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A detailed Study on Improvement in the Drying of Rotary Cotton Seed Dryer

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Abstract: To remove the moisture content from cotton seed, different types of drying mechanisms are used. Out of them rotary cotton seed dryer is most popular and effective tool. It removes moisture content till 6-8 % which was 23-25% in initial stage. There are several farmers and industrialist which use sun drying process. But it consumes much time. Hence drying of cotton seed with the help of rotary dryer will be the effective way.

The rotary cotton seed dryer is an industrial as well as agricultural used dryer employed to decrease or minimize the liquid moisture content of the cotton seeds. Drying is may be the oldest and most commonly and simply use technique in the processing of the cotton seed for removing the cotton seed oil and cotton seed milk of decent quality. In this thesis we have an abstract based on the study of rotary cotton seed dryer and improve the efficiency. Nowadays industries optimization of current process is accepted in progress manner behind industry it is found that due to optimization improve the efficiency and reduced working time and makes the system fruitful for the industry.

In this study the existing rotary dryer heat transfer with the help of CFD Tool like ANSYS Fluent. For this purpose, we will consider three piping-passage rotational velocities i.e. 10, 15 and 20 rad/s. Pressure, Velocity, Turbulence and Temperature change will be recorded for each case. Recorded results will be compared with moisture extraction process time. Based on it, final conclusion will be drawn.

Index Terms - Rotary Cotton Seed Dryer, Moisture Content, CAD Model, CFD Analysis

I. Introduction to Rotary Dryer

1.1 Drying Process

The process of elimination of moisture from the seed is called drying. Seed drying should reduce the seed moisture content to safe moisture limits to maintain its viability and vigour during storage, which may otherwise deteriorate quickly owing to mold growth, heating and enhanced microbial activity. Seed drying also permits early harvesting, long term storage of seeds, more efficient use of land and manpower, the use of plant stalks as green fodder and production of high quality seed.

Depending upon the climate and method of harvesting adopted the threshed seed may or may not be dry enough for safe storage. Under less favorable conditions, threshed seed needs further drying.

1.1.1 Stage of moisture elimination

The moisture from the seed is eliminated in 2 stages

1. Surface moisture of the seed that initially removed by the drying air.
2. The removal of the moisture in the surface cause an imbalance in the moisture potential in the surface of the seed and the inner portion of the seed which leads to the migration of moisture from the inner organ to the surface.

The migration of moisture to the surface is slower than the evaporation and a moisture gradient is developed in the kernel. Elimination of moisture from the seed depends upon the relative humidity and temperature of the environment surrounding the seed. When RH of the atmosphere is less than the seed, moisture is eliminated from the seed. While drying, care should be taken to minimize /prevent oxidation and decomposition and volatilization. In this process there will be loss of dry weight of seed which is widened when the processes take place at high temperature. Hence, high moisture seeds should be dried at low temperature.

1.1.2 Equilibrium moisture content

A seed is in equilibrium with the environment when the rate of moisture loss from the seed to the surrounding atmosphere is equal to the rate of moisture gained by the seed from the atmosphere. Drying temperature Greater the seed moisture content lesser should be the drying temperature and vice versa.

10%	MC and below	110 o F (43.3o C)
10-18 %	MC	100 o F (42.2 o C)
18-30 %	MC	90 o F (32.2 o F)

The rate of drying depends on
Initial seed moisture content
Size of the bin and capacity
Depth of spread of seed
The rate of air blow
Atmosphere air temperature and relative humidity
Static pressure
Drying temperature

1.1.3 Methods of drying

Physical drying (or) natural drying (or) traditional sun drying
Mechanical (or) artificial drying
a) Drying with forced natural air
b) Drying with forced artificially heated air
c) Drying with desiccants
d) Drying with infrared rays

II. AIMS AND OBJECTIVES OF STUDY

1) Study of Existing Rotary Dryer Heat Transfer.
2) Study of ANSYS Fluent 2020R1 as a CFD Tool.
3) Performance of CFD analysis at different cotton seed feeding velocities on existing Rotary Dryer.
4) Development of virtual cotton seed dryer with the help of CAD tool like CATIA V5R21.
5) Performance of CFD analysis at different cotton seed feeding velocities on modified Rotary Dryer.
6) Generating Conclusion based on the CFD Analysis results generated.

