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Development and Calibration of Pendulum Type Test Rig

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A B S T R A C T

Cutting of agricultural crops or biological material is primarily done by shearing and impact. Impact cutting was proven to be more suitable for cutting various. The necessity to determine the physico-mechanical property such as energy requirement for cutting stalks important to design a cutter. The pendulum type test rig was found to be useful for measuring the impact cutting energy. So the pendulum type test rig was developed and calibrated. A linear relationship between the angle of release and reach with high co-efficient of determination (R^2) for all the three weights was observed.

Introduction

Cutting of stalks is an important process involved in cassava sett cutting, sorghum harvesting, forage harvesting, cutting weed, stalk shredding and lawn mowing. The impact type rotary cutters were used in cutting operations due to its simplicity in construction, low maintenance cost and ability to cut both small and large diameter stalks (McRandal and McNulty, 1978).

Visvanathan *et al.,* (1996) used a pendulum impact shear test apparatus to measure the energy required to cut cassava tubers and the apparatus consisted of cutting knife at the end of pendulum arm and a spring loaded lock to release the arm from various heights. Hoseinzadeh *et al.,* (2009) constructed a pendulum impact testing apparatus for

measuring the shearing energy of three wheat varieties and the pendulum test rig consisted of a single sickle knife section, trapezoidal shape with 76 mm base length and 55 mm height, heavy anvil with minimum vibration, a wooden metallic pendulum and a support for stem fixing.

Alizadeh *et al.,* (2011) fabricated and calibrated a pendulum impact testing apparatus for measuring the cutting energy of different rice varieties and they concluded that the angle of release and reach were in linear relationship with high co-efficient of determination. Hemmatian *et al.,* (2012) developed the impact type pendulum for measuring the shearing energy of sugarcane stems by which energy and knife velocity in

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its lowest position quantities were obtained using the theoretical equations. Dange *et al.,* (2012) constructed a pendulum test rig to measure the cutting energy of pigeon pea stems and it has a fixed hand vice for holding the stems, the bench vice could be moved at right angle to the plane of the pendulum swing in order to vary the height of cut. Azadbakht *et al.,* (2014) constructed and calibrated a pendulum system based on the principle of conservation of energy and they concluded that the angle of release and reach were in linear relationship.

Materials and Methods

In order to measure the cutting energy of stems, a pendulum type test rig was developed and calibrated. The pendulum type test rig works under the principle of law of conservation of energy. In this test rig the potential energy was transformed to kinetic energy.

Fabrication of pendulum type test rig

Based on the inferences of researchers (Prasad and Gupta, 1975; Visvanathan *et al.,* 1996; Yilgep and Mohammad, 2005; Reza, 2007; Koloor and Kiani, 2007; Mahmoodi and Jafari, 2010; Dange *et al.,* 2012; Hemmatian *et al.,* 2012; Azadbakht *et al.,* 2014) the pendulum type test rig was developed with the following major components main frame, swing arm, bench vice for holding stalk (Stalk holder) and angle indicator as detailed below.

Main frame

Two trapezoidal frames were fabricated using L-angles for main frame. Lateral supports were provided on both the trapezoidal frame using flats to arrest the lateral movement of the main frame. Two pillow block bearings were mounted on the top of the trapezoidal frame with bolt nut to hold the rotating shaft of the swing arm (Fig. 1).

Swing arm

The main part of the pendulum type test rig is swing arm. The swing arm was made using two mild steel rectangular tubes. Commercially available plain shaft was used as rotating shaft. The rotating shaft along with the swing arm is fixed on the trapezoidal frame through pillow block bearing. A weight holder was attached on one side of the swing arm at 1020 mm from the top. This provision was made to add additional weight if required. On the other side of the swing arm a blade mounting platform was attached at the bottom. Provisions were made on the blade mounting platform to vary the approach angle of blade from 0 to 30º (Fig. 2).

Stalk holder

A commercially available bench vice was used for holding the stalk for cut. The bench wise was bolted to the bed provided in the stalk holder (Fig. 3).

