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Design, Construction and Evaluation of Chrysanthemum Flower Stem Cleaner Machine

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Abstract

The purpose of the present study is to design, construct and evaluate a prototype flower stem cleaner machine. Designing the processing equipments of agricultural products requires information about their physical and mechanical properties. In order to construct the design, the effect of leaf picking velocity and the tensile direction and location were studied on maximum picking force and energy. Results showed that picking force and deformation data ranged from 18 to 61 N and from 4.1 to 8.7 mm, respectively. The mean values of tangent modulus for top and bottom groups were 7.22 MPa and 10.1 MPa, respectively. The effect of the picking velocity, the location and stretch direction on the picking force and the tangent modulus was significant ($P = 0.01$). After measuring the physical and mechanical properties of stems, the machine were designed and constructed. Machine design is based on the use of the rotational axis hit with leaves, which causes leaves to release from the stem. The prototype consists of two axes: rubber fingers that are oriented at angles of 90 degrees on axes, and an axis distance control mechanism and transmission system. After completing the design and construction, the prototype was evaluated to determine the optimum operating conditions. For this purpose, the effects of rotational speed in five levels (200, 350, 500, 650, 800 rpm), axis distance in five levels (-10, -5, 0, +5, +10 mm) and hardness of fingers in two levels (30, 60 shore A) are studied. In the best condition, the machine is able to remove 100% of the leaves. Optimal working conditions happened with 500 rpm for rotational speed, -5 mm for axis distance and 60 shore A for finger hardness. The prototype had the capacity of twenty flower stems cleaning at an average time of 10 s.

Keywords: *Cleaner Machine, Chrysanthemum Flower, Picking, Leaf.*

Nomenclaures

Di	Axes distance (mm)
H	Finger hardness (shore A)
s	Speed (rpm)
m_s	Mass (kg)
n	Rotational speed (rpm)
A	Stem area (mm^2)
C	Stem diameter (mm)
E	Modulus of elasticity (MPa)
F	Force (N)
MC	Moisture of content (%)

1. Introduction

The intersection of art, design and horticulture, represented by the ornamental plant industry, has led to the use of a very wide variety of plant organs, such as cutting flowers for ornamental purposes [1].

Cut chrysanthemum flowers have a longer vase life than most other cut flowers. The loss of quality is mainly due to their leaves wilting [2] because of impeded water transport [3]. The water uptake and the rehydration of chrysanthemum stems have been facilitated by postharvest manipulations, such as immersion into detergent solution and cold water; the addition of antibacterial agents in the holding solution has been recommended [4]. Removing the stem leaves immediately after cutting can lead to retarding flower wilt, and, the subsequence may result in a longer vase life.

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A review of the literature revealed a lack in information on mechanical post harvesting system for removing leaves from cut chrysanthemum flowers, but many old research studies have been conducted on removing leaves and torn from rose flower. Chung invented a rose stem stripper that is accomplished by two metal arms. A rose stem is inserted between the pair of jaws where each jaw has a V-shaped opening, allowing only the rose stem to pass, and, thereby removing thorns and foliage [5]. A flower stem cleaning device including a body through which a cleaning opening extends was invented by Richardson. The opening is defined by a flexible surface portion of the body to prevent damage to the plant stems. The stem to be cleaned is pulled through the opening manually to remove thorns and miscellaneous foliage from the stem [6].

Apparatus for bunching flowers including a rotating endless belt defining made by Monic included stem trimming apparatus, stem cleaning apparatus and tying means mounted adjacent the endless belt downstream of the leaf removing apparatus [7]. Maeyer and Huisman [8] used a rotary brush to defoliate hemp. The use of rotary brush to remove the leaf and seed head was partially successful in that less stem was removed but the brush was not sufficiently effective in removing leaf. A device was developed to harvest cereals by stripping based around a rotor with stripping elements of a 'keyhole' design made of a stiff polymer. Besides being very effective for removing the seed and grain from a range of crops, the stripping system has also proved to be very effective for defolianting crops, including mint, lucerne and nettles [9].