III. VIRTUAL ROTARY COTTON SEED DRYER

Figure 1 and 2 shows the cavity CAD Model developed for the rotary cotton seed dryer. To perform CFD Analysis on dryer, we need cavity model which actually represent the inner section of dryer where actual heated air flows. The model created is also in half section. It is not necessary to develop entire CAD model for CFD Analysis. By developing half model also, we can generate the complete model analysis by applying the symmetry. In Fig. 2 inner section of dryer shown by wireframe model. The heated fluid is flowing through the tubes and sections which provide heat through conduction and convection to the cotton seeds.

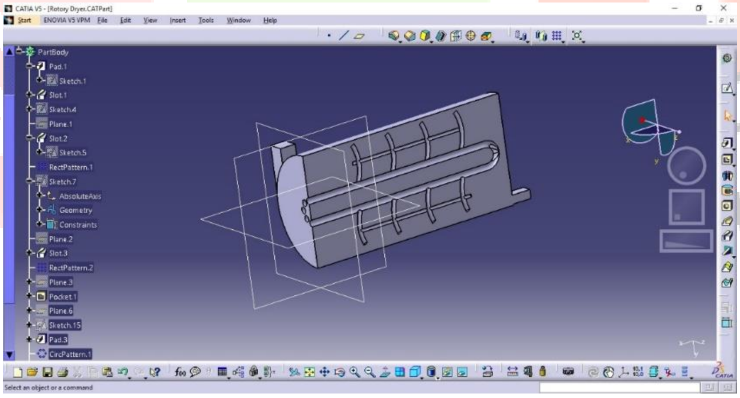

Fig. 1: Cavity CAD model of Cotton Seed Dryer developed in CATIA V5R21

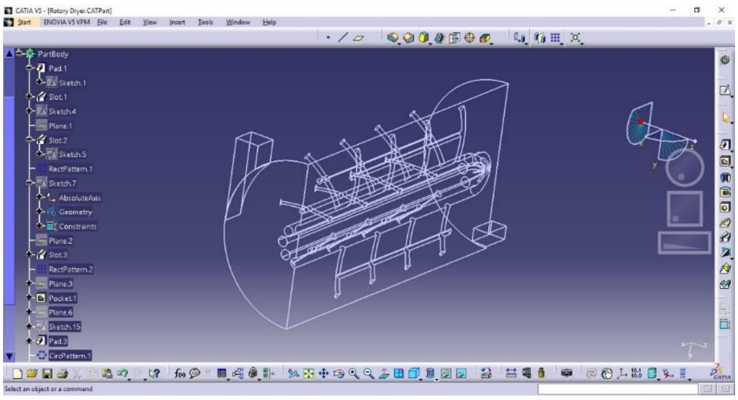

Fig. 2: Inner Sections of Cavity CAD model of Cotton Seed Dryer

IV. CFD ANALYSIS OF COTTON SEED DRYER

4.1 Meshing

This process is also called as descritisation. In this process entire model is divided into small number of pieces called elements and they are connected together by means of points called nodes. Following figure 3 shows the meshed view of Rotary Cotton Seed Dryer along with number of nodes and elements.