Angle indicator

A commercially available protractor with angular divisions was used as angular indicator for measuring the angular displacement. The protractor was graduated with a least count of $0.5^{°}$. Two needles were fixed on the rotating shaft such that one needle called angle indicator needle is free to stay at the maximum angular displacement (non-return type) and other called swing arm needle moves with rotating shaft and swing arm (Fig. 3).

Calibration of pendulum type test rig

The pendulum type test rig was calibrated with different weights and different angle of

release of the swing arm. First, the swing arm was released from one side with an angular displacement of $5°$ (θ) and allowed to swing to other side freely to make an angular displacement (angle of reach) of θ_0. This procedure was repeated upto an angular displacement of $90°$ with an increment of $5°$ and their respective angle of reach on the other side was noted as 'θ_0' and plotted on the graph between angle of release and reach to analyze the relationship. The pendulum type test rig was first calibrated for swing arm own weight, then 1 kg and 2 kg weights were added to the swing arm (Fig. 3).

Results and Discussion

The measured values of angle of reach are presented in table 1. The results obtained on the relationship between the angle of release (θ) and angle of reach (θ_0) of the swing arm without stem is presented in figure 4. A linear relationship between the angle of release (θ) and reach (θ_0) with high co-efficient of determination (R^2) for all the three weights was observed. There was a minimum loss of cutting energy for all the experiments, this might be due to the friction between the movable parts and air resistance.

Table.1 Calibration of pendulum type test rig

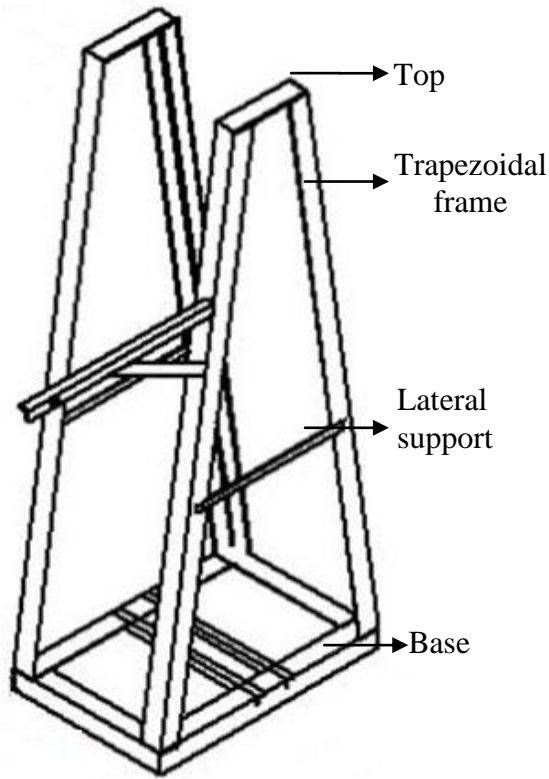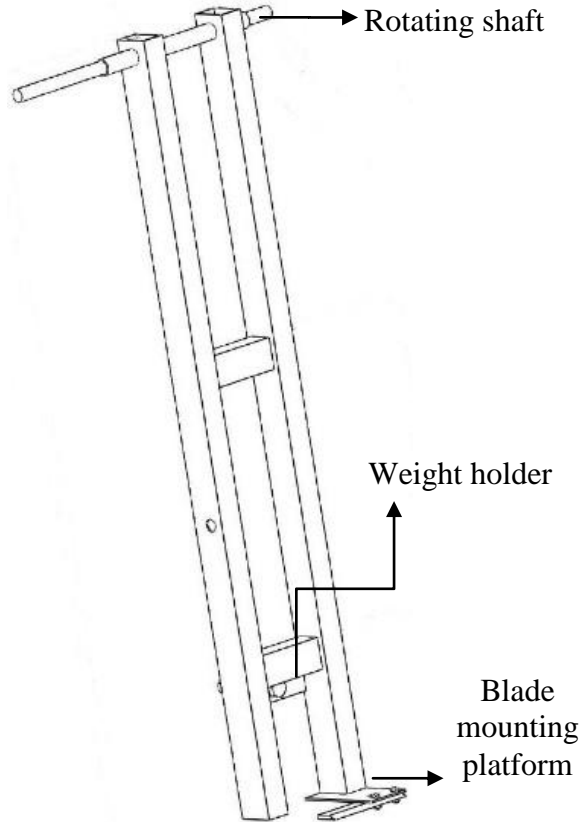| S. No	Angle of release, θ ($°$)	Angle of reach, θ_0 ($°$)		
		Swing arm without weight	Swing arm with 1 kg weight	Swing arm with 2 kg weight
1	5	3	3.5	4.0
2	10	8	8.5	9.0
3	15	13	13.5	14.0
4	20	18	18.5	19.0
5	25	23	23.5	24.0
6	30	27	28.5	29.0
7	35	32	33.5	34.0
8	40	37	38.0	38.5
9	45	42	42.5	43.0
10	50	47	47.5	48.5
11	55	51	52.0	53.0
12	60	56	57.0	58.0
13	65	61	62.0	63.0
14	70	66	66.0	68.0
15	75	71	71.0	72.0
16	80	76	75.0	76.0
17	85	80	80.0	80.5
18	90	84	84.0	84.0

