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# DESIGN AND DEVELOPMENT OF A CUTTER AND FEEDER MECHANISM FOR A CHICK PEA HARVESTER

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**ABSTRACT** Chickpea plants grown in Iran are short and mostly cultivated on rough dry lands. Although it is difficult to use a conventional grain combine to harvest it, chickpea production is limited due to harvesting problems, such as uneven ripening, lodging and shattering losses of hand harvesting. A special tiller mounted harvesting machine was designed and developed. The cutter and feeder mechanism simultaneously performs the tasks of (1) pick up the lodged plant material, (2) guiding the plant to the machine, (3) cutting the material stalk with changeable cutting height and (4) conveying and collecting shoots without threshing. The header consists of a V-shape guide that use three inclined sprockets and a chain on each side, two feeder belts, four identical pulleys and a new cutter bar that cuts the stalks without impact. Bending stress and modulus of elasticity and coefficient of friction of stalk for three varieties, Arman, Hashem and Flips were measured to determine machine design parameters.

**Keywords**: Design, Chick pea harvester, Bending stress, Cutter and Feeder.

**INTRODUCTION** Chick pea plants in Iran are cultivated mostly as follow product which is typical in the Middle East dry land. It is grown in some 650,000 ha. Yielding 800kg/ha as average. They are as short as 30cm and the land is too rough for conventional grain combines to be able to harvest the product. The main problem impeding mechanical harvesting of chick pea is the excessive seed and straw losses at combine harvesting method. The difficulties are associated with plant characteristics. In addition to farmers need to recover straw as animal feed. Problems related to plant characteristics include uneven ripening, lodging, and shattering of seed and pods growing close to the ground. For achieved machine design parameters, the bending and shearing strength, modulus of elasticity and coefficient of friction of stalks need to determine. Most studies on the mechanical properties of plants have been done their development using failure criteria (force, stress) and Young module's (Hirai et al., 2002, Shaw and Tabil, 2007). The physical properties of the cellular material of importance in cutting are compression, tension, bending, density and friction. These properties depend on species, variety, stalk diameter, maturity, moisture content and cellular structure (Persson, 1987). Measurement of the shearing strength of six

Nomenclatures

| | | | |
|---|---|---|---|
| E | modulus of elasticity | $\phi_2$ | outer diameter of stem |
| I | the moment of inertia | $\phi_1$ | inner diameter of stem |
| L | length of stem | $F$ | friction force |
| $F_b$ | bending force on stems | f | coefficient of friction |
| $F_{bm}$ | maximum bending firce | N | normal force |
| $y_{bm}$ | bending deformation | a | the gap between the belts |
| $\delta$ | angle if inclination of stalk | R | the radius of the pulleys |
| d | diameter of stalks | h | the width of the belts |

varieties of wheat straw by O'Dogherty et al. (1995) showed mean values in the range of 5.4-8.5 MPa. Eshaghbeygi et al. (2009) evaluated the bending stress and modulus of elasticity for wheat stem of Alvand variety. They reported that Bending Stress and modulus of elasticity increased as the moisture content decreased and decreased as the cutting height of stem increased. The average of bending stress varied between 17.74-26.77 MPa and modulus of elasticity varied between 3.13-3.75 Gpa. Chattopadhyay and Pandey (1999) determined the bending stress for sorghum stalk as 40.53 and 45.65 MPa at the seed stage and forage stage, respectively. Ince et al. (2005) determined the bending stress and Young's modulus for sunflower stalk as 37.7 to 62.09 MPa and 1251.28 to 2210.89 MPa, respectively. There are no studies on shear and bending strength and Young's modulus of pea stem. Shearing strength of peas stem [Hashem, Arman and flips varieties] as a function of cutting height, moisture content, knife type and oblique angle of cutting knife. Also bending strength and modulus of elasticity of stems as a function of moisture content and height of stems were determined. About harvesting mechanisms of pea Behruzi- Lar and Huang (2002) designed and developed a tractor drawn machine (Pcombine). The main units of Pcombine were striper header, the tunnel for conveying pea pods, threshing and separating units. A field capacity of 0.35 ha/hr was achieved for this machine. Terence and Lawrence (1991) used a striper header for picking pea pods. In this harvester pea pods travels by belt conveyor to thresher unit. The objective of this study was to design and develop a cutter and feeder mechanism that is suitable for harvesting chick pea grown in Iran and India. The cutting height is low to maximize recovery of seeds and straw be achieved. An experimental harvester cuts and collects whole shoots without threshing.

