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Stability Analysis of Pokkali Paddy Harvester

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A B S T R A C T

K e y w o r d s Harvester, Paddy, Pokkali, Water logged, Stability **Article Info** *Accepted:* 10 November 2020 *Available Online:* 10 December 2020	The Pokkali field is a unique eco-system prevailing in the coastal tract of Kerala with rich bio diversity and amazing capacity to produce organic rice and shrimp alternatively. The various farming operations in Pokkali paddy cultivation, the harvesting is done by women labourers by walking on the swampy and marshy inundated paddy fields at waist-deep water, which is laborious, tedious and cumbersome. Though a number of paddy combine harvesters are commercially available, none cannot be used in such marshy water logged areas for harvesting paddy. Hence, a power operated floating harvester with provisions for harvesting and conveying the ear heads of submerged paddy. Overall size of the Pokkali paddy harvester is 6.2 x 1.7 x 1.7 m with a total weight of about 1700 kg. A Pokkali paddy harvester is designed in such a way that to suit for fragmented Pokkali areas. The vertical centre of gravity of the harvester is 0.58 m, longitudinal centre of gravity is 2.67 m and transverse centre of gravity is zero. As the transverse centre of gravity is zero, Pokkali paddy harvester is stable to float and longitudinal centre of gravity lies near to the centre and adjacent to the front and rear side of the harvester, it become a well-balanced machine.

Introduction

The Pokkali field is a unique eco system prevailing in the coastal tract of Kerala with rich bio diversity and amazing capacity to produce organic rice and shrimp alternatively. Rice plants get their nutrients from the left over of the shrimps and the shrimps in turn, feed on the stalks and decaying remnants of the rice crop. Neither chemical fertilizers nor insecticides and pesticides are used. The usual ploughing and transplantation are not required for Pokkali.In more than 90% of the single cropped lands, rice cultivation is done during the low saline phase from May/June to September/October; the traditional prawn filtration is taken up during the high saline phase which sets in December/January.

The Pokkali paddy varieties are having early seedling vigour and attain a height of 40-45 cm in 30-35 days. At this stage, when field conditions become favourable the mounds are made and a few seedlings are uniformly spread on the beds in the field. The clods give anchorage to the seedlings. Generally manuring and plant protection operations are not necessary for pokkali farming systems. The crop matures at about 120 days. The ear heads alone are harvested, leaving the straw

behind in the fields. The average yield of rice with traditional rice varieties is 1500kg ha^{-1}. The conventional method of harvesting of pokkali paddy crop is by using sickles. The various farming operations in Pokkali paddy cultivation, the harvesting is done by women labourers by walking on the swampy and marshy inundated paddy fields at waist-deep water, which is laborious, tedious and cumbersome.

Due to these naturally adverse conditions prevailing in these lands and the non-availability of labourers, the paddy cultivation goes on decreasing every year. Hence, there was a great demand for a suitable harvesting machine, especially for harvesting the paddy, which is under water at the time of harvest due to tidal effects. Though a number of paddy combine harvesters are commercially available, none cannot be used in such marshy water logged areas for harvesting paddy. Hence a power operated floating harvester, 'Pokkali paddy harvester' with provisions for harvesting and conveying the ear heads of water submerged paddy stalks.

Review of literature

Giles *et al.,* (1994) conducted a study on stability of a floating body is divided in two different types, vertical and rotational. A floating body has vertical stability but its rotational stability depends upon the positions of centre of gravity (G) and centre of buoyancy (B). If G is below B the equilibrium is stable. But if G is above B the equilibrium may or may not be stable. The usual method in specification of stability of a floating body is finding the metacentre point and then comparing its position with G. The equilibrium is stable if the metacentre lies above G.

Bansal (2005) conducted a study on a floating body. It said to be stable if it comes back to its original position after slight disturbance,

two alternate moments may act on the floating body depending on the relative position of centre of gravity (G) and centre of buoyancy (B).

