Design and Construction of a Mechanical machine for Separating Stigmas from the Saffron's Petals

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***Abstract*—This project was conducted to look at the feasibility of separating saffron (stigma) from stamens and petals with a vertical airflow to mechanize this task. In this project, a machine for separating the stigma from the saffron petals was designed in a way the early design involved the mentioned needs for decreasing the time and the human force needed in harvesting. Based on the investigations, the researchers found that mean wind speed at the threshold of moving the saffron flower's parts, including petals of 1, 3, and 5 days old, three-filament stigmas of one day old, single-filament stigmas, and stamens should be 0.65 $m.s^{-1}$, 1.99 $m.s^{-1}$, 1.15 $m.s^{-1}$, and 1.28 $m.s^{-1}$, respectively. Also, the horizontal distance wended by the saffron's parts from heights 90, 75, 60, 45, and 30 cm in the wind tunnel with the airflow speed of 210 $m.min^{-1}$ was as follows: 6.8 cm, 7.3 cm, and 7.6 cm and for petals of 1, 3, and 5 days old; 0.06 cm, 0.31 cm, and 1.14 cm, respectively. For three-filament stigmas of 1, 3, and 5 days old; 4.5 cm, 4.64 cm, and 5.13 cm and for single-filament stigmas of 1, 3, and 5 days old; and 4.28 cm, 4.40 cm, and 3.85 cm, respectively and for stamens of 1, 3, and 5 days old per 10 cm decrease in height. The separation capacity of the machine is 11 kg per hour with 70% efficiency.**

Keywords—Saffron, stigma, stamen, petal, separator, equipment, style, feeding container

Introduction

Saffron is the world's most expensive spice and is known as red gold. Iran ranks first in the world about cultivated area and production of saffron, as over 90% of the world's saffron is produced in Iran [4]. Separation of stigmas is one important step in saffron production process [1] and the most costly step for agricultures. The traditional method of separation is time-consuming and no hygienic. Some suggestions, such as using friction cylinder and wind tunnel, have provided for mechanical separation of stigmas, as preliminary designs [5]. The research project conducted and made a small lab air blower using aerodynamic properties for separation of stigmas from other parts of the saffron [10]. Some other researchers suggested using aerodynamic properties and cascade or freefall machines [9 , 3]. In this project, the machine for separating stigmas from the saffron flower was designed in a way that covered the needs mentioned in the early design. The following general characteristics, based on the calculations, were considered in designing the machine:

1. About 10 $kg.h^{-1}$ capacity;
2. About 85% efficiency;
3. As simple a mechanical machine as possible
4. Chaffy saffron as the output.

So, the machine was designed, and the details of each part are provided in next sections. The design consisted of a feeder (conveyor belt), a vertical feeding channel, an accordion conveyor, and a wind tunnel. The schematic separation line is shown in Figure 1. The deficiencies and limits of the design are as follows:

- Few season of harvesting flowers from farms;
- Lack of scientific and practical records about the mechanism for separating stigmas from the petals
- The flexibility of saffron flowers during harvesting.

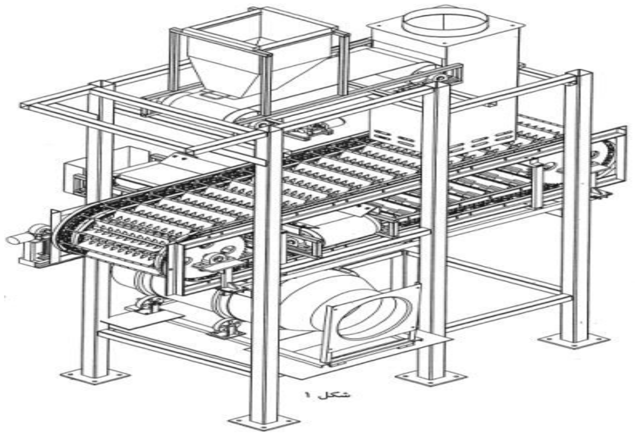

Fig.1 *Schematic of the machine*

Materials and Methods

The machine consists of the following units:

1- Feeding unit

This unit has two parts:

A) Conveyor belt: It consists of a conveyor belt and a reservoir that adjusts the capacity and line feed speed. The conveyor belt gets saffron flowers from the relevant part (feeding container) and transfers them to the next part (feeding channel).

B) Vertical feeding channel: It consists of a fan and a wind tunnel. The fan creates airflow in a direction opposite to the flowers' movement and makes them fall on their receptacle and enter the accordion conveyor.

2- Flowers cutting unit

This unit has two parts:

A) Accordion conveyor: It is one of the most important basic parts of the machine and of special sensitivity. It gets the flowers from the feeding channel and, holds them fixed to be cut through a series of plates. After cutting, the accordion conveyor transfers the flowers to the next part (separation).

