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DEVELOPMENT AND TESTING OF MEDIUM CAPACITY GRAIN FLOUR SEPARATOR

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ABSTRACT

A power operated (0.5 hp electric motor) grain flour separator was designed and developed for separation of grain (wheat, corn, chickpea and soybean) flour into various fractions based on the size of the particles of the product. The separator is made of mild steel and consists of a hopper, power driven agitating mechanism, feed control, cylindrical separator unit and an eccentric mechanism. The machine was tested for wheat (variety : Sujata) flour separation into four fractions, viz; semolina, Gr-I and II, flour (coarse) and white (fine) flour. Wheat samples (6.8% m.c., db) were first pearled by CIAE pearler for 15.8% bran removal. The pearled wheat grains were then milled for semolina by a burr mill. The product and machine characteristics were determined at different capacities varying from 24 kg/h to 143 kg/h. It was found that 76 kg/h capacity gave reasonably best results in terms of purity and recovery of semolina vis-a-vis the market product. The energy requirement of the machine at no-load was found to be 230 W and at load conditions, it varied between 36.3-6.4 kJ per kg of feed separation.

The machine could be used by small flour millers, small/medium size traders and retailers and other processors for making available various flour products of different particle size in the market for ready use of the consumers.

Key Word : Wheat, Flour, Separation, Semolina

INTRODUCTION

Wheat, corn, chickpea and soybean are used in India in whole, split or in ground (flour) form. Wheat grains, when milled, yield various fractions based on the size of the particles of the product, viz. bran, flour (coarse), white (fine) flour and semolina. Similarly, corn, soybean and chickpea grains are milled into corn/soybean flour or grits and chickpea flour.

The size reduction in case of wheat, corn, chickpea grain at small scale, is achieved by using small burr mills having capacity upto 100 kg/h. If need be, the final product is then separated for bran and coarse/fine flour by sieving it manually. However, for semolina and fine wheat flour production, big commercial roller mills with very high capacity are used. In the burr mills, because of the faulty adjustments and at times of electric power failures, the broken grains or coarser flour particles get mixed-up in the final product, which is not desirable. The product thus, needs to be screened/separated for various fractions.

The feed back from the market survey had revealed that there is a consumer need for packed and graded wheat, soyblend wheat, corn and chickpea flours. To this effect, matching machines, which are compact, medium capacity and low cost are needed to be developed to meet the said purpose. The machine could be used by small flour millers, small/medium size traders and retailers and other processors for making available various flour products of different particle size in the market for ready use of the consumers.

The objectives of the study were;

1) to design and develop a power operated grain flour separator, and
2) to determine machine and operating parameters for effective separation of various fractions of wheat flour.

MATERIALS AND METHODS

Development of grain flour separator

The grain flour separator (overall dimensions : 1,270 x 1,000 x 1,510 mm) was made-up of mild steel and consists of a hopper (capacity : 30 kg, wheat flour), power driven agitating mechanism, feed control, cylindrical separator unit (500 mm dia. x 450 mm) and an eccentric mechanism (20 mm) (Fig.1). The circular separator table consists of a cylindrical frame made of 1.5 mm thick mild steel sheet, to which are attached three screens (475 mm dia.) made of bolting cloth of different sizes (upper : 26GG, middle :40GG, lower :9XXX), spaced appropriately at a slope (4.5°) with four discharge spouts. The provision was made for interchangeability of screens for separating various grades of grain flour. The screen cloth was held in uniform tension in all directions by fixing it to a circular flat ring (Fig. 2). The ring was then placed on fixed brackets attached to the main cylindrical frame.

Below each screen, inclined circular pans were provided for diverting undersized material to be carried to the upper end of the next screen (Fig. 2). Separation takes place on the basis of difference in size. The grain flour from hopper is dropped to top sieve by gravity with the help of an agitator (25 rpm) and controlled by an adjustable feeding mechanism (Fig.1). Gyrating motion (200 rpm) of the separation unit was achieved by providing an eccentric mechanism beneath at the center, driven by V-pulley belt drive from electric motor (0.5 hp) shaft. The whole unit is suspended on four springs which are mounted on a base frame and the screen assembly floats freely on them (Fig.1). As a result, when the separator is mounted on a firm level surface, vibration is not transmitted to its supporting base.

