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## Role of physical and engineering properties of paddy for design of hybrid thresher

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### Abstract

The purpose of this research project is to experimentally find out the physical and engineering properties of paddy for optimizing design of hybrid paddy thresher with aspirator. In this experiment the local variety of Paddy such as Damini Krishna, Damini Gold, Dilkhush, Tata Mandsuri and Kanak Tata were collected as a sample from Tenduvavan and Kanti village in Prayagraj, Uttar Pradesh on November 2021. The experimental studies were carried out at workshop of "Department of Farm Machinery and Power Engineering" SHUATS, Prayagraj (U.P.). During the experiment Crop Parameters, Panicle Parameters and Grain Parameters were found out. The results obtained for all varieties of paddy from the experiments are as follows- Average plant length of paddy varieties ranged from 84.8 cm to 121.96 cm. Average weight of the plant of the sample was found to be 5.1 g, 5.8 g, 5.12 g, 5.04 g and 5.8 g respectively for all varieties. Average weight of grains per panicle of the samples was found to be 1.92 g, 2.84 g, 1.32 g, 2.28 g and 2.38 g respectively for all varieties. Under the grain parameters, it was found that maximum grain size was of Kanak Tata ( $8.04 \times 2.32 \times 1.32$ ) and the minimum size was of Damini Krishna ( $6.18 \times 1.52 \times 1.13$ ). Average 100-grains weight of each sample was found to be 1.19 g, 1.5 g, 1.3 g, 1.9 g and 1.7 g respectively. Kanak Tata variety recorded maximum bulk density of  $490 \text{ kg/m}^3$ . It was observed, Average Angle of Repose varies from  $25.15^\circ$  to  $32.68^\circ$ . By experiments, highest Coefficient of Friction was found on Wood surface and the lowest on the Steel surface. Based on these results, Hybrid Paddy Thresher was developed and its performance was studied. Hybrid Paddy Thresher so designed will reduce drudgery and increase the efficiency and output. This Hybrid Paddy Thresher will be very useful for the small and marginal farmers.

**Keywords:** Hybrid thresher, winnowing, aspirator, panicle etc

### Introduction

Rice (*Oryza sativa*) belongs to the grass family Oryzaceae. Paddy is the basic food for two-thirds of the world population and is the most important cereal crop cultivated in the world as per the data, the total Rice production area in India during 2020-21 is 401.05 Ha (GOI). The rice production in India during (2020-21) 1023.64 lakh tonne. The paddy yield in India in 2020-21 is 2552 kg/Ha. The second position in the world in rice production. The knowledge of physical and engineering properties of paddy kernels is very much essential in design of threshing cylinder, aspirator and other components of hybrid paddy thresher. In India, around 4000 varieties of paddy are obtained.

It is essential to find out and recognize the data about physical and engineering (mechanical and aerodynamic) properties of paddy kernels because these kinds of properties play an important role in design and develop a new machine and their function such as threshing and winnowing. Hence, this research aimed to find out the optimum values of basic physical and engineering properties of grains of some main and popular feed crops to utilize the obtained result to optimize the best design parameter in agricultural equipment.

Various physical properties including grain dimension (length, width, thickness), weight of 100 grains, bulk density, sphericity, and mechanical properties including angle of repose and coefficient of friction as well as aerodynamic properties such as terminal velocity, drag coefficient and Reynolds number is very much essential in designing of threshing cylinder, aspirator and other components of hybrid thresher. As per the ergonomic evaluation 12% less human energy is required with respect to heart rate and oxygen consumption rate for the foot operated equipment as compared to the hand operated equipment. (Rajaram *et al.* 2011) [10]. Hence there is a need of pedal cum power operated paddy thresher with aspirator to facilitate the threshing and winnowing actions done at a time. This machine will be useful for the small farmers.

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Hence the present study was carried out to find the effect of physical and engineering properties of different varieties of paddy, on the design parameters of the hybrid paddy thresher.