B) Flowers cutting unit: It cuts saffron flowers from their sepals when the accordion conveyor plates get them.

3- Separation unit

Once the flowers are cut from the petals, that is, the petals are plucked, they entered the separation step. This part consisted of an angled/slanted rotating cylinder and a fan. The cylinder rotation speed can be adjusted, the fan creates airflow in a direction opposite to the flowers' movement in a way the petals and stamens move toward airflow, and stigmas are separated from the petals in a direction opposite to the airflow and directed outside on the slope.

4- Output unit

The output unit includes two products as follows:

A) Clean stigmas as their three filaments remain attached (known as chaffy saffron)

B) Stamens and petals of saffron flowers.

The procedures performed in designing the machine are as follows:

1. Using the results of the previous studies on the preliminary design, the detailed design started based on the preliminary design's specific characteristics, including the capacity, efficiency, mechanism, and technology.
2. Different parts of the machine were designed using engineering design methods and acceptable standards and preparing executive plans.
3. Computing and cartography software programs such as QBasic and Mechanical Desktop software were used for preparing design and technical reports.

Results of designing the separation unit

The unit consists of a fan and a rotating cylinder. The cut flowers enter the cylinder through a conveyor belt and are separated from each other by the wind force produced by the fan.

1. Selecting the fan

The most important matter in designing the unit is the calculation or selection of the wind speed because the unit should be able to separate different parts of flowers about their difference in surface area and density. Separation speed was calculated using the equation (1):

$$V_P = 7655.4 \times \sqrt{\frac{m}{A}} \quad (1)$$

Where, Vp is the wind speed (pick-up speed) at the threshold of moving the object; m is the weight of each part in gram; and A is the effective surface of the object in mm2.

Vp was the wind speed that could lift every part from its surface. The weight of each saffron part varies with the time of plucking. So, different speeds could be gained considering the interval between harvesting and separating. Reference mentioned ages of 1, 3, and 5 days for flowers and calculated the cross-sectional area and Vp based on the mentioned ages. The relevant values are shown in Table 1.

TABLE 1 WIND SPEED AT THE THRESHOLD OF MOVING SAFFRON'S PARTS

Saffron's parts	Weight (g)	Efficient surface (mm^2)	Pick-up speed $(V_p)^2$	Mean pick-up speed
1-day old petal	0.02761	300.5	73.4	
3-day old petal	0.02882	404	64.7	65.2
5-day old petal	0.03074	545.5	57.5	
1-day stigma (three-filament)	0.02603	35	208.8	
3-day stigma (three-filament)	0.02963	41.85	203.7	199.8
5-day stigma (three-filament)	0.0365	61.25	186.9	
1-day stigma (single-filament)	0.0087	35	120.5	
3-day stigma (single-filament)	0.0099	41.85	117.6	115.3
5-day stigma (single-filament)	0.0122	61.25	107.9	
1-day old stamen	0.01063	40	124.8	
3-day old stamen	0.00717	28	122.5	126.9
5-day old stamen	0.00667	22	135.5	

According to Table 1, maximum wind speed (about 210 $m.min^{-1}$) at the threshold of lifting parts was about the three-filament stigma of one day old. Speed was determined for the separation speed because Iranian farmers usually collect and separate saffron flowers on the first day. In designing the wind tunnel, the diameter mentioned for the rotating cylinder was 600 mm. So, the needed flow rate was calculated using the equation (2) [2]:

$$Q = A \times V \quad (2)$$

Where, Q is the airflow in $m^3 h^{-1}$; A is the cross-sectional area the air passes through; and V is the wind speed in $m.s^{-1}$.

$$Q = \frac{\pi d^2}{4} \times V_p = \frac{\pi}{4} \times 0.6^2 \times \frac{210}{60} = 0.9896 \frac{m^3}{s} \cong 1 \frac{m^3}{s} = 3600 \frac{m^3}{h}$$

To gain various speeds, a fan with a higher flow rate and variable rpm was selected. The fan blower had the following characteristics:

Model: VIE-40 TUS
Volt: 220 V
RPM: 1400
$m^3 h^{-1}$: 4350
Fan: DIA.: 400 mm

The selected fan is axial type and can help separating flower parts with its vertical airflow.

2. Calculating the proper angle for the rotating cylinder

Table 2 shows the horizontal distance wended through the wind tunnel by the saffron parts. As shown by the table, flowers of 1, 3, and 5 days old were tested at different heights.

TABLE 2 THE HORIZONTAL DISTANCE WENDED BY THE SAFFRON PARTS DROPPED FROM VARIOUS HEIGHTS THROUGH THE WIND TUNNEL WITH THE AIRFLOW 210 $M.MIN^{-1}$.

