclone separator unit.

Design of the blower unit

For designing of the blower unit, the dimensions of the impeller blade and centrifugal casing of the existing dal mill was measured and after that the design dimensions of the new blower was finalized according to the capacity of the developed dal mill.

Radius of the blade of impeller in existing dal mill = 76 mm

Diameter of bush to which the blades are attached = 32 mm

Radius of blade for the new blower = 60 mm

(Assumption, according to the capacity of the mill)

Diameter of bush to which the blades are attached = 32 mm

Ratio of radius of blade of existing dal mill to developed mini dal mill = 76/60 =1.26

According to the procedures mentioned in the materials and methods section, the clearance between the blade and the cover at different angle of the existing mill were measured, which is shown in Fig. 5. Using the quadratic relation shown in Fig. 5, the new clearance value at different blade angles were calculated and then those values were divided by the scale factor i.e. 1.26, to get the design clearance of the developed blower unit. These clearance values and corresponding distance of casing from the center are shown in Table 2.

The design dimensions of the developed blower unit are shown in Fig. 6.

According to the design dimensions, the new blower unit was developed, which is shown in Fig. 7.

Design of the cyclone separator

For design of cyclone separator, the design dimensions and air flow and velocity of air from the exhaust of cyclone of the existing high capacity dal mill was measured and accordingly different dimensions of the cyclone separator was calculated to meet the required air flow.

Different data of cyclone separator of existing dal mill-

Outlet velocity of cyclone separator, v =0.9 m/s

Outlet diameter=13 cm= 0.13 m

So area of the outlet=$(\pi/4)(0.13)^2=0.0132 m^2=A_1$

So flow rate=$A_1\times v=0.0132\times0.9=0.01188\ m^3/s$

Inlet diameter =0.076 m

So area, $A_2=0.004536\ m^2$

So velocity at inlet,V_2=(flow rate/ A_2)=(0.01188/0.004536)=2.619 m/s

Capacity of the dal mill=100 kg/h=0.0111 kg/s

Design of the cyclone related to the above data –

Capacity of mini dal mill= 40 kg/hr

So the ratio between two capacities=100/40=2.5

So, the volume of air flow required=0.01188/2.5=0.004752 m^3/s

Let design diameter of outlet= d_o

Table.1 Standard cyclone separator dimensions

	Cyclone Type					
	High Efficiency		Conventional		High Throughput	
	(1)	(2)	(3)	(4)	(5)	(6)
Body Diameter, D/D	1.0	1.0	1.0	1.0	1.0	1.0
Height of Inlet, H/D	0.5	0.44	0.5	0.5	0.75	0.8
Width of Inlet, W/D	0.2	0.21	0.25	0.25	0.375	0.35
Diameter of Gas Exit, D_e/D	0.5	0.4	0.5	0.5	0.75	0.75
Length of Vortex Finder, S/D	0.5	0.5	0.625	0.6	0.875	0.85
Length of Body, L_b/D	1.5	1.4	2.0	1.75	1.5	1.7
Length of Cone, L_c/D	2.5	2.5	2.0	2.0	2.5	2.0
Diameter of Dust Outlet, D_d/D	0.375	0.4	0.25	0.4	0.375	0.4

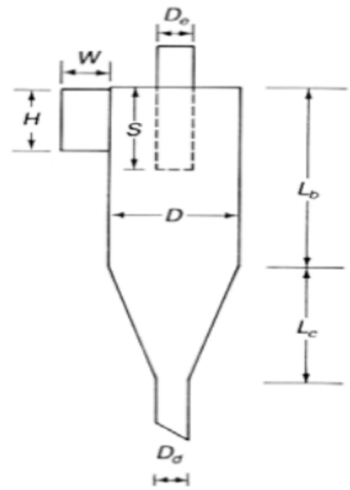

Table.2 Design dimensions of the developed blower's casing unit

Blade angle (degree)	Design clearance of casing (mm)	Design distance of casing from centre (mm)
30	25.18	101.18
60	27.91	103.91
90	30.93	106.93
120	34.24	110.24
150	37.83	113.83
180	41.71	117.71
210	45.88	121.88
240	50.33	126.33
270	55.06	131.06
300	60.08	136.08
330	65.39	141.39

Fig.1 Developed mini dal mill

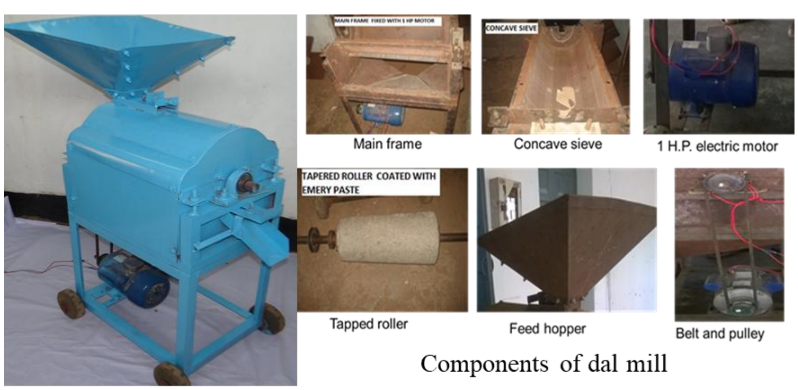

Fig.2 Resistance type variac unit

Fig.3 Digital type anemometer

Fig.4 Terminal velocity of different dal samples at three different conditions

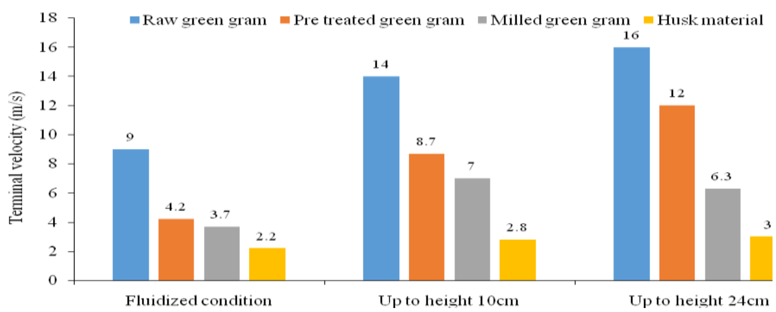

Fig.5 Relation between casing clearance at different blade angle in the existing dal mill