### Material and Method

This chapter deals with the description of various materials, techniques, the methods used and experiment conducted for determining various engineering properties like physical, frictional and aerodynamic properties of paddy. This experiment is comes under “Centre of Excellence for Small and Medium Farm Implements Project” Prayagraj (U.P.) India. The field and laboratory test for experiment were conducted to determine various properties of paddy and performance evaluation of machine

### Sample preparation

Paddy sample were collected from Tenduvavan and kanti village in Prayagraj district, (U.P.) on November 2021. The local variety of paddy in these region such as Damini Krishna, Damini Gold, Dilkhush, Tata Mandhuri and Kanak Tata were selected to experiment. this work was carried out in the laboratory. therefore, the present study under taken to determine physical and engineering properties of paddy was experimentally determined in laboratory such as Length (l), Breadth (b), Thickness(t), Equivalent Diameter (de), Sphericity ( $\phi$ ), Bulk Density ( $\gamma$ ), True Density ( $\rho$ ), 100 Seed Weight(w) and Engineering Properties, Angle Of Repose ( $\theta$ ) and Co-Efficient Of Friction ( $\mu$ ) is essential for design of any post-harvest machine.

The samples were selected at random from the harvested heap.in each varieties for experiments or to find out proprieties of each verities of paddy Dimension of any paddy plant, panicle and grain was determined experimentally in laboratory with using instruments. Length and thickness of plant, panicle and grains was measured by using measuring tape and vernier calipers after placing it on a horizontal platform or table. For determine properties of different variety of paddy approximately divide is 5 bundle(treatments),each bundle having 1 kg, in 1 kg bundle only 5 plants are selected for finding properties of paddy. The total 25 samples of different varieties of paddy were selected. The sample were placed into different colour polythene bags and sealed. The sealed samples were used for determine of properties of paddy by using following methods. The sample was cleaned to remove all impurity or all foreign matter such as dust, stones, and chaff etc.



Fig 1: Collection and preparation of sample

### Heights of Plants

For determining the height of plants was selected at random from the harvested heap in each variety. Length and thickness of plant was measured by using measuring tape after placing it on a horizontal platform or table. The same procedure was

repeated in five plants in each varieties paddy and observation was recorded. So, total 25 samples of paddy plants selected for experiment. Similarly, same procedure repeated four other verity of paddy. All the observation obtained by this experiment is express in tabulated form.



Fig 2: Sample and Measurement of Plant Height

### Length of Panicle

For determining the Dimension of panicle of any paddy verity was selected at random from the harvested heap. In each varieties. Length and thickness of panicle was measured by using measuring tape after placing it on a horizontal platform on table.

The same procedure was repeated in five panicles in each varieties paddy and observation was recorded. So, total 25 samples of paddy panicles selected for experiment. Similarly, same procedure repeated four other verity of paddy. All the observation obtained by this experiment is express in tabulated form.

### Weight of grain per panicle

A panicle of paddy was selected randomly. The grains from panicles separated by hand and were weighed using electronic balance having a sensitivity 0.1 g. Similarly, five other varieties of paddy were selected for observation. from each verity of paddy 5 panicles of taken to carry out the same procedure. The observations found out by carrying out procedure were noted in tabular form

### Engineering Properties

The engineering properties of paddy, is important for detachment of paddy grain from panicle and also for separating grains from impurities. The development of any machine is also depends upon crop parameters, machine parameter and interaction parameter for efficient work and for achieve more output. The crop parameter such as length and thickness of panicle, weight of grains per panicle, size and shape, thousand grain weight, bulk density, true density, porosity, and angle of repose and static coefficient of friction. Since, various thresher and winnower equipment were designed on the basis of engineering properties of material handled by them.

The engineering properties of paddy sample and manners of measurement are discussed in following section. The popular verities of paddy such as Damini Krishna, Damini Gold, Dilkhush and Tata are selected as a sample throughout the Experiment..

### Physical properties of paddy

Moisture content is depend upon the physical properties and engineering properties of paddy was experimentally determined in laboratory such as length (l), breadth (b), thickness (t), equivalent diameter (de), Sphericity, bulk

density, true density, 100 seed weight (w) and engineering properties such as angle of repose (degree) and co-efficient of friction is essential for design of any post harvest machine.