	Falling height (cm)				
	90	75	60	45	30
The horizontal distance wended by the saffron parts (mm)					
Petals					
1-day old	97.53	89.02	79.62	68.96	56.3
3-day old	103.74	94.49	84.69	73.35	59.89
5-day old	108.89	99.38	88.88	76.99	62.86
Three-filament stigmas					
1-day old	0.86	0.78	0.7	0.61	0.49
3-day old	4.5	4.11	3.67	3.18	2.6
5-day old	16.49	15.05	13.46	11.66	9.52
Single-filament stigmas					
1-day old	63.9	58	52.16	45.81	36.89
2-day old	65.97	60.21	53.85	46.65	38.09
3-day old	72.9	66.54	59.51	51.14	42.08
Stamens					
1-day old	60.83	55.52	49.66	43.01	35.11
2-day old	62.48	57.02	51	44.17	36.06
3-day old	54.76	49.98	44.7	38.72	31.61

According to Table 2, if the separated parts of flowers are fed into the rotating cylinder at the height of 30 cm and maximum horizontal distance of 35 mm from the end of cylinder, petals and stamens will fall outside the cylinder from the beginning. But, this was not practical (no flowers could be dropped from the height of 35 mm because of the large feed opening) because the flower parts are not separated from one another, and so, it could stigmas fall out with other parts, and the machine efficiency decrease. So, the separated parts of flowers should be dropped into the cylinder from a height over 35 mm, and this procedure should be performed repeatedly until all the parts exit from the machine. (Directing the flower parts from the bottom to the top of the cylinder); radial blades were set in the cylinder with proper intervals. Figure 2 shows the rotating cylinder with α angle and movement direction of petals and stamens (ABC …) and stigmas (AGL …). According to the figure 2, the distance petals and stamens return to the front of cylinder (BF) and the distance stigmas return to the front of cylinder (GP) depend to the slope of the rotating cylinder with α angle, as the distance the parts return to the front of cylinder increase with α angle.

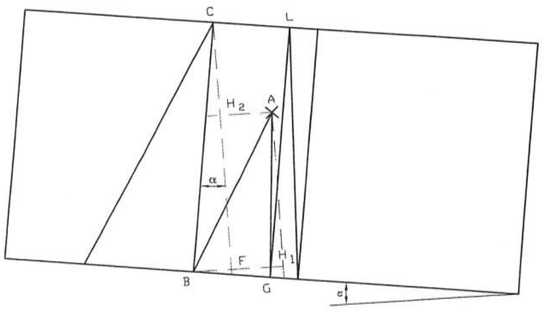

Fig.2 *Rotating cylinder*

If α angle exceeds some, all the parts will exit from the beginning of the rotating cylinder. In such a situation, the distance the parts return to the front depends on the airflow speed and falling height. So, the AH2 should not be less than the difference between horizontal movements of the two consequent falls. On the figure and trigonometry, the AH2 was calculated using the equation (3):

$$BF = BC\sin\alpha = d\sin\alpha$$

$$AH_2 = BH_1 - BF \qquad (3)$$

Where, d is the diameter of the rotating cylinder (mm); α is the angle of the rotating cylinder with horizon (°); BH1 is the each part's horizontal movement caused by the airflow (mm); and BF is the distance the parts return to the front of cylinder under the impact of α angle (mm).

The angle could be calculated for each part, then minimum degree was chosen for the cylinder angle, assuming the diameter of the cylinder as 600 mm, and the early falling height (the interval between feed opening and the cylinder surface) as 300 mm. On explanations, AH2 was calculated for petals and stamens. So, using Table 2, it can be argued:

Petals: $AH_2 \geq 56.3 - 79.62 = -23.32mm$

Stamens: $AH_2 \geq 35.11 - 49.66 = -14.55mm$

So, maximum degree for petals is as follows:

$BH_1 = 56.3mm$ and $BF = 600\sin\alpha$

$$AH_2 = -23.32 = 56.3 - 600\sin\alpha \Rightarrow \sin\alpha = 0.1327 \Rightarrow \alpha 7.6$$

Maximum α angle for stamens is as follows:

$$BH_1 = 35.1mm$$

$$AH_2 = -14.55 = 35.11 - 600\sin\alpha \Rightarrow \sin\alpha = 0.0828 \Rightarrow \alpha = 4.7$$

α angle should not be greater than 4.7° for petals and stamens getting out of the cylinder. But faster exit of petals and stamens seems more essential than that of stigmas because of the high volume they occupy. α angle for the cylinder was determined as 3° after trial and error.