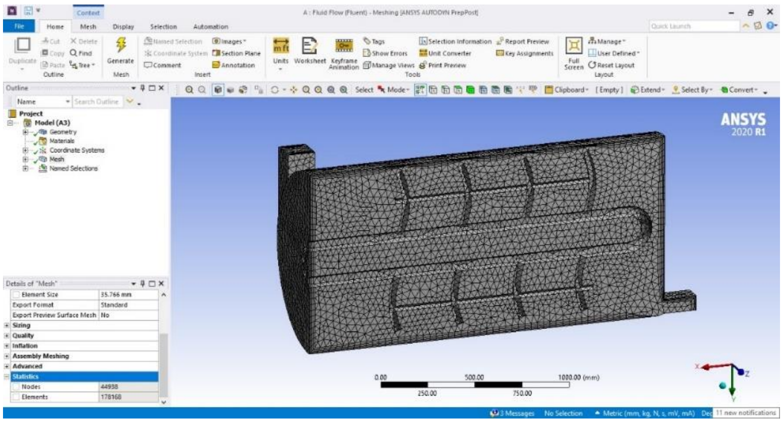

Fig. 3: Meshed view with number of nodes and elements

Table 1: Nodes and Elements

Sr. No.	Parameter	Value
1	Number of Nodes	44938
2	Number of Elements	178168

4.2 Solution methods

Energy equation was turned on and the (k-ε) model, with standard wall functions was used to model the turbulent behavior.
Scheme:- SIMPLEC
Skewness Correction:- 1
Gradients:- Least Square Cell Based
Pressure:- Linear
Momentum:- Power Law
Turbulent Viscosity{k}:- Power Law
Turbulent Dissipation {ε}:- Power Law
Energy:- Power Law

4.3 Performance of CFD Analysis

By applying all the boundary conditions and required properties, CFD analysis is to be performed. It involve following steps.
Importing of geometry into module.
Performing meshing operation on imported geometry.
Applying boundary conditions.
Applying air properties.
Applying velocity, pressure, temperature, hydraulic diameter etc.
Performance of solution intervals.
Result obtaining and saving.

4.4 Boundary Conditions Applied

While performing CFD analysis, different boundary conditions are needs to be applied. These boundary conditions will be same as the physical conditions. Means the velocity and pressure values ate the inlet and outlet must be same. Similarly the other physical conditions must be simulated well. The fluid properties and metal properties are needed to be applied in CFD Tool.

4.5 Flowing Fluid Properties

Rotational Velocity {rad/s}:- 10, 15, 20 rad/s
Convective Heat Transfer Coefficient{h} of outer surface of tube and passages:- 1000 W/m2-K
Free-stream temperature inside the dryer{T free}:- 300 K(approx)
Temperature of flowing fluid (Oil) at the inlet{T inlet}:- 1673 K(approx)

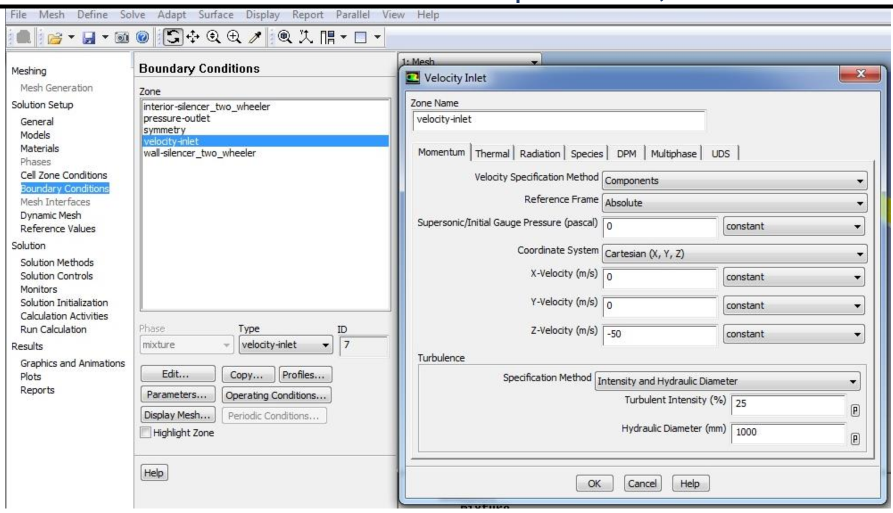

Fig. 4: Boundary Conditions and properties of Flowing Fluid Applied on Dryer

V. TEMPERATURE DISTRIBUTION IN DRYER1

5.1 Temperature Distribution in Dryer

5.1.1 Results for case I (10 rad/s Rotational Velocity)

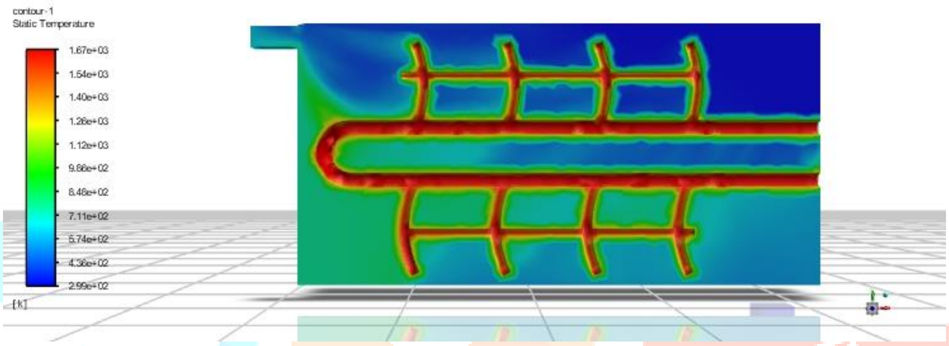

Fig. 5: Temperature Distribution along the dryer for 10 rad/s rotational velocity