Without a database of basic and mechanical characteristics, engineers must design plant handling and processing equipments using empirical methods that increase the development time and costs. information about the physical and the mechanical properties is vital for the proper and effective design of mechanization and automation equipment when the plant material is to be directly handled or manipulated. Equipment, such as transplanters [10], singulation devices [11] and robotic work cells [12], has been developed without benefitting from accurate property data concerning the crop for which the apparatus was intended. To support the mechanization research on flower process, related information is needed on physical (average diameter, specific gravity, and moisture content) and mechanical (bending strength, compression strength, shear strength and leaf picking force) properties of chrysanthemum. Mcrandal and McNulty [13] evaluated the shear strength of grass stems with quasi-static shear test. They studied the effect of shear velocity, at 15, 28, and 41 mm/min, bevel angle, at 10, 30, and 45, and diameter of stem. They found that shear velocity and bevel angle did not have a significant effect on shear strength, but their interaction was significant at the 5% level. Prasad and Gupta [14] determined the shearing force and energy for cutting maize stem. They concluded that the ultimate shear strength and the shear energy in the direct shear test were observed to decrease with the shear velocity. Average ultimate shear strength decreased from 36.36 bar to 21.07 when the shear velocity was increased from 200 to 1000 mm/min. Maximum shear energy was related to 300 mm/min, and with increasing the shear velocity it was decreased. Halyk and Hurlbut [15] observed that the shear strength of alfalfa stem internodes varied from 4.08 to 183.5 bar. Singh and Burkhardt [16] investigated spikelt detachment strength in tension parallel to the grain under a quasi-static load. Khazaei *et al.* [17] studied the effect of bevel angle, oblique angle, shear velocity and blade type on shear strength, and shearing energy of pyrethrum flower stem, tensile strength and energy per unit area for picking up the flowers were evaluated. Chattopadhyay *et al.* [18] determined shear properties of sorghum stalks with quasi-static shear test, They found that the maximum shear strength increased from 3.74 to 8.18 MPa at the forage stage and from 4.68 to 9.02MPa at the seed stage when the bevel angle was increased from 30 to 70 degree at a 10 mm/min rate of loading. Specific shearing energy was determined for sunflower stalk by Ince *et al.* [19]. Their results showed that the shearing stress and the specific shearing energy increased as the moisture content increased, also both the shearing stress and the specific shearing energy were found to be higher in the lower region of the stalk due to structural heterogeneity [19].

The objective of this research is to design, construct and evaluate a prototype machine for removing leaves of cut chrysanthemum flowers.

2. Material and Method

2.1. Design and Operation

The method that was developed causes cut chrysanthemum flower stem to be cleaned from foliage as a result of hit the rotating fingers with leaves. The prototype consists of two rotational axes and rubber fingers that are oriented at angles of 90 degrees on axes. Bouquet is entered between two rotational axes as the flower stems are perpendicular to the axes. The axes rotate in opposite directions to each other and fingers strike foliage's and clean the flower stems. The required outcomes and the principles of this method are as follows: (1) the machine must be cleaned to cut flowers in bouquet without damaging the flower stems; (2) the operating mechanism must be based on impacting the rotating fingers with stationary bouquet; (3) the construction must be compact and portable; (4) the mechanism must be simple, strong and sturdy; (5) the mechanism must be capable of being operated by one person; the prototype comprised two rotational axes, rubber fingers, a distance control, a rotary speed control and a power transmission system (Figure 1).

Finger shaped as a frustum of height 50 mm with main diameter 10 mm and small diameter of 8 mm made from molded rubber, each rotational axe is made of steel bar Ø30mm which drilled and threaded 13 holes with 20 mm distance on each side for finger mounting, an 0.37 kW electromotor with 2980 rpm and four 6006-2z ball bearing has been selected for rotating axes.