### Size and shape of grain

The design of threshing cylinder and aspirator for detachment of grains from panicle and separation of grains from straw grains was selected random in each variety for finding out dimension of particles. In each variety of paddy 10 grains were selected for measurement their size and shape of particles. The size and shape of particle was measured by using vernier callipers. The same procedure was repeated in Damini Krishna, Damini Gold, Dilkhush And Tata variety of paddy. The size and shape of paddy varieties viz. Damini Krishna, Damini gold, Dilkhush and tata were obtained by following method detailed below-

**Size:** Size of paddy grains was obtained in the terms of its geometric dimension length (l), width (b) and thickness (t). Geometric dimension of particles is important for threshing and winnowing operation. A 10 grains in each variety was selected as a sample in random and to determine geometric dimension of grains in the laboratory. The dimension were measured with the help of vernier caliper, whose least count is 0.002mm the A total number of sample 50 was taken to find out their particle size in mm. therefore, the procedure were repeated for remaining varieties of paddy. The observations are recorded and represent in tabulated form.

**Shape:** The shape of agriculture materials is representing in the form of roundness and sphericity. The paddy grain has ellipsoid shape. The shape of paddy determine through grain geometric dimension, the length (longitudinal dimension), width (lateral dimension) and thickness (dorsoventral dimension) it can be found out through formulas. As already know, the ratio of length to width of grain is more than 3.0 is called as slender paddy, the ratio of length to width of grain is 2.0 to 3.0 is called as bold grain paddy, the ratio of length to width of grain is less than 2.0 is called as short or round grain paddy. Similarly, in the same way shape of paddy variety such as Damini Krishna, Damini Gold, Dilkhush And Tata were found out and categorized simultaneously.



Fig 3: Calculation of Sample Data

It was determined using following equation (mohsenin, 1986)

$$\phi = \frac{d_g}{L}$$

Where,

D<sub>g</sub>= Geometric mean diameter, (mm), L=length of grain (mm).

ϕ= Sphericity (decimal)

### 100-Grain weight

For determining 100 grains weight from heap of paddy of a particular variety were selected randomly and weighed by using weigh balance machine whose sensitivity is 0.1 g. The same procedure redeployed three times for all the varieties in consideration in these experiment and observations were noted down.

$$D_m = \frac{(L+B+T)}{3}$$

$$D_g = (LBT)^{1/3}$$

where,

d<sub>m</sub> = Arithmetic mean diameter, (mm) d<sub>g</sub>= Geometric mean diameter, (mm), L=length of grain (mm).

B= breadth of grain (mm). T= thickness of grain, (mm).

### Bulk Density

Bulk density is defined as the mass per unit volume (bulk volume, including the pore space) of the sample. This property is used for designing of aspirator for separation of desirable materials from impurities, cleaning and grading. A bulk density of paddy was determined by 200ml beaker was taken thoroughly cleaned and weighed by electronic balance. Then beaker was filled with freshly threshed paddy grains up to the 60 ml level without compaction and weighed. The weight was notes down. Then bulk density of paddy grain was calculated as follows

$$P_b = \frac{(w_2 - w_1)}{v}$$

Where, P<sub>b</sub>=bulk density of grain, g/cm<sup>3</sup> w<sub>2</sub>= weigh to empty beaker, g

w<sub>1</sub>= weigh to empty beaker + grain, (g) v = volume of beaker

The same procedure was repeated for all varieties of paddy to find out bulk density of grains. All the observations were noted down in tabulated form.

### True density

The toluene displacement method is used for determine true density of paddy grain having different varieties. In this method 100 cc measuring cylinder was used. In this experiment, 10 gram samples were immersed in a jar containing toluene. In each sample after immersed displaced toluene was recorded and true density of grains was obtained by the formulas as the ratio of weight of sample to its volume displaced.

### Porosity

Porosity is measures of the void space in porous medium. Porosity can be obtained by the true density and bulk density of paddy. Porosity of sample is inversely related to the grain size and decreases linearly as grain size increases. The porosity of paddy grains was obtained by these formulas-

$$\text{Porosity (\%)} = \frac{\text{true density} - \text{bulk density}}{(\text{true density})} \times 100$$

### Frictional properties of paddy

The frictional properties of paddy such angle of repose and co-efficient of friction of paddy on selecting surface were studied to understand the easy with which the paddy move over selected surfaces. This is necessary to identify the materials suitable for design of different parts of the machine/surface. The method adopted for determining these properties are detail below-

#### Angle of repose

The angle of repose is the angle made by the paddy with the horizontal surface. When piled from a known height. The angle of repose of paddy grains was obtained by waziri and metal suggest method. In theses method the material were heaped in round disc whose diameter is 200. When grains was freefall in these disc the height of material obtained 300 mm. According to formula put the values and obtained angle of repose same way all the varieties. The angle of repose was obtained by these formulas-

$$\theta = \tan (h/r)$$

Where,  $\theta$  = Angle of repose, degree (*degree*) h= Height of cone, (mm)

r = Radius of disc, (mm)

Similar, the same procedure was repeated for all varieties of paddy to find out angle of repose of grains. all the observations were noted down in tabulated form.