Mohammad (2011) conducted a study on the stability of floating bodies. The potential energy of a system in stable equilibrium has a minimum value. This property is used to derive a formula that is useful in determination of stability of a floating body. It is found that a floating body is in stable equilibrium if its centre of gravity has a minimum height with respect to its related centre of buoyancy.

Omofunmi *et al.,* (2016) conducted a study on design of water hyacinth (*Eichhornia crassipes*) harvester. The purpose of this study was to design a harvester for control of water hyacinth. The anatomy and physiology of the water hyacinth were used to design the machine using basic engineering procedures. The main parts of the water hyacinth harvester included an electric motor (2.0 h p), mower disc (100 x 70 x 7.36 mm), shaft (26 mm diameter) with 4 blades made of stainless steel. The machine operates with capacity of 10,646 tons hr^{-1} at the speed of 3.04 m s^{-1}. The capacities of the loading and delivery conveyors are 846.60 and 538.75 tons hr^{-1} respectively. The water hyacinth harvester is also known as aquatic scavenger. The harvester is a boat which is capable of cutting and carrying the harvested weeds to the shore. The water hyacinth harvester was designed, fabricated and tested on laboratory. The average harvesting capacity was found to be 6.5 t/hr/m width of the conveyor when the traveling speed was 0.56 km hr^{-1}.

Materials and Methods

Stability analysis

Buoyancy is an upward force exerted by a fluid that opposes the weight of an immersed

object. When the floating barge is at certain weight of harvester, it sinks to a certain depth. This allows adequate freeboard to prevent any water from getting on board. A floating object is stable if it tends to restore itself to an equilibrium position after a small displacement.

The upward buoyancy force on an object acts through the centre of buoyancy, being the centroid of the displaced volume of fluid. The weight force on the object acts through its centre of gravity.

One of the key design criteria for the harvester is the stability requirement of the floating structure. The barge has to be stable in water and unaffected by waves, wind, tides and at the same time safe for holding mass imposed on it.

Transverse stability

Transverse centre of buoyance is the point through which the force of buoyancy supporting the vessel acts vertically upwards. Transverse centre of gravity is the point through which all of the weight of the vessel including deadweight items can be considered to act vertically downwards. When the machine is upright, both the centre of buoyancy and the centre of gravity are on the centre line of the vessel.

i.e. $T_{CG} = 0$

$$T_{CG} = \frac{\sum T_{mt}}{\sum Wt} = 0$$

Where,

T_{CG} = transverse centre of gravity, m
W_t = weight of the machine, t
T_{mt} = transverse weight, t
The transverse centre gravity for pokkali paddy harvester is zero. Hence the harvester is stable to floating on the water.

Longitudinal stability

If longitudinal centre of gravity and longitudinal centre of buoyancy are in the same vertical line and if there is no trimming moments on the machine,

$$L_{CG} = \frac{\sum L_{mt}}{\sum Wt} \text{ meters.}$$

Where,

L_{CG} = longitudinal centre of gravity, m
W_t = weight of the machines, t
L_{mt} = longitudinal weight, t

Vertical stability

Let the W be the weight of the Floating body and V_o be the submerged volume. Thus, downward weight of the body is balanced by the upward buoyancy force (B).

$$B = \rho_o V_o g$$

$$V_{CG} = \frac{\sum V_{mt}}{\sum Wt} \text{ meters.}$$

Where,

V_{CG} = Vertical centre of gravity, m
Wt = weight of the machine, t
V_{mt} = vertical weight, t

Results and Discussion

Stability of harvester

The stability of Pokkali paddy harvesting. The overall size of the Pokkali paddy harvester is 6.2 x 1.7 x 1.7 m with a total weight of about 1700 kg. A harvester is designed in such a way that to suit for fragmented Pokkali areas. The vertical centre of gravity of the scale down prototype is 0.58 m, longitudinal centre of gravity is 2.67 m and transverse centre of gravity is zero. As the transverse centre of

gravity is zero, Pokkali paddy harvester is stable to float and longitudinal centre of gravity lies near to the centre and adjacent to the front and rear side of the harvester, it become a well-balanced machine. A draft of 47 cm for floats, 39 cm for air chamber was observed for the scale down prototype of harvester of 1.70 tonnes.