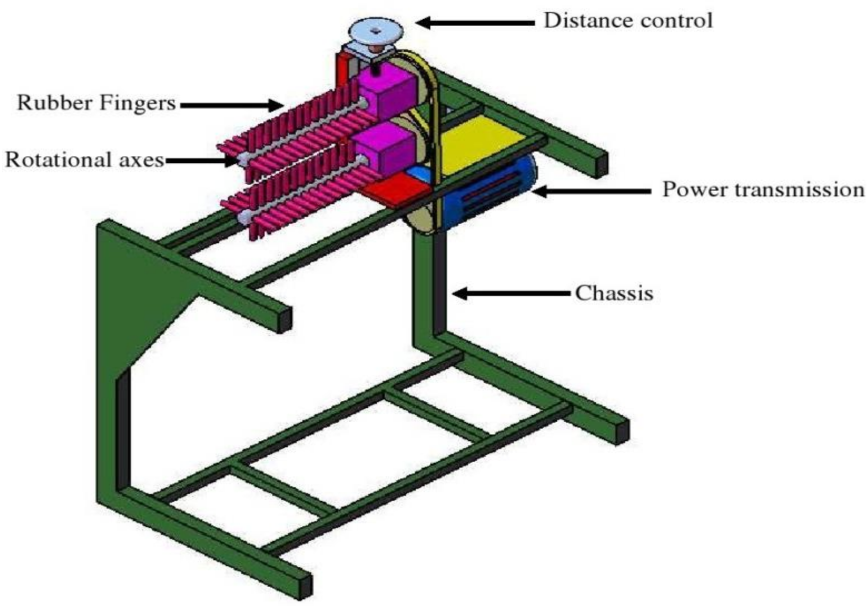

Figure1. Schematic of flower stem cleaner machine

The operating procedure is as follows. First, the cleaning machine is switched on and the axes were rotated. The Bouquet which is held with operator in perpendicular direction to axes is entered between two axes slowly. Rubber fingers are impacted through foliage and removed until bouquet was completely cleaned.

2.2. Test Procedure

2.2.1. Determining Physical Properties of Cut Chrysanthemum Flower

The stems of chrysanthemum flower were harvested from Ashian-e-Sabz greenhouse in Tehran, Iran, from healthy mother stock plants by a sharp knife at a height of 10 cm above the soil surface in the morning of each testing date. Harvested stems were covered and transported in an insulated container to a cooling chamber (1°C) to the Tarbiat-modares university biomechanics research laboratory for testing. Testing was completed as rapidly as possible in order to reduce the effects of drying. Two tests were conducted. Test I involved measuring the stem diameter and moister content. Test II measured bending strength and leaf picking force in relation to variation in load speed. In the first test, the diameter of the stem was measured by a vernier calliper and the specimen was dried in an electric oven (ISOTEMP, USA) to determine its moisture content according to the ASAE Standard [20]. The second test measured specimens from the growth tip end and the root internode end of the stem. A universal testing machine (UTM, HOUNSFIELD H50K-S) with a 500 N load cell was used for measuring the bending and picking force. A three-point loading apparatus with a span of 15 mm was used to support the stem specimens below the UTM probe (Figure 2a) for measuring the bending strength. Support and indenting rods were 3 mm in diameter. Specimens were placed in the three-point loading apparatus under the UTM probe and the force was applied to the centre of the stem at a loading speed of 25 mm/min (ASAE Standard, 1998) until it fractured. For the beam experiment, an apparent modulus of elasticity was computed using equations from Mohsenin (1980, p. 200)

$$E_d = \frac{f.l^3.10^6}{48\pi.d.c^4/64} \tag{1}$$

A device similar to the one shown in Figure 2b is constructed for picking force measuring. The device held the leaf and connected it to the UTM crosshead. The end of the stem was also clamped by the lower UTM jaw. Effect of picking velocity at 10, 100, and 500 mm/min, tensile direction, up and down direction and two sample groups were studied on maximum picking force and energy. Each test was replicated 10 times. Analysis of variance and the Duncan Multiple Rang Test were applied to determined the influence of factors upon the picking force and determine proper axes rotation speed for prototype machine.

2.2.2. Performance Test of Prototype Cleaning Machine

Before starting the test, the number of leaves from each flower stem was counted, then the axes rotational speed was calibrated with tachometer (Prova). To obtain optimum operating condition of cleaning, machine initial tests were conducted in accordance with the Table 1. Independent affecting factors on machine performance are rotational speed, axes distance and finger hardness (Figure 3). Performance parameters of the cleaning machine, which include the percent of removed leaves, the time required to stem cleaning and cleaned flower vase life were recorded and analyzed. Analysis of variance and the Duncan Multiple Rang Test were applied to determine the influence of factors upon the picking performance parameters. For vase life determination and flower stem bases were immersed to a depth of 4 cm in glass vials containing 400 ml of the double-distilled water include 2% ethanol, 2% methanol, 5ppm BA and 5ppm paclobutrizol. Experiments were carried out at 21 ±1°C and 60% RH under continuous fluorescent light (49 mol m^{-2} s^{-1}). Wilting of flower was used as the criterion for termination of vase life.