Fig.1 Main frame

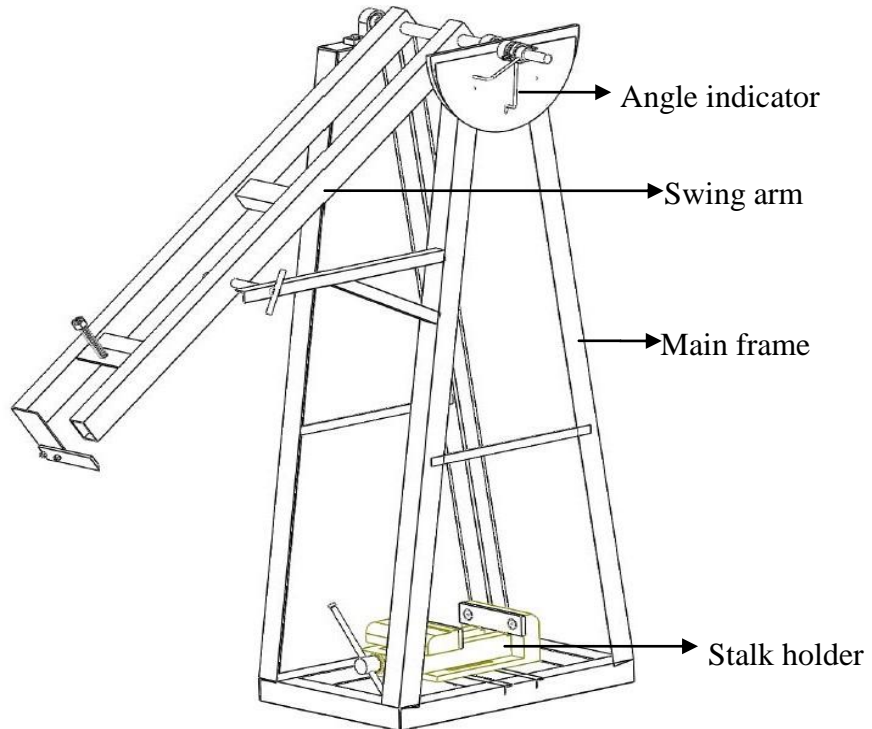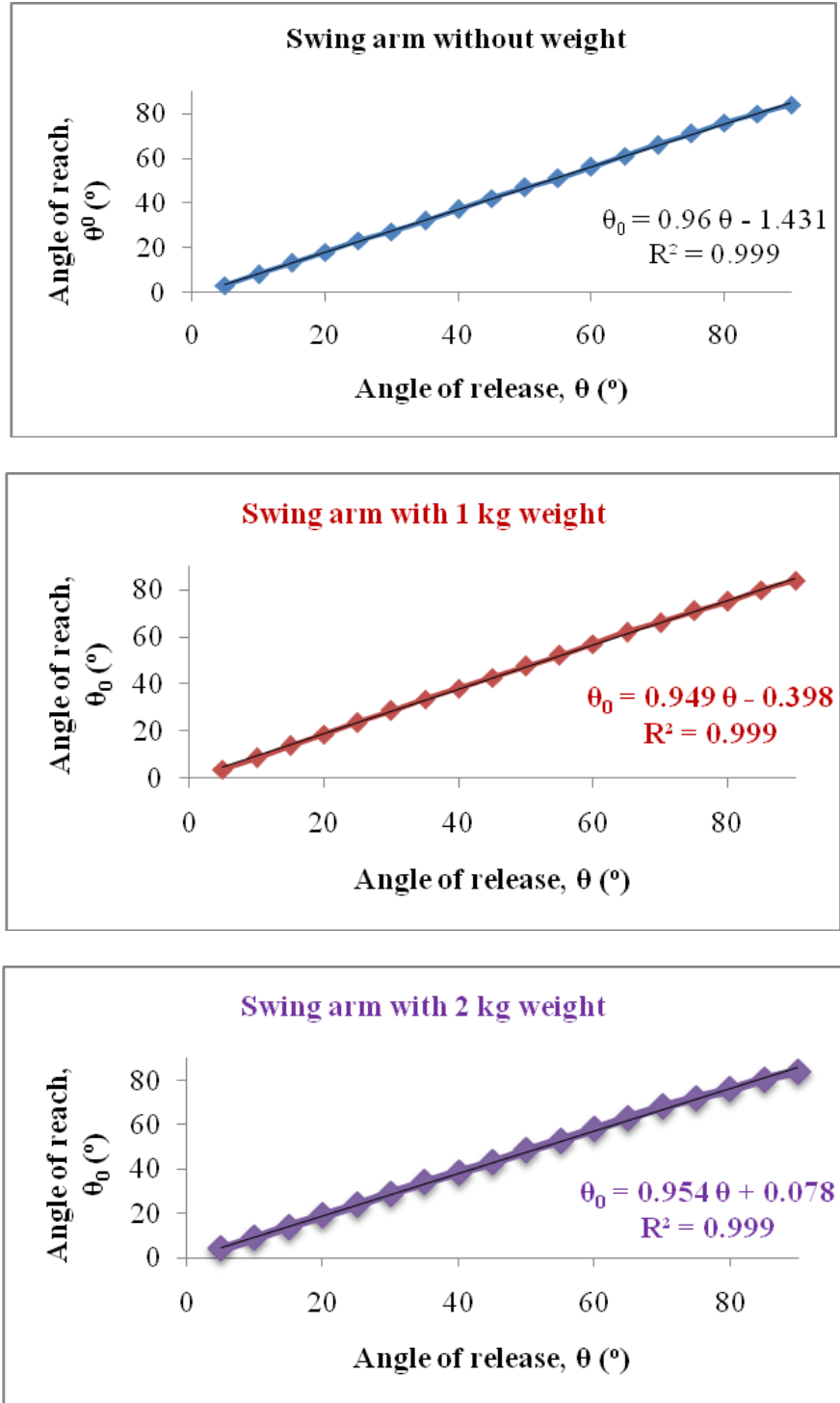**Fig.2** Swing arm

Fig.3 Pendulum type test rig

Fig.4 Calibration of pendulum type test rig with different weight on swing arm

The angle of reach for a pendulum type test rig was calculated by substituting angle of release (θ) in linear equation.

Swing arm without weight,

$$\theta_0 = 0.96\,\theta - 1.431 \quad \text{------------- (1)}$$

Swing arm with 1 kg weight,

$$\theta_0 = 0.949\,\theta - 0.398 \text{ ------------ (2)}$$

Swing arm with 2 kg weight,

$$\theta_0 = 0.954\,\theta + 0.078 \text{ ------------- (3)}$$

Where,

θ_0 = Angle of reach of the swing arm without stem ($^{\circ}$)

θ = Angle of reach of the swing arm ($^{\circ}$)

The above equations have many similarities with the equation earned by Yiljep and Mohammad, 2005; Alizadeh *et al.,* 2011 and Azadbakht *et al.,* 2014.

A pendulum type test rig was developed to find the cutting energy of various crop stems. It was calibrated to analyze the cutting energy lose and it was found that a linear relationship between the angle of release and reach with high co-efficient of determination (R^2) for all the three weights was observed. Three linear equations were obtained to find the angle of reach for the respective weights.

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