#### Co-efficient of static friction

Coefficient of friction may be defined as frictional force induced between surface of contact and sample with respect to each other when material are force to move over the surface. The resistance of free flow and uniform flow of paddy grains is depending on the coefficient of static friction. The experiment was conducted for determining co-efficient of static friction for paddy grains in different surface. Such as wood, galvanized iron and mild steel. etc by using inclined plane method. In this method, paddy grain was kept on horizontal surfaces and then slope was increased gradually. The angle at which paddy starting sliding was recorded. Co-efficient of static friction obtained by these formulas-

$$\text{Friction co-efficient} = \tan \alpha$$

Where,  $\mu$  = co-efficient of static friction,

$\alpha$  =angle of static friction (degree)

#### Aerodynamic properties

Terminal velocity of paddy grains plays a major role in separation/cleaning the grain from the impurities. If the terminal velocity of paddy grain is known, the air velocity can be adjusted to separate the paddy grains from impurities. It was calculated experimentally by using apparatus. The air

velocity was measured by anemometer in field.

### Result and Discussion

The samples were selected at random from the harvested heap in each varieties for experiments or to find out proprieties of each varieties of paddy was experimentally determine such as length and weight of plants, length, weight and thickness of panicle, weight of grains per panicle, 100 grains weight, size and shape of grains, bulk density, angle of repose, and static coefficient of friction for five varieties were taken. The obtained values were used to optimize design of hybrid thresher with aspirator components and their mechanism in terms of size and shape of thresher cylinder, aspirator air flow rate, terminal velocity etc.

#### Length of panicles

Length of panicle was measured through measuring tape for all varieties of paddy. The observed values was statistically define by table (1).

**Table 1:** length of panicles

Statistical inference	Length of panicle				
	V1	V2	V3	V4	V5
Maximum	23.2	26	21	24	25
Minimum	20.1	15	14	16	22
Average	21.65	19.4	17	15.4	23.6

From the table (1), it is find that the varieties V<sub>1</sub> (Damini Krishna) varies from 20.1 to 23.2 cm. And its mean values 21.65 cm. same as the other varieties V<sub>2</sub>, V<sub>3</sub>, V<sub>4</sub>, and V<sub>5</sub> whose mean values are 19.4, 17, 15.4 and 23.6 cm.

#### Weight of grains per panicles

Weight of grains per panicles is experimentally determined and observed values is represented in statistically on table 2.

**Table 2:** Weight of grains per panicles

Statistical inference	Weight of grains per panicle				
	V1	V2	V3	V4	V5
Maximum	2.4	4.8	1.8	2.8	3.7
Minimum	1.1	1.3	0.9	1.4	1.2
Average	1.75	3.05	1.35	2.1	2.45

From this table 2, it is find that varieties V<sub>1</sub> having weight of grains per panicles varies from 2.4 to 1.1 grams and its average values of 1.75 gram. Same as the other varieties V<sub>2</sub>, V<sub>3</sub>, V<sub>4</sub> and V<sub>5</sub> whose mean values are 3.05, 1.35, 2.1, 2.45 grams.