3. Selecting rotational speed of the cylinder

The introduced rotational speed 15 rpm was selected for the considering separation capacity 5 $kg.h^{-1}$[7]. So, the speed 30 rpm was selected for the cylinder because the rotational speed has a direct correlation with the separation capacity. But, the speed was selected experimentally. The drive unit had the variable rotation mechanism for reaching the final capacity 10 $kg.h^{-1}$.

4. Calculating the power of the rotating cylinder

To supply the rotational movement, the cylinder was placed on four rubber rollers of which one roller was the drive and others acted like fulcrums. Power needed for rotating cylinder equaled to the power needed for overcoming the weight of the cylinder and the friction between the roller and cylinder. Considering the size and thickness of the plate used for the cylinder body and appurtenants of the cylinder, weight of the cylinder is 5.1 kg, and the coefficient of friction between rubber and steel (µ) is 0.5. So, weight of the cylinder is:

$$W = 51 \times 10 = 510N$$

The vertical force exerted on each roller by the cylinder's weight is:

$$F_N = \frac{1}{4}W = \frac{510}{4} = 127.5N$$

The friction between rollers and cylinder is:

$$F_N = \frac{1}{4}W = \frac{510}{4} = 127.5 = 63.75N$$

As there were four rollers, the total friction is:

$$(F_f)_t = 4F_f = 255N$$

The torque needed for rotating the cylinder is:

$$T = (F_f)_t \times d/2$$

Diameter of the rubber rollers:

$$d = 125mm$$

The torque needed for rotating the cylinder:

$$T = 255 \times 125/2 = 1593.7N.mm = 15.9N.m$$

As mentioned before, the rotational speed 30 rpm is selected for the cylinder, so, the rotational speed of rollers is:

$$n / n' = d' / d$$

Where, n' and d' are the rotational speed and diameter of cylinder, respectively.

$d' = 600mm$

$n' = 30rpm$

The rotational speed of motor gearbox:

$$n = \frac{n'd'}{d} = \frac{30 \times 600}{125} = 144rpm$$

So, the power needed for motor gearbox is:

$$P = \frac{T.\frac{\pi.n}{30}}{e}$$

Where, e is the mechanical efficiency of the power transmission. Considering 80% efficiency for the machine, it can be argued:

$$P = \frac{15.9 \times \pi \times 144}{30 \times 0.8} = 300w = 0.4hp$$

On the catalog of Sharif Co., the proper electro gearbox with the power 0.5 hp and output speed 80 rpm was selected [9].

5. Designing the accordion conveyor

The accordion conveyor is the most important part of the machine for separating stigmas from saffron flowers. In this part, all the flowers should be cut from their sepals in a way that all the parts of flowers are separated from one another, but the three-filament stigmas should remain attached together. The acceptable tolerance for cutting was ±1. The accordion conveyor consists of some plates hinged together on one side and move on a specific path (railway), as the gap between them could vary with changing the gap between rails. The plates are located between two chains that supply their linear movement by the hinge axis. According to Figure 3, the decreased intervals of rails cause the plates near one another, and the other way around. So, the flowers can be fixed at their cutting site and be cut more accurately.

After measuring diameter of sepals (the cut site) in 50 flowers, the researchers found that mean diameter of open sepals was around 8 mm varying between 6 mm and 10.6 mm, and mean diameter of closed sepals was around 2.1 mm varying between 1.5 mm and 2.6 mm. Based on the measurements, the conveyor was designed in a way the distance between the edge of plates and the site the flowers fall from the feeding channel outlet is 10 mm that decrease to 2 mm at the cut site and increase to 40 mm at the site of performing cut flowers. In this situation, the cut flowers are directed to the stigma separation tunnel through a horizontal conveyor belt.

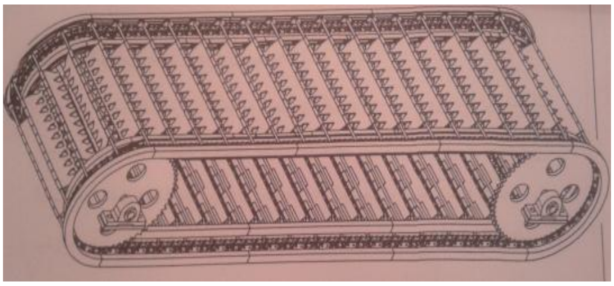

Fig.3 *Accordion conveyor*

6. Selecting the chain and sprocket wheel [8]

The power needed for moving plates with saffron flowers is little, thus, the chain is not selected based on the power rather the size of plates and shafts determined the grade of chain. A grade 80 chain was selected. As mentioned above, a conveyor belt directs the cut flowers to the stigma separation tunnel. The conveyor belt is placed in the path the accordion conveyor goes and back. So, the size of conveyor belt settles minimum diameter of the sprocket wheel. According to the executive plans, minimum diameter of the sprocket wheel is around 660 mm. Thus, sprocket wheel's teeth number is calculated as:

$$dp = \frac{P}{\sin(180 / N)}$$

Where, dp is the pitch diameter of the sprocket wheel (mm); P is the pitch diameter (mm); and N is sprocket wheel's teeth number.