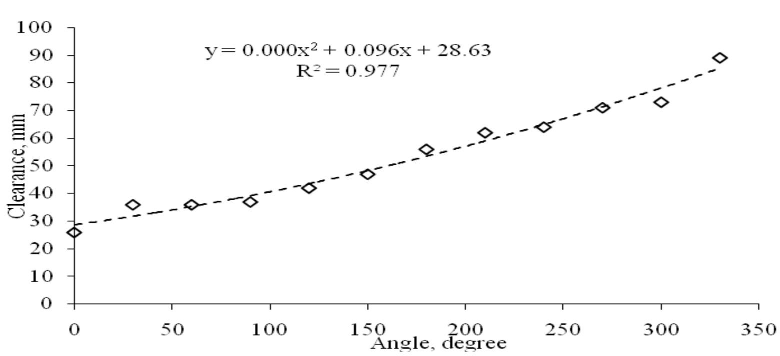

Fig.6 Design drawing of the blower with the dimensions in mm

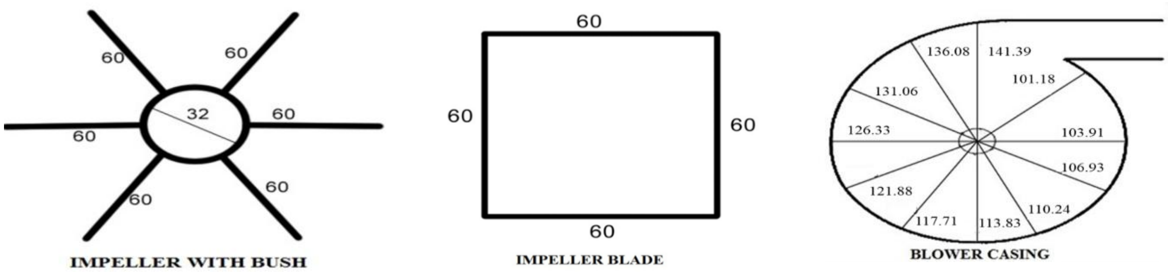

Fig.7 Developed blower unit for the mini dal mill

Fig.8 Developed cyclone separator

Assume, outlet velocity = 0.9 m/s (As this velocity is less than the terminal velocity of husk i.e. 2.2 m/s)

So $(\pi/4)\ d_o^2 = (0.00475/0.9) = 0.00528\ m^2$
So $d_o = 0.0819$ m=8.19 cm

Let Design diameter of inlet= d_i
Assume, inlet velocity = 2.5 m/s (As this velocity is less than the terminal velocity of cleaned dall i.e. 3.7 m/s and more than the terminal velocity of husk i.e. 2.2 m/s)
So $(\pi/4)\ d_i^2 = (0.00475/2.5) = 0.0019$

So $d_i = 0.0491$ m=4.91 cm

Other design dimensions were calculated using the standard given in Table 1. The values of these are given below.

Diameter of body (D) = 0.16 m; Height of inlet (H) = 0.08 m; Length of vertex finder (S) = 0.1 m, Width of inlet (W) = 0.04 m; Length of cone (L_c) = 0.32 m; Length of body (L_b) = 0.32 m; Diameter of dust outlet (D_d) = 0.04 m.

According to the designed dimensions the cyclone separator unit was developed which is shown in Fig. 8.

Testing of the designed cyclone separator unit

The rotation of the impeller of the blower was 2420 rpm. The suction velocity of the blower i.e. the inlet velocity of the cyclone separator was 2.57 m/s. So this velocity was very much suitable for the cyclone because the terminal velocity of the husk was 2.2 m/s and the terminal velocity of the milled dal was 3.7 m/s. So this velocity helped to suck the husk material from the outlet not the milled dal. The outlet velocity of the cyclone was 0.88 m/s.This velocity also satisfied the design requirement because it was less than the terminal velocity of the husk materials. So husk material did not come with the outgoing air and fall by the force of gravity.

Since this unit satisfied all the parameters required for an efficient cleaning system, so it was successfully installed with the developed mini dal mill.

In conclusion the outlet of a developed mini dal mill had both dal and husk. So, in order to get clean dal, a separating unit which consists of a hopper, blower and cyclone separator was designed and developed. After testing of the developed separating unit, the suction velocity of the blower i.e. the inlet velocity of the cyclone separator was found to be 2.57 m/swhich was higher than the terminal velocity of the husk (2.2 m/s) and less than the terminal velocity of milled dal (3.7 m/s). Similarly, the outlet velocity of the cyclone was 0.88 m/s, which was less than the terminal velocity of husk. So, the developed separating unit satisfied all the required parameters for an efficient cleaning of milled dal. Along with this, the separation unit was operated with 1HP single phase motor which has never done previously. So, the developed unit will be efficiently and easily accessible by farmers to get milled dal with less investment.

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