**Material and method**

**1. Determine the some mechanical properties of pea stems.**

For determine the some mechanical properties of three varieties of chickpea, the samples after harvesting were transferred to laboratory of department of farm power and machinery of Shiraz University. The method for the determination of mechanical properties was developed on basis of quasi static test, using the Instron strength tester. For measuring the bending strength the samples supported at both ends that the long of samples were 5 cm. the bending force being applied in the middle of stems and the force values were record for any samples. With having the force values and cross section of stems in cutting location by use of determined equations, the maximum bending strength and the module of elasticity of any variety were determined. To identify the variability of the mechanical properties along the length of the stems, measurements were taken at three points on the stem length, from the root to the top of the plant. The equations, figure 1 in associated to modulus of elasticity, maximum bending stress and table 1 in associated to some mechanical properties of pea stems, were shown in below.

$$E = \frac{F_b . L^3}{48 \Delta Y_b I} \quad \text{Where } I = \frac{\pi}{64}(\phi_2^{\ 4} - \phi_1^{\ 4})$$

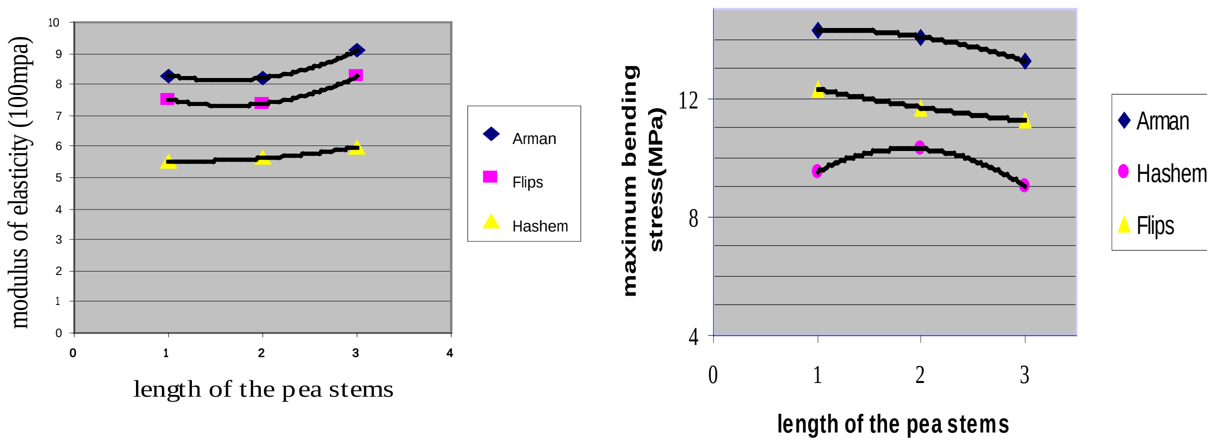


Figure 1-Modulus of elasticity (E) and maximum bending stress ( $\sigma_{max}$ ) of the stems chick pea varieties (1, 2, 3 points on the length of the stem from the root to the tip)

Table 1- some mechanical properties of pea stems

| | Mechanical properties | | | | | |
|---|---|---|---|---|---|---|
| | Arman | | Hashem | | Flips | |
| | $E\times10^2$ (N mm $^2$ ) | $\sigma_{max}$ $(MPa)$ | $E\times10^2$ (N mm $^2$ ) | $\sigma_{max}$ $(MPa)$ | $E\times10^2$ (N mm $^2$ ) | $\sigma_{max}$ $(MPa)$ |
| 1 | 9.82 | 14.32 | 6.86 | 9.52 | 8.92 | 12.30 |
| 2 | 9.76 | 14.06 | 6.94 | 10.28 | 8.54 | 11.68 |
| 3 | 9.02 | 13.25 | 6.54 | 9.04 | 8.60 | 11.23 |

It was found that the Arman variety had a much higher modulus of

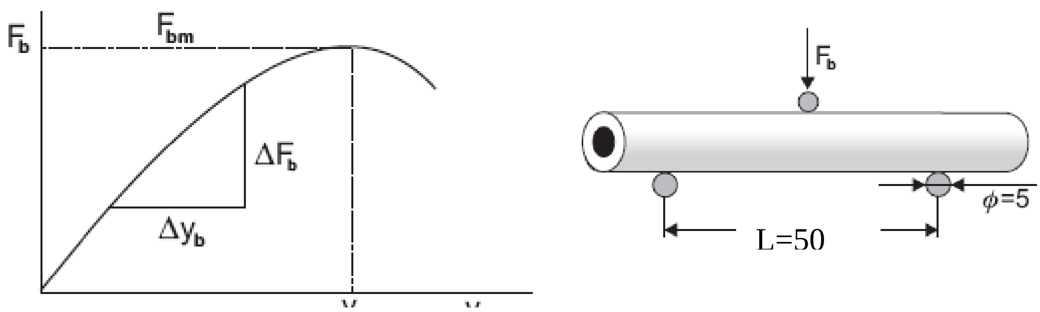


Figure2-schematic presentation of the test used in the study of mechanical properties of pea stems

elasticity and bending stress than other varieties. So this variety need to more power and energy to cut. In other words the power design for the mechanism of cutter and feeder must to determine on basis of mechanical properties of Arman variety.