The separator, because of its gyratory motion can be described as a rigid screening device that vibrates about its center of mass. rotation of the screens causes vibration in the horizontal plane of motion, which causes the material to move across the bolting cloth from entry point to the periphery and finally towards the discharge spout (Fig. 2).

The springs act to cause vibration on the vertical plane of motion giving the material a bouncing effect on the screen. The metallic chains, to which five spherical rubber balls (30 mm dia.) are hooked, were loosely fixed at its ends to the screen ring (Fig. 2). During the operation, bouncing of the rubber balls and sliding of the loose chain on each screen gave extra stirring of the flour material and avoided any clogging effect on the screen.

Testing of separator

Wheat grain (variety : Sujata) was first cleaned by power operated grain cleaner, pearled by general purpose mill to remove bran, milled by burr mill and then tested by grain flour separator for the separation of semolina, flour (coarse) and white (fine) flour. Larger particles (semolina) were retained over the top two screens giving semolina, Gr-I and II. The coarse flour, retained over the third screen and the undersize, i.e; white (fine) flour, retained on the bottom pan were delivered/collected outside through the spouts (Figs. 1 and 2).

Moisture content of wheat grain and flour samples were determined by using hot air oven method at 105°C for 72-96 h "Hall (1957)". Samples of various constituents were analysed to get the product-matrix data for Table 1. The product and machine characteristics were determined as under :

1. Product recovery based on actual in feed was determined by using Eq.(1)

$$(RP)_k = \frac{100\, x_{kk}}{\sum_{i=1}^{4} x_{ik}} \qquad \ldots(1)$$

where, $(RP)_k$ = product recovery based on actual in feed,%

x_{kk} = weight of product in desired outlet, kg

$\sum_{i=1}^{4} x_{ik}$ = weight of the total product available in all the outlets, kg

i = outlet no. and k = product type.

2. Product recovery based on mixture in outlet was determined by using Eq. (2)

$$(RM)_k = \frac{100 \sum_{j=1}^{4} x_{kj}}{\sum_{i,j=1,1}^{4,4} x_{ij} \,.\, (PF)_k} \qquad \ldots(2)$$

where, $(RM)_k$ = recovery of product based on mixture, %

$\sum_{j=1}^{4} x_{kj}$ = weight of product in desired outlet, kg

$\sum_{i,j=1,1}^{4,4} x_{ij}$ = total weight of feed, kg and

$(PF)_k$ = product fraction in feed, decimal.

3. Purity of various fractions separated by the machine was determined as fraction of that product at the desired outlet by using Eq. (3).

$$P_k = \frac{100\, x_{kk}}{\sum_{j=1}^{4} x_{kj}} \qquad \ldots(3)$$

As shown in Table 4, purity of semolina (combined Gr-I and II) varied as high as 82.55% at 52.80kg/h capacity and 74.03% at 84.75 kg/h. However, the purity for coarse flour was maximum of 87.14% at 23.80 kg/h capacity and minimum of 58.40% at 143.10 kg/h. As expected, purity of fine flour was 100% at all the capacities.

The machine characteristics, viz; screen effectiveness and overall machine efficiency are given in Table 5. The overall efficiency of the separator was found to vary between 77.26% to 52.83% at 23.80 kg/h and 143.10 kg/h capacity, respectively.

Energy requirement to run the machine at no-load was found to be 230 W. While, on load conditions, energy requirement varied between 36.30 and 6.44 kJ/h of feed separation at 23.80 kg/h and 143.10 kg/h capacity, respectively (Table 5).

From the analysis of data (Tables 2 to 5), it was found that for the separation of wheat flour into semolina and coarse and fine flour, capacity of 75.7 kg/h may be used. This capacity gave semolina (Gr-I and II combined), considered to be the main product, with a recovery of 100% and 120.4%, based on actual product in feed and mixture in outlet, respectively. The purity of the product at this capacity was found as 79.07% which was almost similar to the market sample of semolina having 79.17% purity. Besides, whiteness of semolina produced by the separator as 65% was quite comparable to 69% of market sample.