Centre of gravity of the components of Pokkali paddy harvester

Sl. No	Part List	Weight (t)	LCG (m)	VCG (m)	TCG (m)	LMT	VMT	TMT
1	i)Propeller (Left)	0.0185	0.62	0.43	-0.554	0.01147	0.007955	-0.01024
	ii)Propeller (Right)	0.0185	0.62	0.43	0.554	0.01147	0.007955	0.01024
2	Hydraulic motor for back conveyer	0.0123	0.06	0.618	0.38	0.000738	0.0076014	0.00467
3	i)Hydraulic motor for float(Left)	0.02298	1.14	0.53	-0.27	0.026197	0.0121794	-0.00620
	ii)Hydraulic motor for float(Right)	0.02298	1.14	0.53	0.27	0.026197	0.0121794	0.006204
4	i)Float (Left)	0.267	2.815	0.37	-0.54	0.751605	0.09879	-0.14418
	ii)Float (Right)	0.267	2.815	0.37	0.54	0.751605	0.09879	0.14418
5	Air chamber	0.096	2.815	0.29	0	0.27024	0.02784	0
6	Centre conveyor	0.139	1.5	0.618	0	0.2085	0.085902	0
7	Chassis	0.1	2.21	0.731	0	0.221	0.0731	0
8	Engine	0.18	1.681	1.273	0	0.30258	0.22914	0
9	Hydraulic tank	0.137	2.71	1.05	-0.15	0.37127	0.14385	-0.02055
10	Diesel tank	0.03	2.67	0.9	0.168	0.0801	0.027	0.00504
11	Chair	0.02	3.071	1.022	0	0.06142	0.02044	0
12	Front conveyor	0.117	4.91	0.55	0	0.57447	0.06435	0
13	Front conveyor frame	0.059	4.91	0.55	0	0.28969	0.03245	0
14	Hydraulic motor for front conveyor	0.0123	3.98	1.02	0.43	0.048954	0.012546	0.00528
15	i)Hydraulic cylinder (Left)	0.006	4.89	0.523	-0.39	0.02934	0.003138	-0.00234
	ii)Hydraulic cylinder(Right)	0.006	4.89	0.523	0.39	0.02934	0.003138	0.00234
16	Cutter bar	0.04	5.8	0.03	0	0.232	0.0012	0
17	Hydraulic motor for cutter bar	0.0068	5.7	0.37	0.6	0.03876	0.002516	0.00408
18	Reel assembly	0.03	6.08	0.4	0	0.1824	0.012	0
19	Man	0.1						
	TOTAL	**1.70**	**67.027**	**13.128**	**1.424**	**4.5078**	**0.985**	**0**

Vertical stability

$$V_{CG} = \frac{\Sigma V_{mt}}{\Sigma Wt} \text{ meters.}$$
$$= \frac{0.985}{1.70}$$
$$= 0.58 \text{ m}$$

Longitudinal stability

$$L_{CG} = \frac{\Sigma L_{mt}}{\Sigma Wt} \text{ meters.}$$
$$= \frac{4.50}{1.70}$$
$$= 2.67 \text{ m}$$

Transverse stability

$$T_{CG} = \frac{\Sigma T_{mt}}{\Sigma Wt}$$
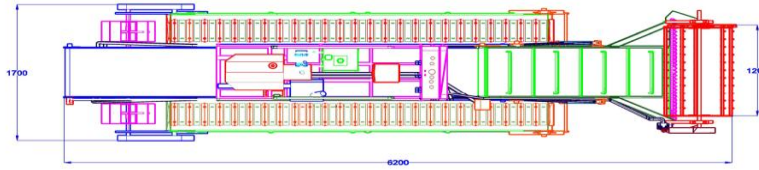
$$= \frac{0}{1.70}$$