The grade 80 chain has the pitch $1'' = 25.4$ mm, therefore:

$$\sin\left(\frac{180}{N}\right) = \frac{P}{dp} = \frac{25.4}{440} = 0.057 \Rightarrow N = 54.4$$

As sprocket wheel's teeth number should be a round number, thus:

$$N = 55 \Rightarrow dp = \frac{25.4}{\sin(180 / 55)} = 444.92mm$$

Other dimensions of the sprocket wheel could be determined using DIN 8196 standard that was considered in the executive plans.

7. Calculating the linear speed of the chain

On the selected chain with 1" pitch and size of plates, the pitch of plates equals to 5 pitches of the chain, that is, 127 mm. Nominal capacity of the conveyor was 10 kg/h, so, to reach this capacity, the nominal capacity is higher by 10%.

$$C = 10 + 0/1 \times 10 = 11kg / h$$

Given that one kilogram of the flowers comprises 2170 flowers (Mollafiabi, 1991), capacity of the conveyor based on flowers number is:

Flower/h = 6.6, flower $/ s \cong 7$ flower.s^{-1}

$$C = 11 \times 2170 = 23870$$

Considering the length of each plate and the size of each flower, 10 flowers can be placed between every two plates (in each row). But, because of uneven distributing flowers in the feeding channel, and so in the accordion conveyor, 8 flowers are assumed to be placed in each row. So, as the distance between every two plates is 127 mm, linear speed of the chain is:

$$C = \frac{V \times m}{P_1}$$

Where, V is linear speed of the chain (mm/s); m is flowers number in each row; and P1 is the pitch of rows (the distance between consecutive rows).

$$7 = \frac{V \times 8}{127} \Rightarrow V = 111.5 \,{}^{mm}\!/_{s}$$

About the diameter of the sprocket wheel, its rotational speed is:

$$V = \frac{\pi n}{30} \times \frac{dp}{2} \Rightarrow n = \frac{60V}{\pi .dp} = \frac{60 \times 11.5}{\pi \times 444.92} = 4.8 rpm$$

Based on the rotational speed of 5 rpm, the linear speed of the chain is:

$$n = 5 \Rightarrow V = \frac{\pi \times 5}{30} \times \frac{444.92}{2} = 116.5 \,{}^{mm}\!/_{s}$$

With rounded rotational speed and mean weight of each flower, equals to capacity of the machine (Mollafiabi, 1991):

Flower $/s \cong 12.2 \,{}^{kg}\!/_{h}$, $C = \frac{116.5 \times 8}{127} = 7.3$

8. Calculating the length of chain [8]

About the needs of different parts of the machine, the distance between centers of sprocket wheels (D) is calculated as 2020 mm. Pitch diameter of the sprocket wheels is 444.92 mm, therefore, length of the chain can be calculated through the following equation in which: N is teeth number of the large sprocket wheel; n is teeth number of the small sprocket wheel; R is the radius of the large sprocket wheel; and r is the radius of the small sprocket wheel. As the diameters of the drive and moving sprocket wheels are equal, thus:

$$\sin \alpha = 0 \Rightarrow \alpha = 0$$

Teeth number of the drive and moving sprocket wheels are the same and equal 55, and pitch of the chain (p) is 25.4 mm, therefore:

$$L = \frac{180}{360} \times 55 \times 25.4 + \frac{180}{360} \times 55 \times 25.4 + 2 \times 2020 = 5437 \; mm$$

Chain rings number is:

$$m = \frac{L}{P} = \frac{5437}{25.4} = 214.1$$

Rings number should be a round number, thus:

$$m = 215 \Rightarrow L = m \times p = 215 \times 25.4 = 5461 mm$$

The distance between centers in such a situation is:

$$D = \frac{L - NP}{2} = \frac{5461 - 55 \times 25.4}{2} = 2032 mm$$

9. Calculating the needed power [8]

The accordion conveyor is a chain conveyor. The power needed for this conveyor is calculated through the equation (4):

$$HP = \frac{1.15 \times 5 \times P_m}{33000} \quad (4)$$

In equation, the efficiency of machine is regarded as 87%. But, taking account of the mechanism of the accordion conveyor and the large number of ball bearings and hinged plates, the efficiency is much less than percent and decreased to almost 70%., the power is calculated as:

$$HP = \frac{1.43 \times S \times P_m}{33000}$$

Where, S is the linear speed of the chain (sf/min), and Pm is tensile force of the chain (lb) and calculated using the equation (5):

$$P_m = f_1.L(2W_c + W_m) + W_m H + \frac{f_2 \times DP \times h^2}{100} \times L \quad (5)$$