CONCLUSIONS

1. A power operated (0.5 hp electric motor) grain flour separator, costing about US$ 350, was designed and developed for separation of wheat flour into semolina, coarse and fine flour.
2. The capacity of the machine at 76 kg/h was considered optimum for semolina (Gr-I and II combined) separation, in terms of purity at 79.07% and recovery at 100% and 120.4%, based on actual and mixture, respectively, vis-a-vis the efficiency of separator as 63%.
3. The semolina product at 76 kg/h capacity was quite similar/comparable in purity and whiteness (65%) to the market sample of 79.17% and 69%, respectively.
4. The energy requirement at no-load and at load for 76 kg/h capacity of the machine was found to be 230W and 11.7 kJ/kg of feed separation.

REFERENCES

1. Hall, C.W. 1957. Drying farm crops. The AVI Publishing Co; West-port, Connecticut.

Where, P_k = purity of product, %

x_{kk} = weight of product in product outlet, kg and

$\sum_{j=1}^{4} x_{kj}$ = total weight in product outlet, kg.

The machine characteristics, viz; screen effectiveness and overall efficiency of separator were determined by using Eq. (4) and Eq.(5), respectively.

4. **Screen effectiveness**

$$e_1 = \frac{100 \sum_{i,j=2,1}^{4,4} x_{ij}}{\sum_{i,j=1,2}^{4,4} x_{ij}}; \quad e_2 = \frac{100 \sum_{i,j=3,1}^{4,4} x_{ij}}{\sum_{i,j=1,3}^{4,4} x_{ij}}; \quad e_3 = \frac{100 \sum_{j=1}^{4} x_{4j}}{\sum_{i=1}^{4} x_{i4}} \quad \ldots(4)$$

Where, e_1, e_2 & e_3 = screen effectiveness of top, middle and bottom screen, respectively, %

5. **Efficiency of machine**

$$e_S = \left[\prod_{i=1}^{3} e_i\right]^{1/3} \quad \ldots(5)$$

RESULTS AND DISCUSSION

The proportion (by weight) of semolina, Gr-I and II, flour (coarse) and white (fine) flour in the feed sample (m.c.: 8.72%, db) of the separator was 1.74%, 50.46%, 31.81% and 15.99%, respectively.

Tables 2,3 and 4 give the product characteristics, viz; recovery based on actual product in the feed, recovery based on mixture in the desired outlet and purity of various products separated, respectively at various capacities. Though the recovery of semolina, Gr-I or combined Gr-I and II in terms of actual semolina in feed was 100%, the recovery on the basis of total mixture was found to be more than 100% (Table 3). This was because of the overlapping of other fractions, viz; coarse and fine flour on the top screen.

For coarse flour, recovery based on actual, varied from 60.69% at 23.80 kg/h capacity to 48.56% at 143.10 kg/h (Table 2). However, based on the total mixture of the product at the desired outlet, the recovery varied between 58.12% and 82.38% (Table 3). For fine flour separation, recovery based on actual and mixture decreased from 76.24% to 29.35% and 89.34% to 30.16%, respectively (Tables 2 and 3).

Table 1. Product-outlet matrix of wheat flour separtor

Outlet (i)	Product (j)				Total
	S1	S2	CF	FF	
1	x_{11}	x_{12}	x_{13}	x_{14}	$\sum_{j=1}^{4} x_{1j}$
2	~~x_{21}~~ → o	x_{22}	x_{23}	x_{24}	$\sum_{j=1}^{4} x_{2j}$
3	~~x_{31}~~ → o	~~x_{32}~~ → o	x_{33}	x_{34}	$\sum_{j=1}^{4} x_{3j}$
4	~~x_{41}~~ → o	~~x_{42}~~ → o	~~x_{43}~~ → o	x_{44}	$\sum_{j=1}^{4} x_{4j}$
Total	$\sum_{i=1}^{4} x_{i1}$	$\sum_{i=1}^{4} x_{i2}$	$\sum_{i=1}^{4} x_{i3}$	$\sum_{i=1}^{4} x_{i4}$	$\sum_{i,j=1,1}^{4,4} x_{ij}$