Fig. 5 shows the temperature contours for 10 rad/s rotational velocity of Tube-passage section. The initial flowing fluid (Oil) temperature was considered as 16730 K. The maximum temperature recorded is 16700C which is approximately same as supplied. This is only due to the continuous heat supplement to the flowing oil.

Inner pipe has a maximum temperature throughout the section, while the passage section has massive heat transfer due to rotational velocity and convection. As hot oil enters into passage section, heat transfer accurses through convection and radiation. The outer surface of passages and tubes are in the contact with the cotton seeds which has much lower temperature and moisture content than oil temperature. Due to this temperature difference heat transfer phenomenon takes place.

If we observe color patter obtained, then it is clearly indicating the hot sections on the pipes and passages. It is only due to the rotation of the piping-passage section inside the dryer. This varying temperature inside the dryer helps to extract the maximum moisture from the cotton seeds.

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If we observe color patter obtained, then we come to know that the heat transfer at this speed is better than previous case. But the time required to extract the moisture from the cotton seed is reduced. Due to increased speed of rotation, moisture extraction process is disturbed and actual purpose of drying will not be fulfilled.

By observing the temperature distribution inside the dryer in all three cases, we found that the hat transfer rate will be increased, if we increase rotational speed. But the moisture extraction process gets disturbed. if we increase the speed. Hence it is desirable to rotate the heating mechanism with particular (10Rad/s) speed.

By performing CFD analysis of rotary cotton seed dryer, various results are obtained. These results are generated as per the case selected. We have considered three cases namely 10, 15, 20 rad/s rotational velocity for this study. All results are listed and discussed as follows.

VI. Remaining CFD Results

6.1 Results for case I (10 rad/s Rotational Velocity)

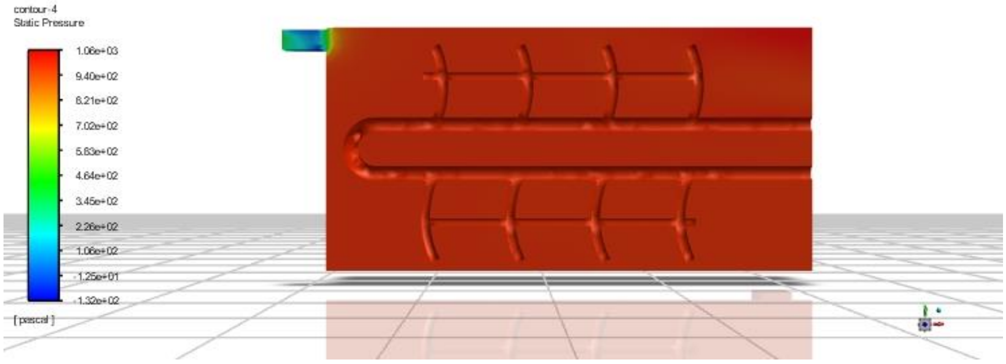

Fig. 8: Contours of Static Pressure for 10 rad/s Rotational Velocity

Fig. 8 shows the pressure contours within the rotating Cotton seed dryer. This result is obtained for 10 rad/s Rotational Velocity. If we observe the color pattern generated then we found that, pressure is constant throughout the dryer (1.06 MPa). At the inlet, it is minimum i.e. 0.128 MPA. While travelling through dryer, it is increased to 1.06 KPA as per the color pattern obtained.