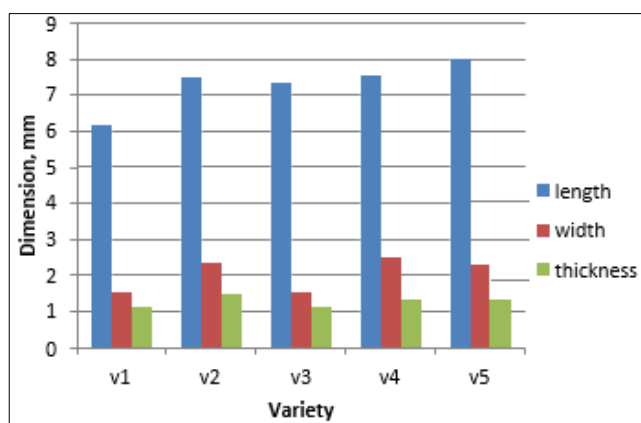
#### Size and shape of the grains grain

The geometric dimensions were determined for 5 different varieties of paddy grains via V<sub>1</sub>, V<sub>2</sub>, V<sub>3</sub>, V<sub>4</sub> and V<sub>5</sub> under observation. In these experiment paddy grain were randomly selected and each of their dimension was measured, and observed values recorded and represent on table 3.

**Table 3:** Dimensions of paddy grains

Statistical inference		Length(mm)	Width (mm)	Thickness (mm)
V1	Maximum	8.4	2.1	1.15
	Minimum	1.13	1.15	1.12
	Average	6.18	1.52	1.36
V2	Maximum	8.3	2.7	2
	Minimum	7.13	2.12	1.16
	Average	7.54	2.34	1.5
V3	Maximum	8	2.2	1.14
	Minimum	7.12	1.13	1.11
	Average	7.55	1.53	1.128
V4	Maximum	8	2.9	2
	Minimum	7.12	2	1.14
	Average	7.55	2.54	1.35
V5	Maximum	8.1	2.7	2
	Minimum	7.9	2	1.13
	Average	8.04	2.32	1.32

It was observed that the average length, width and thickness of V<sub>1</sub> variety of grain is 6.18 × 1.52 × 1.36 (mm) and other varieties respectively V<sub>2</sub>, V<sub>3</sub>, V<sub>4</sub>, and V<sub>5</sub> were average values of grain dimension (length width × thickness) V<sub>2</sub> (7.54 × 2.34 × 1.5), V<sub>3</sub> (7.55 × 1.53 × 1.12), V<sub>4</sub> (7.55 × 2.54 × 1.35), V<sub>5</sub> (8.04 × 2.32 × 1.32), are shown in table 4 these result obtain



**Fig 4:** Dimension variations of paddy grains

**Bulk density**

According to table 4, it was found that the bulk density of V<sub>1</sub> variety of paddy varies from 456 to 467 and whose average value was taken 460.0 kg/m<sup>3</sup>. The was obtained in tabulated and representation in tabulated form on table 4.

**Table 4:** Bulk density of paddy grains

S No.	Bulk density				
	V1	V2	V3	V4	V5
1	459	458	440	431	490
2	456	456	439	429	488
3	467	448	436	432	486
4	464	458	439	428	488
5	457	456	435	439	483

Similarly other V<sub>2</sub>, V<sub>3</sub>, V<sub>4</sub>, and V<sub>5</sub> verity of paddy average values we taken from experiments were 455.2, 437.8, 429.8 and 487 kg/cm<sup>3</sup>.

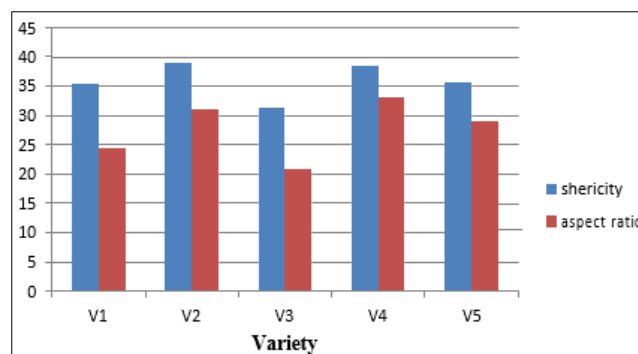
**Shape of paddy grains**

The shape of paddy grains is representing by sphericity and aspect ratio. It is important properties for design of machine. Through the experiment we determine the sphericity and aspect ratio of verities V<sub>1</sub>, V<sub>2</sub>, V<sub>3</sub>, V<sub>4</sub>, and V<sub>5</sub> of paddy. The obtained result is shown on table 5.