x_{ij} = weight of product constitutent (j) in outlet (i) of the separator

S1 = semolina, Gr-I ;
S2 = semolina, Gr-II ;
CF = coarse flour
FF = fine flour

Table 2. Recovery of various products based on actual product in feed

Capacity, kg/h (C)	Semolina, Gr-I $(RP)_{S1}$	Semolina, Gr-II $(RP)_{S2}$	Semolina, Combined Gr-I & II $(RP)_{S12}$	Coarse flour $(RP)_{CF}$	Fine flour $(RP)_{FF}$
	Product Recovery, %				
23.80	100	70.4	100	60.69	76.24
52.80	100	65.7	100	62.73	56.28
75.70	100	64.9	100	60.64	41.11
84.75	100	64.2	100	56.76	42.59
94.20	100	64.9	100	60.46	33.50
143.10	100	59.0	100	48.56	29.35

$$(RP)_{S2} = 71.8 - 0.88C; \quad r=0.9650$$

$$(RP)_{CF} = 58.74 + 0.13C - 0.0014\,C^2; \quad r=0.9481$$

$$(RP)_{FF} = 163.7 - 27.7\ \ln C; \quad r=0.9846$$

Table 3. Recovery of various products based on mixture in outlet

Capacity, kg/h (C)	Semolina, Gr-I (RM) S1	Semolina, Gr-II (RM) S2	Semolina, combined (RM) S12	Coarse flour (RM) CF	Fine flour (RM) FF
	Product recovery, %				
23.80	1111	94.9	128.8	58.12	89.34
52.80	1241	86.7	125.2	78.00	61.59
75.70	1139	85.3	120.4	92.61	47.92
84.75	1119	87.7	122.1	91.81	44.28
94.20	1153	85.2	120.8	98.11	35.85
143.10	1361	89.7	132.1	82.38	30.16

$$(RM)_{S1} = 1202-2.6C+0.025C^2 ; r=0.8114$$

$$(RM)_{S2} = 101.3-0.34C+0.0018C^2 ; r=0.9348$$

$$(RM)_{S12} = 137.9-0.42C+0.0026C^2 ; r=0.9686$$

$$(RM)_{CF} = 29.19+1.32C-0.0066C^2 ; r=0.9889$$

$$(RM)_{FF} = 198-34.6 \ln C; r=0.9911$$

Table 4. Purity of various products in wheat flour separation

Capacity, kg/h	Product recovery, %				
	Semolina, Gr-I	Semolina, Gr-II	Semolina, combined Gr-I & II	Coarse flour	Fine flour
(C)	$(P)_{S1}$	$(P)_{S2}$	$(P)_{S12}$	$(P)_{CF}$	$(P)_{FF}$
23.80	17.89	75.36	81.39	87.14	100
52.80	12.90	76.84	82.55	72.22	100
75.70	11.97	71.37	79.07	65.14	100
84.75	7.69	68.57	74.03	67.32	100
94.20	10.97	70.87	77.96	65.34	100
143.10	7.16	65.51	75.47	58.40	100

$$(P)_{S1} = 1202-2.6C+0.025C^2 \; ; \; r=0.8114$$

$$(P)_{S2} = 78.8 - 0.094C \; ; \; r=0.9014$$

$$(P)_{S12} = 84.9-0.11C+0.0003C^2 \; ; \; r=0.7617$$

$$(P)_{CF} = 88.13\, e^{-0.00315C} \; ; \; r=0.9392$$

Table 5. Screen effectiveness, separator efficiency and energy requirement for wheat flour separation

Capacity, kg/h	screen effectivenss,%			Efficiency of separator, %	Energy require-ment/kg of feed, kJ
	Top Screen	Middle screen	Bottom screen		
(C)	(e_1)	(e_2)	(e_3)	(e_S)	(E)
23.80	83.56	72.38	76.24	77.26	36.30
52.80	80.66	75.24	56.28	69.90	16.50
75.70	82.13	73.82	41.11	62.93	11.70
84.75	81.74	70.78	42.59	62.69	10.45
94.20	81.74	72.66	33.50	58.38	9.55
143.10	77.66	64.71	29.35	52.83	6.44