Where, $f1$ is the chain-rail friction coefficient; $f2$ is the materials-channel friction coefficient; BD is the density of the carried materials (lb/ft3); Wm is the weight of materials in each foot (lb/ft); Wc is the weight of moving pieces in each foot of the chain (lb/ft); L is the horizontal distance between centers of sprocket wheels (ft); and H is the vertical distance between centers of sprocket wheels (ft).

Considering the materials (flowers) are placed on the conveyor, $f2$ = 0, and as the conveyor is installed horizontally, H = 0.

So, the equation (6) for calculation of Pm is summarized as follows:

$$P_m = f_1 L(2W_c + W_m) \quad (6)$$

The weight of flowers on the conveyor (Wm) is much less than that of the moving pieces and could be ignored, therefore,

$$P_m = f_1.L.2W_c$$

The $f1$ friction coefficient for the rolling chains is calculated through the equation (7):

$$f_1 = f_r \frac{d_a}{d_r}$$

Where, da is diameter of the axis; dr is the outer diameter of the roller (outer diameter of the ball bearing) (mm); and fr is the material-dependent coefficient that is 0.4 for steel rollers in the dry state [8].

The da and dr diameters are:

$$d_a = 10mm$$

$$d_r = 22mm$$

So:

$$f_1 = 0.4 \times \frac{10}{44} \cong 0.2$$

The distance between centers of sprocket wheels is:

$L = 2032mm = 6.7\,ft$

The weight of moving pieces about the executive maps is:

$\omega_c = 25 \, kg/m = 16.9 \, lb/ft$, tensile force of the chain is as follows:

$P_m = 2 \times 0.2 \times 6.7 \times 16.9 = 45.3lb$

The linear speed of the chain is:

$S = 111.5 \, mm/s = 22 \, ft/\min$

So:

$$HP = \frac{1.43 \times 22 \times 45.3}{33000} \cong 0.04 = 33W$$

10. Selecting motor gearbox

About the low rotational speed of sprocket wheels, the most proper gearbox is the helical gearbox. Referring to the catalog of helical gearboxes made by Mashhad Gearbox Company., the suitable electro-gearbox is selected as follows:
The rotational speed of sprocket wheels is 5 rpm that is not available in the catalog. So, the speed should be decreased two times to reach the speed. Through selecting a gearbox with a conversion ratio of 1 to 60 in the first step and selecting a pulley belt with a conversion ratio of 1 to 3 in the second step, the power of gearbox is calculated as follows:

$$P_1 \geq \frac{P}{\eta d} \times S.F$$

Where, P_1 is the input power of gearbox (kw); P is the output power of gearbox (the needed power) (kw); ηd is the gearbox efficiency; and $S.F$ is the coefficient of working conditions.
According to Diagram 1, gearbox efficiency is 62% for the conversion ratio of i=60.

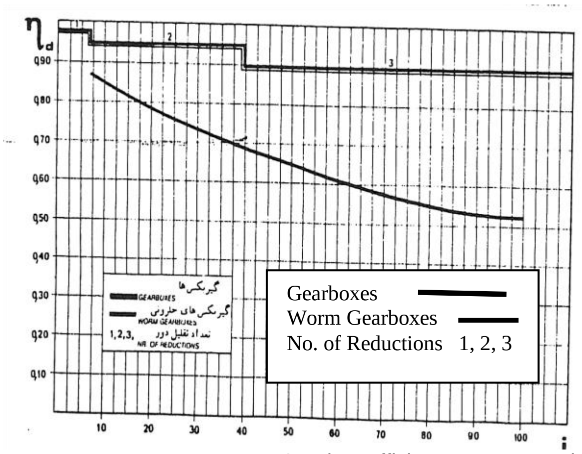

Diagram 1. Gearbox efficiency vs. conversion ratio

Based on Table 3, the coefficient of working conditions with light and constant overload is 2. So:

$SF = 2$

$$P_1 \geq \frac{31}{0.62} \times 2 = 100W = 0.1KW$$

TABLE 3 FRICTION FACTOR AND LENGTH FACTOR FOR CONVEYOR TENSION FORMULAS

FRICTION FACTOR (C) AND LENGTH FACTOR (Lo) FOR CONVEYOR TENSION FORMULAS

Class of Conveyor	Friction Factor (C) *	Length Factor (L_o), ft *
For conveyors with permanent or other well-aligned structures and with normal maintenance	0.022	200
For temporary, portable, or poorly aligned conveyors. Also for conveyors in extreme cold weather that are either subject to frequent stops and starts or are operating for extended periods at -40 deg. F or below	0.03	150
For conveyors requiring restraint of the belt when loaded	0.012	475

* The C and L_o factors have proven to be satisfactory for the great majority of conveyor belt tension and horsepower calculations. However, when long, relatively level, heavily loaded conveyors are encountered where power requirements are large and made up primarily of friction, it is recommended that a belt manufacturer be consulted for additional engineering assistance in selecting these factors.