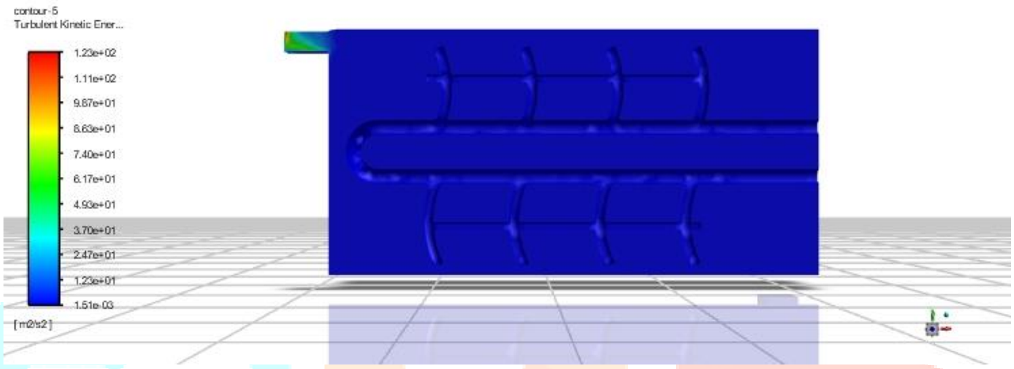

Fig. 9: Contours of Turbulent Kinetic energy inside the cotton seed dryer

Fig. 9 shows the contours of turbulent kinetic energy. It indicates the blue and sky blue color which possesses value between 1.51 to 123 m2/s2 on color scale. The maximum kinetic energy will be generated at the outlet i.e. 123 m2/s2. But throughout the dryer it only up to 12.3 m2/ s2.

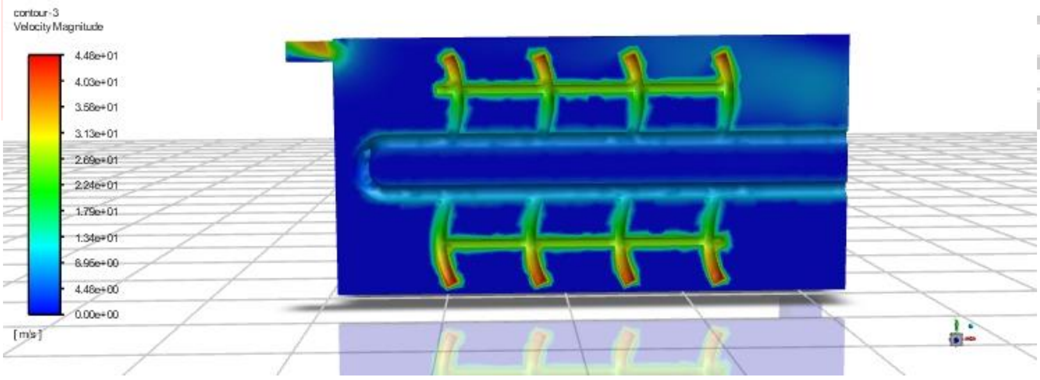

Fig. 10: Contours of velocity distribution along the rotating Cotton seed dryer

Velocity contours shown in Fig. 10 indicates the velocity drop in chamber section. Whereas at the piping section it again drops to 4 m/s. Initially 10 rad/s rotating velocity is applied to the piping-passage section. With this rotating speed, maximum cotton seed moving speed inside the dryer is observed as 44.6 m/s.

VII. TABULATED RESULT FORMATION

All results generated for 10, 15, 20 rad/s rotational velocity are tabulated in following table.

Table 2: Tabulated Results for all three cases

Sr. No.	Rotational Velocity Cases	Pressure (Max.)	Velocity (Max.)	Turbulence (Max.)	Temperature
1	Case I 10 rad/s R.V.	1.06 MPa	44.8 m/s	123 m2/s2	16700 K
2	Case II 15 rad/s R.V.	2.40 MPa	57.1 m/s	310 m2/s2	16700 K
3	Case III 20 rad/s R.V.	4.12 MPa	75.7 m/s	579 m2/s2	16700 K

By observing all above results we found the values of each pressure, velocity and turbulence increases as the rotational velocity increases. But the temperature in each case inside the dryer is constant and does not change with the change in the rotational velocity. Amount of seeds entered onto the dryer are defined by the feed velocity. Hence the velocity of seed movement inside the dryer is also increases. On the basis of these results we can generate following Column chart diagrams.