Figure 2a. Apparatus for the strength in bending experiment

Figure 2b. Device to held and connect the leaf to UTM for picking force measuring

Figure 3. Prototype of the flower stem cleaner machine**.**

Table 1. Initial test levels of cleaning machine

Parameter	Level I	Level II	Level III	Level IV	Level V
Rotational speed (rpm)	200	350	500	650	800
Axes distance (mm)	-10	-5	0	+5	+10
Finger hardness (shore A)	30	60	-	-	-
Replication	3	3	3	3	3

3. Results and Discussion

3.1. Physical Properties of Cut Chrysanthemum Flower

Samples taken from the bottom of the cutting were significantly larger in diameter than those taken from the top of the cutting. Samples taken from the bottom tended to be lower in the moisture content than those from the top (Table 2). The results of variance analysis showed that the sample group had a significant effect on all the measured physical properties ($P = 0.01$). Observations indicate differences in the woody versus succulent nature of tissue depending upon the physiological age of the stem section (Table 2).

Compiled data from the strength in the parallel plate compression tests can be seen in Table 2. The summarized data are segregated by group. As with the strength in bending tests, differences between groups were primarily in magnitude of force and deformation. Note that the bio-yield "hump" is the dominant and characterizing feature of each force-deformation curve for the compression tests (Figure 4). The nature of the failure of the stem cross-sections versus the resistive loading of the compacted tissue indicates that the data past the bio-yield region is of little value for machine design purposes. Samples from the bottom of the cutting had significantly higher bio-yield forces and deformations than did those from the top. Force and deformation data for calculating the tangent modulus were taken from the point of inflection on the force-deformation curve (Figure 4).

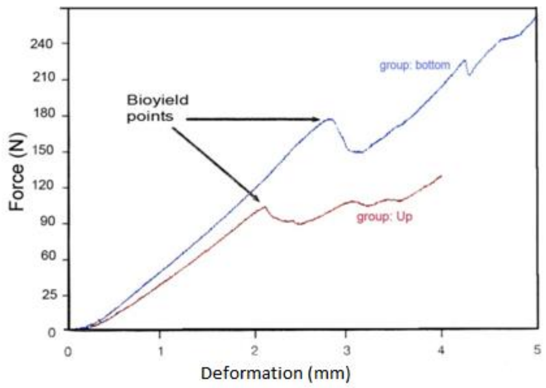

Figure 4. Typical force-deformation curve for strength in compression experiment.

Table 2. Summary of results of the strength in Compression

Property	Mean	Minimum	Maximum	Std
Group top				
Diameter (mm)	4.44[a]	3.38	5.37	0.65
MC (%)	78.17[a]	74.52	80.81	2.43
Bio yield force (N)	23[a]	18	29	4.17
Bio yield deformation (mm)	5.1[a]	4.1	6.5	0.65
Tangent modulus (MPa)	7.22[a]	5.8	8.1	0.66
Group bottom				
Diameter (mm)	5.45[a]	4.19	6.85	0.92
MC (%)	75.99[a]	72.43	80.15	2.46
Bio yield force (N)	45.25[a]	30	61	9.14
Bio yield deformation (mm)	6.8[a]	5.4	8.7	1.25
Tangent modulus (MPa)	10.1[a]	8.5	12.3	1.14

a significant at 1% and ns not significant.

Picking force increased with the increase in the stem diameter. Based on variance analysis (Table 3), the picking force was affected significantly with the picking velocity ($P = 0.01$).

Results of the Duncan Multiple Range Test show that, with increasing the picking velocity from 10 to 500 mm/min, the mean values of the picking force increased from 4.475 to 7.312 N. There was no significant difference between mean values of the picking force at 10 and 100 mm/min levels. Result of the variance analysis for location of samples showed that the difference between the picking force was not significant. Mean values of the picking force varied from 5.335 to 6.471 N for top and bottom location.

The picking direction had a significant difference at 0.01 levels on force values. Results of Duncan's Multiple Range Test show that the mean values for up and down direction were 10.52 N and 1.89 N, respectively. Hag *et al.* (1971) found that the effect of loading rate on tensile strength of cotton stem was further influenced by the density of the stem. For high density specimens (0.400 g/cm^3), the tensile strength increased directly as the rate of loading, but for lower density specimens (0.3759 g/cm^3) the tensile strength decreased with an increase in loading rate from 7.6 to 25.4 mm/min and then increased with further increases of loading rate. Results of Kazaie *et al*. (2002) research showed that the picking velocity has a significant effect on the picking force and energy of pyrethrum flower stem.