Using the catalog, the VF44/N gearbox with 900-rpm electromotor is selected.
Electro-gearbox has output rotating 15 rpm. The diameter of output shaft was 18 Ø.

11. Designing the channel for vertically feeding the flowers onto the accordion conveyor

Experiences have shown that when flowers fall freely, their tail is always downward, and petals and sepals are downward. This physical property is used for lining flowers and designing the feeding channel. The channel is designed in a way that flowers have enough time to change into the desirable state. Through practical tests, the height needed for flowers' fall is estimated one meter. But, mild airflow opposite to direct flowers' fall should be created in order the flowers would change into the desirable state more rapidly. The mild airflow is the important point in designing the channel and should be created by a fan that is installed in one of the following two ways:

1- In the inner space of the accordion conveyor as an air blower (Figure 6); or
2- On the top of the channel as an air vacuum (Figure 7).

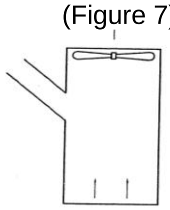

Fig. 7

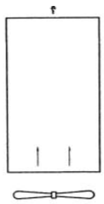

Fig. 6

Two ways are analyzed as follows:

According to Figure 6, if the fan were set in the inner space of the accordion conveyor, weeds around the flowers or farm soil collected with the flowers plucked in the farm would fall on the fan through the feeding channel. Besides, another problem is the airflow passing through the gap between plates would much speed up and might affect on the position of flowers. The second way in which the fan is installed as an air vacuum above the feeding channel seems more suitable than the first way because of the technical matters of installation and operation, maintenance and repair, and creation of the mild even airflow in the tunnel. So, the fan is installed above the feeding channel.

1. Settling the size of feeding channel

Considering the length of each plate of the accordion conveyor is about 455 mm, and for better distribution of the flowers on the accordion conveyor, the channel opening is supposed to be it could cover at least three pitches of the conveyor per moment, that is, 3×127=381 mm. So, the channel's cross-section is determined to be a 400×400 mm square. As mentioned before, the height needed for flowers' fall should be at least 1 m. So, the height of channel from flowers' point of entry is determined as 1 m.

2. Selecting the fan

Given there is no specific for selecting a fan, a fan with a variable-rotation motor is selected to supply the needed airflow. The specifications of the selected fan from the catalog are as follows:

$$n_{max} = 1360 rpm$$

$$Q_{max} = 2500 \, {m^3}/{h}$$

$$Fandia = 350mm$$

$$\bmod el = VIE - 355L4S$$

3. Designing the feeding conveyor belt

The conveyor belt acts as the main feeder (adjuster of input flowers number) of the feeding channel. As mentioned before, the nominal capacity of the conveyor is calculated as 11 kg/h., on the mean weight of each flower:

$$T = 11 \, {kg}/{h} = 7 \text{ flower.s}^{-1}$$

The conveyor belt is installed in the middle of the feeding channel, and distribution of flowers on the conveyor could be controlled through setting in a feeder at the beginning of the conveyor. The feeder should not be large because the collection of a large value of flower makes the flowers crush and stick together. So, the capacity of the feeder is supposed to be maximum 5 kg that could be performed in half an hour on the conveyor's capacity. The conveyor belt could not be inclined because the flowers might fall down because of their lightweight. So, the conveyor belt is installed horizontally, and a staircase is set in for getting the feeder of the conveyor belt.

Settling the width of the conveyor

The conveyor belt should feed the flowers into the channel in a way the flowers spread over the channel's cross-section equally. Given the width of the feeding channel is 400 mm, and the width of the conveyor should be less than 400 mm, the conveyor is determined to be 300 mm wide.

Settling linear speed of the conveyor

The linear speed of the conveyor should be determined in a way the conveyor could feed seven flowers into the channel per second. Dimensions of a flower are 15×15×45 mm [6]. So, 20 flowers could be placed across the conveyor's width (300 mm), but this assumption is ideal rather real. So, at least seven flowers are supposed to be placed in each row as they are not over one another. But, as the each flower is 45 mm, an interval of minimum 45 mm is supposed between every two rows. The conveyor's speed is:

$$x = s.t \Rightarrow s = {x}/{t} = {45}/{1} = 45 \, {mm}/{s}$$

To set up conditions, the feeder's outlet should be adjustable that could be placed in a way the flowers on the conveyor are not over one another.