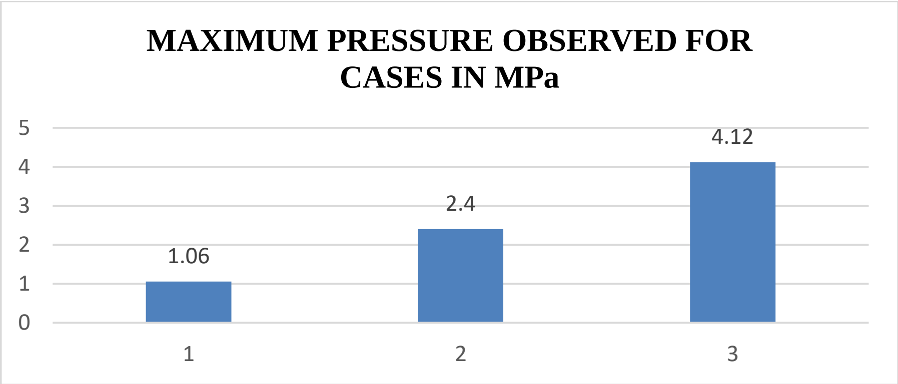

Fig. 14: Pressure increment found in Case I, II and III

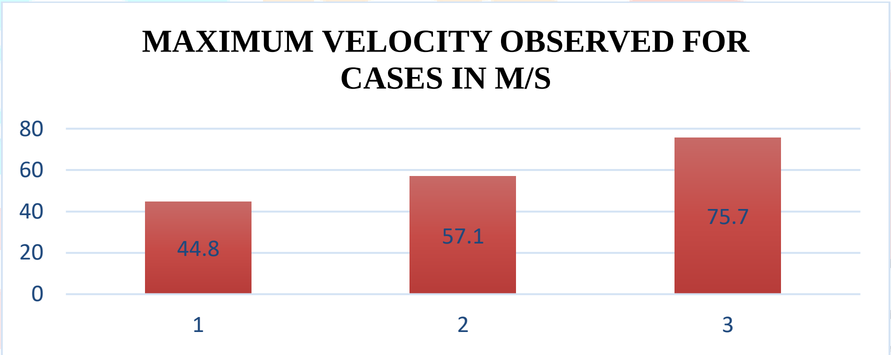

Fig. 15: Velocity increment found in Case I, II and III

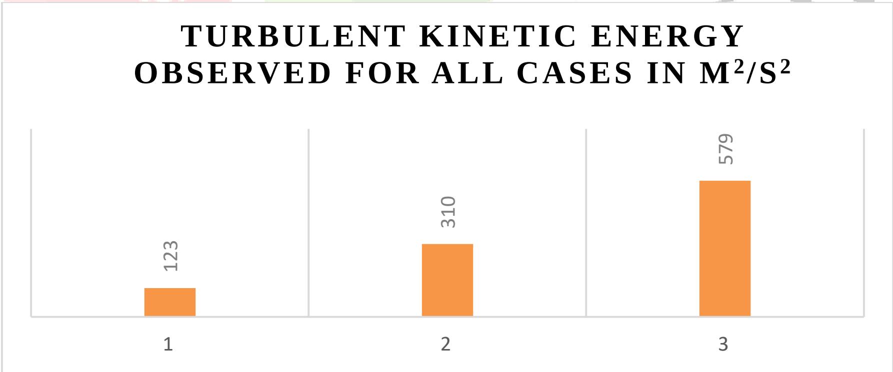

Fig. 16: Turbulence increment found in Case I, II and III

By observing all above graphs, we found that the increment in each parameter is only due to the rotational velocity of the piping-passage section. But no increment observed in temperature. Hence the time required to extract moisture from the cotton seed will be same in all cases. But due to increased feed velocity cotton seed will not get sufficient time to extract its moisture completely. Hence increment in the rotational velocity is not desirable for the extraction of the moisture from the cotton seed. Hence based on above observations, final conclusion will draw.

VIII. CONCLUSION

By conducting CFD analysis on rotary cotton seed dryer for a different rotation velocity (10, 15 and 20 rad/s) it is found that the increased rotational speed will also increase the feed velocity at a constant temperature. Hence the time to extract moisture from the cotton seed is also reduces. Hence to perform proper moisture extraction process dryer must rotate with particular speed (i.e. 10 rad/s). No speed increment should be done. Lowering feed rate up to some extent at the 10 rad/s rotational velocity will give more superior moisture extraction.

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