**Table 5:** Sphericity and Aspect ratio of paddy grains

Statistical inference	Sphericity	Aspect ratio
V1	35.3	24.5
V2	39.1	31.1
V3	31.4	20.8
V4	38.5	33.1
V5	35.8	28.9

According to analysis of data, result was obtained the highest values of Sphericity was V<sub>2</sub> variety and the highest value of aspect ratio of grains was found of V<sub>4</sub> verity of paddy.



**Fig 5:** Shape parameter of paddy grains

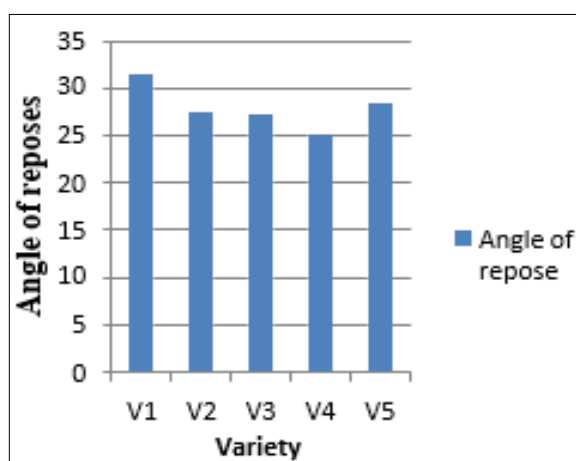
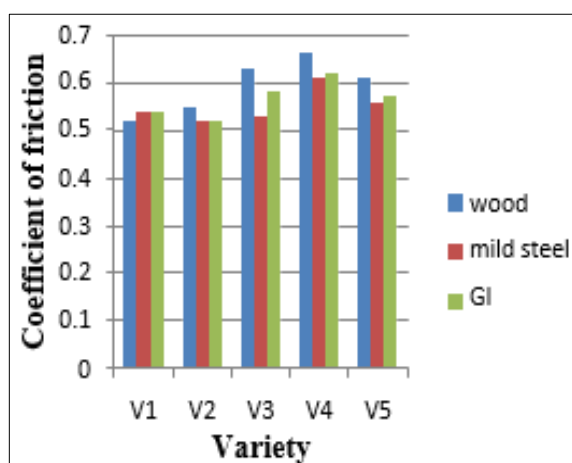
**Angle of repose and coefficient of friction**

Angle of repose and coefficient of friction was find out in three different surfaces such as wood, mild steel and galvanized iron (GI) and static coefficient of friction of different varieties of paddy for different surface like wood, mild steel and galvanized iron result was shown on table 6: Frictional properties of paddy grains.

**Table 6:** Angle of repose (Degree) and Static coefficient of friction

Statistical inference	Angle of repose(degree)	Static coefficient of friction		
		Wood	Mild steel	GI
V1	31.54	0.52	0.54	0.54
V2	27.55	0.55	0.52	0.52
V3	27.36	0.63	0.53	0.58
V4	25.07	0.66	0.61	0.62
V5	28.46	0.61	0.56	0.57

The average angle of repose for V<sub>1</sub>, V<sub>2</sub>, V<sub>3</sub>, V<sub>4</sub>, and V<sub>5</sub> varieties obtained from 31.54, 27.55, 27.36 25.07 and 28.46.

**Fig 6:** Angle of repose of paddy grains**Fig 7:** Coefficient of friction of paddy grains

### Conclusion

In this research, experimentally determine the effect of physical and engineering properties of five varieties of paddy such as damini Krishna, damini gold, dilkhush and tata for optimize design of thresher and aspirator.

From the above study undertaken following conclusions are drawn-

- The performance of hydride paddy thresher with aspirator was satisfactory.
- It was observed that the grain length varied from 8.04 to 6.182(mm), the grain width varied from 2.54 to 1.52 (mm), the grain thickness varied from 1.12 to 1.36 (mm), the grain sphericity varied from 39.1to 31.4, the 100 grains weight varied from 1.99 to 1.19 (gram), the average angle of repose varied from 25.07<sup>0</sup> to 31.54<sup>0</sup>. The bulk density of grains varied from 429 to 490 kg/m<sup>3</sup>.

- On increasing moisture content the threshing efficiency, cleaning efficiency, is decrease respectively.
- On the value of threshing capacity decreased when moisture content increase.
- Steel and galvanized iron has the lowest values of coefficient of friction.
- In order to get maximum output capacity when the grain moisture 13%.

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