$$e_1 = 82.74-0.011C-0.0003C^2 \quad ; \; r=0.8773$$

$$e_2 = 70.56+0.126C-0.0012C^2 \quad ; \; r=0.9494$$

$$e_3 = 163.68-27.66 \ln C \quad ; \; r=0.9846$$

$$e_S = 82.19\, e^{-0.0033C} \quad ; \; r=0.9852$$

$$E = 38.83\, e^{-0.014C} \quad ; \; r=0.9506$$

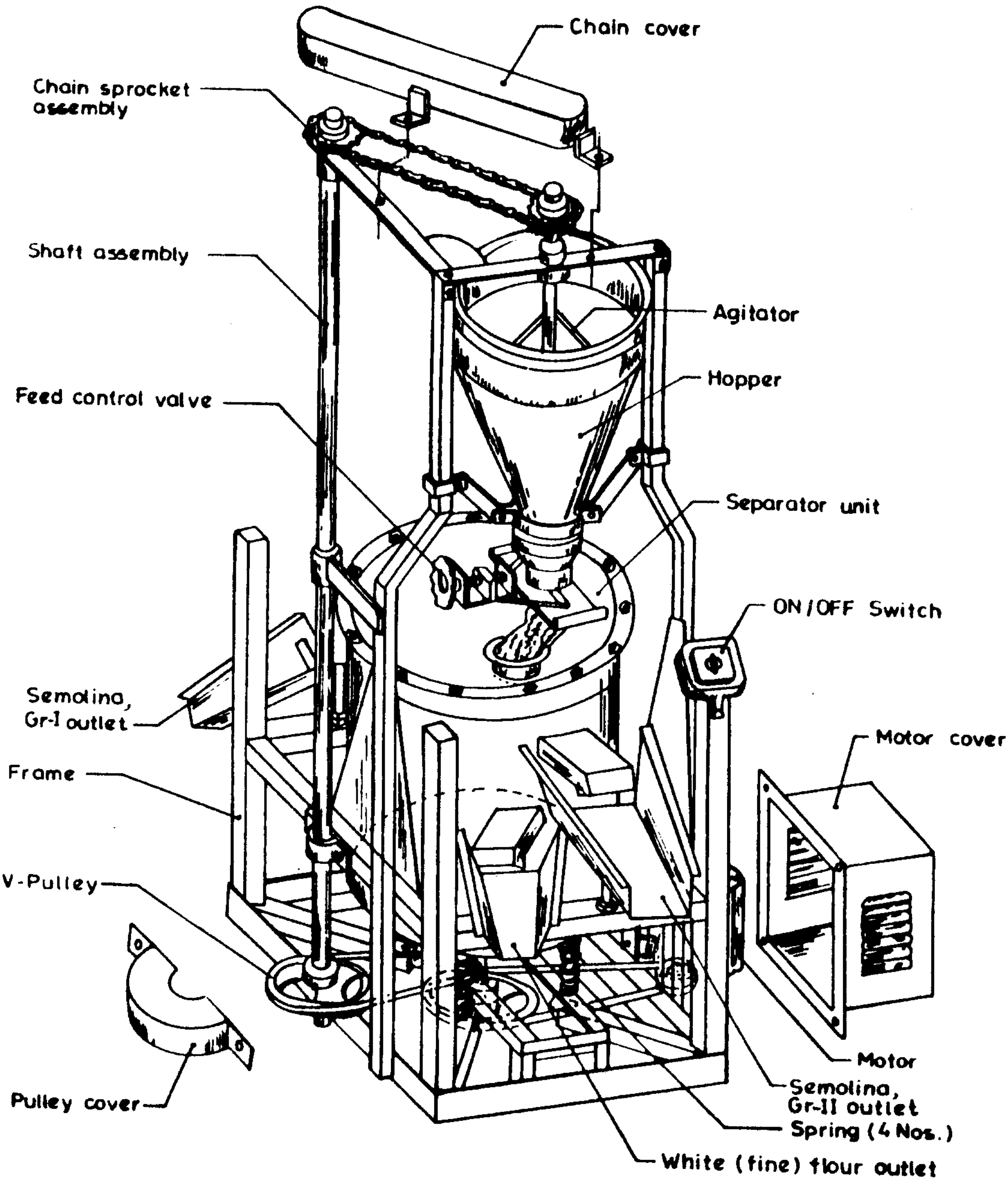

Fig.1. Grain flour separator

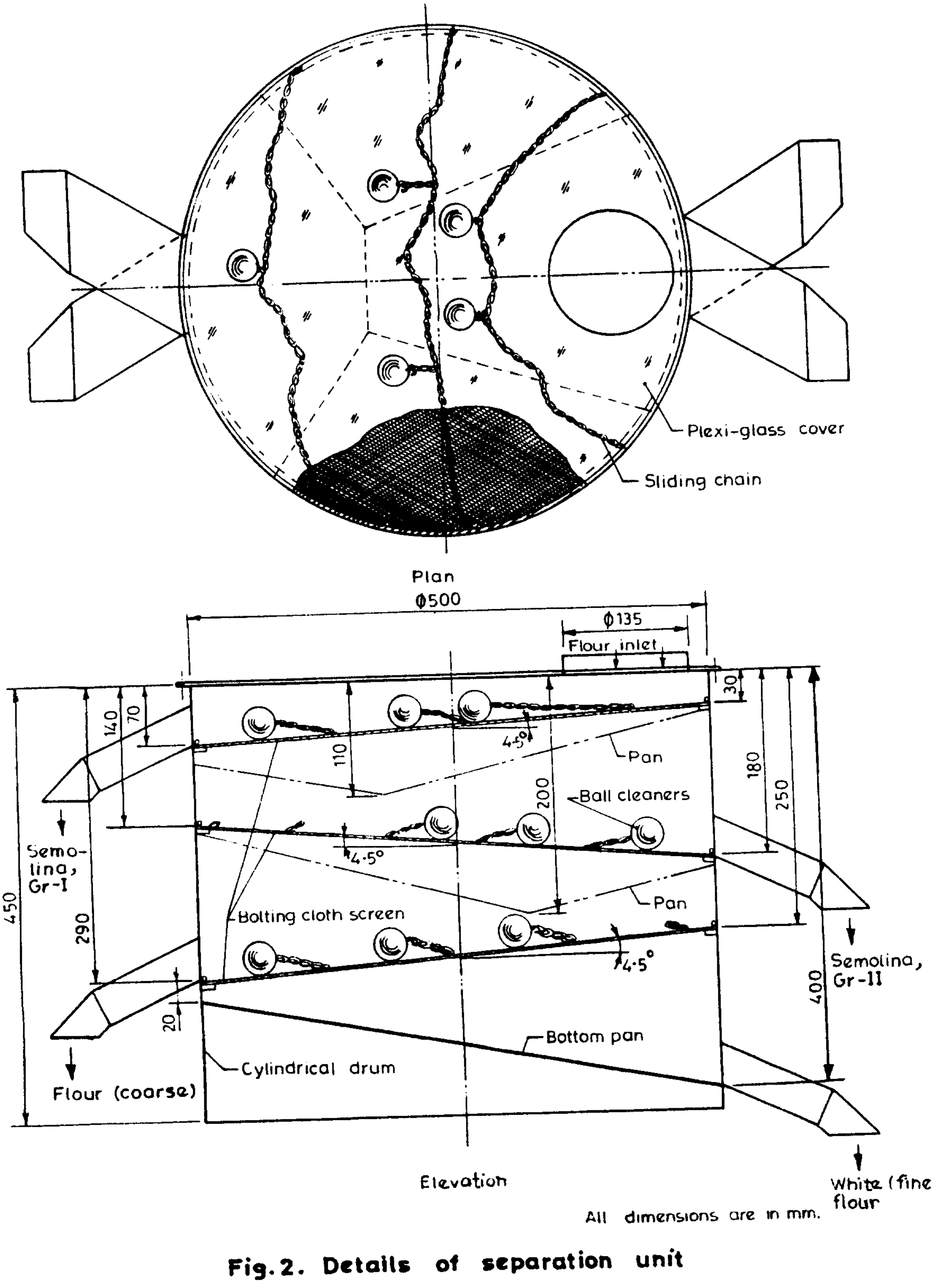

Fig. 2. Details of separation unit