Table 3. Analysis of variance of effect of velocity, Location on picking force

Source of variation	Degree of Freedom	Picking force (N)
Treatment	11	163.72[a]
Location (*L*)	1	6.244[ns]
Tensile direction (*D*)	1	1353.13[a]
Velocity (*V*)	2	68.12[a]
*L**D*	2	1.34[ns]
*L**V*	2	4.05[ns]
*D**V*	2	45.41[a]
*L**D*V*	2	3.09[ns]
Error	48	321.68

3.2. Performance of Prototype Cleaning Machine

Table 4 shows the results of the statistical analysis carried out to examine the effect of axes distance, rotational speed and finger hardness on the percentage of the removed leaves for chrysanthemum flower. ANOVA indicated that two independent variables axes distance, rotational speed significantly influenced the percentage of the removed leaves (Table 4). The interaction effects of the independent variable were also significant, except for the interaction between axes distance and finger hardness. Additionally, a difference in the rate of increase in the percentage of the removed leaves was obtained in the interction between the factors. The data showed that it is possible to remove nearly 100% of the chrysanthemum flower leaves with a minimal damage to flower stalk.

Table 4. Analysis of variance of considered parameters on removed leaves.

Source of variation	Degree of Freedom	Sum Squares	*F* Value	*P* Value
Treatment	49	14676	18.95	0.0001
Distance (*Di*)	4	481.9	7.58	0.0001
Speed (*S*)	4	11166	175.6	0.0001
Hardness (*H*)	1	1.21	0.07	0.7841
*Di**S*	16	1421.1	5.59	0.0001
*Di**H*	4	142.4	2.24	0.049
*S**H*	4	353.5	5.59	0.0004
*Di**S*H*	16	1201.1	4.72	0.0001
Error	98	1558.1		

The results of the interaction effects of axes distance and rotational speed on the percentage of the removed leaves are reported in Figures 5 and 6 for finger hardness of 30 and 60 shor A, respectively. With an increase in rotational speed from 200 to 800 rpm, the value of the percentage of the removed leaves for both Fingers 30 and 60 shor A increased. Additionally, with decreasing the axes distance from +10 to -10 mm, the value of the percentage of the removed leaves for finger hardness 30 shor A increased, but for finger hardness 60 shor A, most value of the percentage of the removed leaves related to axes distance -5 mm. For this finger, with an increase in rotational speed from 200 to 650 rpm, the value of the percentage of the removed leaves increased from 91.88 to 100% for axes distance of -5mm. Wheras for finger hardness of 60 shor A and axes distance of -5mm, increasing the rotational speed from 200 to 500 rpm caused increases in the value of the percentage of the removed leaves from 94.3 to 100%.

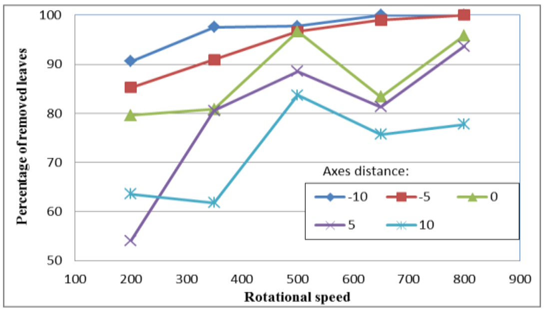

Figure 5. Effect of rotational speed on percentage of removed leaves for hardness 30 shor A.

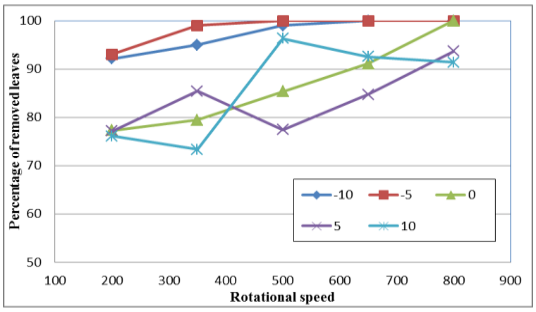

Figure 6. Effect of rotational speed on percentage of removed leaves for hardness 60 shor A.

Optimal working conditions happened with 500 rpm for rotational speed, -5 mm for axis distance and 60 shore A for finger hardness. Bruce *et al.* (2001), with the same method, succeded to remove more than 92% of leaves and flower heads using a rotor fitted with stiff polymer teeth. Also they found that a high rotation speed can increase damage of stems; therefore, from 545, 645 and 770 rpm, they introduced 645 rpm as an optimal speed [22].

4. Conclusion

Testing of a prototype for flower stem cleaning machine resulted in the determination of the optimal operating conditions in terms of rotational speed, axis distance and finger hardness. Subsequent performance tests of the prototype using the selected machine settings indicated that the machine could clean a bouquet with twenty flowers stem at an average time of 10 s. Good levels of cleaning efficiency and consumer acceptance were achieved.

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