$$= 0$$

Fig.1 Top view
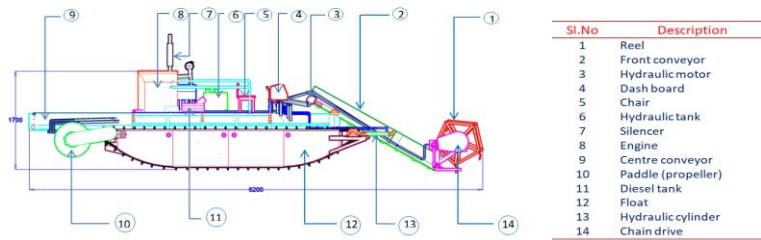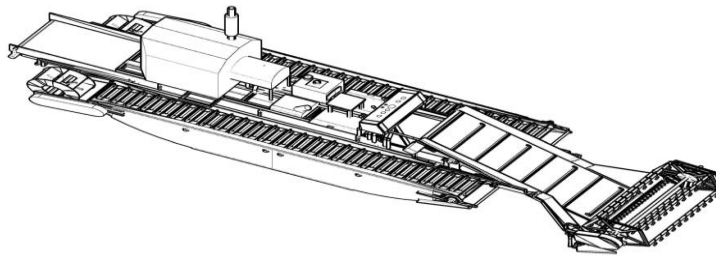

Fig.2 Side view

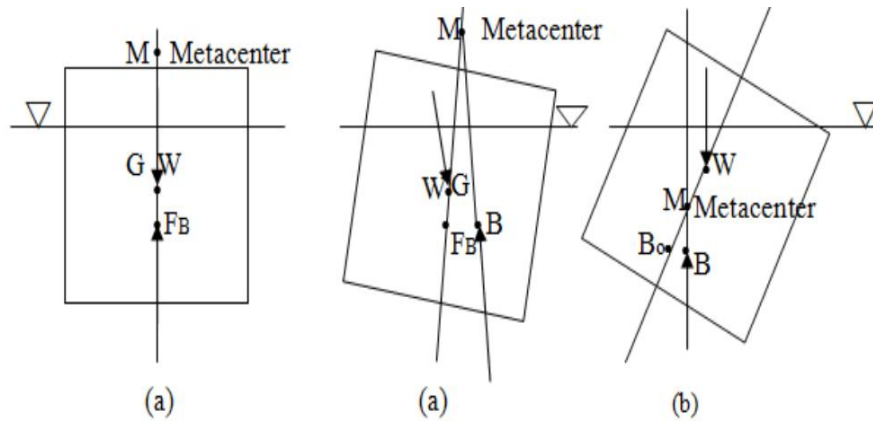| Sl.No	Description
1	Reel
2	Front conveyor
3	Hydraulic motor
4	Dash board
5	Chair
6	Hydraulic tank
7	Silencer
8	Engine
9	Centre conveyor
10	Paddle (propeller)
11	Diesel tank
12	Float
13	Hydraulic cylinder
14	Chain drive

Fig.3 Isometric view

Plate.1 (a) Stable equilibrium, M is above G **(b)** Unstable equilibrium, M is below G

In conclusion the conventional method of pokkali paddy harvesting, manual harvesting using sharp sickles are practiced. For the harvesting, highly labour intensive, drudgery and more time consuming operations are required. The paddy cultivation goes on decreasing every year. Hence, there was a great demand for a suitable harvesting machine, especially for harvesting the paddy. The Pokkali paddy harvester was designed for harvest panicles (ear heads) of paddy crop. The harvester was operated by a hydraulic system. The total weight of the Pokkali paddy harvester comes around 1700 kg. The overall dimension of the harvester is 6.2x1.7x1.7 m (LxWxH) and the stability of harvester was founded the vertical centre of gravity for harvester is 0.54 m and longitudinal centre of gravity is 2.67 m and transverse centre of gravity is zero. If transverse centre of gravity is zero, pokkali paddy harvester is stable to float. When the longitudinal centre of gravity is centre to the front and rear side of the harvester it is balanced.

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