**2. System component designs**

The cutter and feeder mechanism (C&F mechanism) was designed as a tiller mounted instead of self- propelled system for easier manipulation in the rough terrain. Tiller is self propelled machine which has range about 7-14 hp power and there is PTO shaft in side of machine. C&F mechanism will mount in front of tiller and get its power from PTO shaft. The main components of experimental harvester are the header, elevator conveyor and tank all carried on a chassis supported by front of tiller.

The generally V- shaped design of the chick pea harvester head permits all of the plants that guide to between the belts and kept by belts to cut by cutter bar. Two endless belt having implements or tools are mounted on the V shaped head that pick up the lodged plants. The angle of inclined feed- in V shaped guide is 30. The V shaped guides force to the stalks towards the cutter. As the plants are being cut, they are also being held between the feeder belts, which carry the cut stalks to the elevator conveyor at the rear of the header.

**Kinematics considerations**

An important consideration in the design of the cutter/feeder mechanism was the kinematics index of the cutter $\lambda$, which is dimensionless parameter defined by the following equation (Klenin and Popov, 1985).

$$\lambda = \frac{U}{V} = \frac{\omega r}{V}$$

Where U is the peripheral speed in m/s of the sprockets relative to the frame of the experimental harvester; V is the travel speed of the experimental harvester in m/s; and $\omega$ and $r$ are the angular speed in rad/sec and radius of the sprocket in m, respectively. An essential requirement for the feeder to be operative was to maintain $\lambda \rangle 1$ otherwise the chickpea plants would be either stationary relative to the feeder (the case of $\lambda = 1$) or pushed away from the feeder (the case of $\lambda$ <1). The range of $\lambda$ was 1.3-1.7

**b) Cutter bar design**

Shattering losses is a main problem that exists in chick pea harvesting. By use of conventional cutter bar, it may be shattering occur because of imposing forces on stalks separate the pea pods from plant. So a new cutter bar design and developed that rotate and impose the lowest forces on stalk. Figure 3 shows the actual view of the experimental cutter bar which consider for this study.

Figure 3- the actual view of the experimental cutter bar

The cutter bar mechanism is driven by PTO shaft. The speed of pto shaft was 1600 rpm and for change to 800 rpm, the speed of driven pulley must be 2 times of driver pulley.

**c) The feeder belts and pulleys design**

In harvesting unit of this mechanism there are four pulleys and two belts added to hold the stalks. The distance between two pulleys in each side is 300 mm.

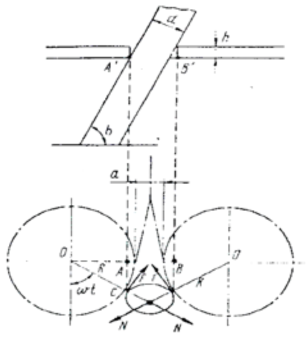

Fig 4- capture of a stalk by the belts

Fig.5. the actual view of the mechanism without the cutter bar and cover.

The distance between the left and right sides pulleys is adjustable to control the contact pressure required to hold the stalks (Sidahmed and Jaber, 2004).

**Capture of Stalks**

Stalks directed to the zone where the belts are closely pressed together are captured or griped by the latter. The capture of the stalks depends upon the design and operating parameters of the belts and the size and physical and mechanical properties of the chickpea.

The belts would capture the stalks when [9]:

$$2F \sin \omega t \geq 2N \cos \omega t$$

$$F_{\max} = fN$$

$$f \sin \omega t \geq \cos \omega t$$

From the triangle OAC we find that

$$\sin \omega t = {OA}/{R} \rightarrow OA = R + {a}/{2} - {1}/{2} A'B'$$

From the figure 4:

$$A'B' = \frac{d}{\sin \delta} + \frac{h}{\tan \delta}$$

Substituting the above in the expression for $\sin \omega t$ we have:

$$\sin \omega t = 1 + \frac{a - \frac{d}{\sin \delta} - \frac{h}{\tan \delta}}{2R}$$

Replacing $\sin \omega t$ and $\cos \omega t$ in above equation we have:

$$\frac{2R + a - \frac{d}{\sin \delta} - \frac{h}{\tan \delta}}{\sqrt{4R^2} - (2R + a - \frac{d}{\sin \delta} - \frac{h}{\tan \delta})^2} \geq \frac{1}{f}$$

For chick pea harvester the parameters in inequality are R=10cm, h=2cm, a=6mm, if f is assumed to be 0.3, is satisfied for stalks.

As the plants are being cut, they are transferred between the feeder belts. The cut stalks are being carried to the elevator conveyor at the rear of the header. The elevator conveyor is an endless belt which associated by fingers that are mounted on bars. The fingers sweeps the cut plants and straw along the inclined surface of the elevator conveyor into the tank. All moving parts are covered for safety. There are some another safety devices such as slip clutch between power shaft and cutter bar and easily accessible lever for adjusting the height of cutter and feeder mechanism.

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