On assumptions accounted in calculating the linear speed of the conveyor belt, the drive unit is equipped with remote switching tools to adjust the speed and ensure its reliability.

Calculating the power needed for the conveyor belt's motor [2]

The power needed for the conveyor belt is calculated through the equation (8):

$$HP = \frac{T_E \times S}{33000} \quad (8)$$

Where, S is the linear speed of the conveyor (ft/min); and T_E is the tensile force of the conveyor (lb) that is calculated as:

$$T_E = C(L + L_0)\left(Q + \frac{100T}{3S}\right) + \frac{100T}{3S} H$$

Where, C is the friction coefficient of the composite; L is the length of the conveyor belt (the distance between centers of drums) (ft); L0 is the equivalent length (ft); Q is the weight coefficient (lb/ft); T is the capacity of the conveyor belt (ton/h); and H is the difference in height of drums (ft).

$\Rightarrow C = 0.022$ Class of Conveyor: for conveyor with permanent or … $l_0 = 200 \, ft$

The width of the conveyor belt:

$$300Mmm = 11.8in \Rightarrow Q = 7\frac{lb}{ft}$$

$$S = 45 \, {mm}/{s} = 8.9 \, {ft}/{\min}$$

$$T = 11 \, {kg}/{h} = 0.011$$

According to the executive maps, the distance between centers of drums (L) is 1.5 m, and the conveyor is installed horizontally. On the 80% efficiency for the drive unit, the needed power is:

$$HP = \frac{32 \times 8.9}{0.8 \times 33000} = 0.01 = 7.5W$$

Selecting the belt
The tensile force of the belt is:

$T_E = 32lb = 143N$

So, as the width of the belt is 300 mm, the tensile force per unit of width is:

$T_E = 143/300 = 0.5\ N/mm$, $E_P 100/3$ belt with a high confidence coefficient would be suitable. Belt has the tensile force limit 100 N/mm and three layers, including one cotton layer and two rubber layers, with the thickness 4 mm.

Settling diameter of drums and calculating their rotational speed
The minimum diameter of drums could be calculated using the standard BS2890. Based on this standard, for the tensile force 0.5 N/mm and the thickness 4 mm, minimum diameter (d) suggested for the drive pulley is 200 mm.
The linear speed of the belt is 45 mm/s, thus, the rotational speed of drums would be:

$$S = \frac{\pi n}{30} \times d/2 \Rightarrow n = \frac{60S}{\pi d} = \frac{60 \times 45}{\pi \times 200} = 4.3rpm$$

Selecting the gearbox
Considering the low rotational speed of drums, the most proper gearbox is the helical gearbox. Referring to the catalog of helical gearboxes made by Mashhad Gearbox Company., the suitable electro-gearbox is selected as described below:
The rotational speed of drums is 3 and 4 rpm, and the needed power is 7.4 w, but these speeds and power are not available in the catalog. So, the speed should be decreased two times to reach speed. Through selecting a gearbox with a conversion ratio of 1 to 70 in the first step and selecting a pulley belt, the power of gearbox should fulfill the formula (9):

$$P_1 \geq \frac{P}{\eta d} \times S.F \quad (9)$$

Where, P_1 is the input power of gearbox (the power available in the table) (kw); P is the output power of gearbox (the needed power) (kw); ηd is the gearbox efficiency; and $S.F$ is the coefficient of working conditions.
According to Figure 1 in the previous section, gearbox efficiency is 57% for the conversion ratio i=70.

$\eta d = 57\%$

According to Table 3, the coefficient of working conditions with light and constant overload is 2.

$S.F = 2$

Therefore:

$$P_1 \geq \frac{7.5}{0.57} \times 2 = 26.3W$$

Using the catalog, the VF44/N gearbox with 900-rpm electromotor and the conversion ratio (i) 70 is selected. electro-gearbox has output rotating 13 rpm, and its output shaft has a diameter 18 mm. Other dimensions and sizes of the gearbox are available in the catalog.

Conclusion

To separate saffron's parts, including petals, stigmas, and stamens, through the wind tunnel is possible on the high difference between floating speeds of stigmas and those of other parts of the saffron. The threshold floating speed of petals and stamens is 0.65 $m.s^{-1}$, 1.99 $m.s^{-1}$ and 1.28 $m.s^{-1}$, respectively, and the vertical distance wended by the petals and stigmas at airflow speed of 210 $m.min^{-1}$ is 43.28 cm and 24.82 cm, respectively.

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