



**CAIRO UNIVERSITY**



**FACULTY OF AGRICULTURE**

# **DEVELOPMENT OF A POTATO DIGGER**

By

**TAREK HUSSEIN ALI MOHAMED**

B.Sc. Agric. Mech., Cairo Univ., 1985

M. Sc. Agric. Eng., Cairo Univ., 2002

**Thesis**

**Submitted In Partial Fulfillment of  
The Requirements for the Degree of  
Doctor of philosophy  
In  
Agricultural Engineering**

**Agricultural Engineering Department  
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**2006**



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IN

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### **ABSTRACT**

The aim of this study was to develop a local machine that deals with the root crops, using the theory of vibratory digging blades to decrease the required drawbar pull. This aim was planned to be realized through the following stages:-

1) Study some characteristics of some potato varieties. These characteristics were tuber length, tuber diameter, tuber height, tuber weight, tubers surface are, tubers volume and firmness.

2) Evaluation the performance of the original digger. 3) Modification steps:- A vibratory device was fitted to the digger. The vibratory device was consists of 3 subsystems added to the original digger:-

(1) Beam holder. (2) Vibrating device. (3) Vibrating transmission system.

Technical and economical evaluation of the developed digger. The technical evaluation showed that :-

- The developed digger success to decrease the drawbar pull at forward speeds of 0.9, 1.5, 1.9 and 3.2 km/h with decreasing percentage of 25.17%, 25.91%, 28.43% and 30.47% respectively comparing with the original digger records at amplitude and frequency (  $A=10$  mm &  $(\omega)=1200$  rpm).

- The optimum amplitude was 0.6 mm with frequency of 800 rpm that give suitable draw bar pull with low bruising ratio. The drawbar pull was reduced with decreasing percentage of 15.42, 16.93, 19.7 and 12.29 % at forward speeds of 0.9, 1.5, 1.9 and 3.2 km/h respectively comparing with the original digger records.

- The results shows that a mathematical relation ship can be equated with the performance parameters (  $\lambda$  ,  $k$  and  $T$  ) and the drawbar pull.

- The developed digger can operate with 110 hp tractors instead of 140 hp tractors or more thus the harvesting costs would decrease.

- The modification success to increase the digger field capacity by 8.3% and decrease the operation costs per feddan by 28.98%.

- The economical evaluation showed that the total cost of the machine with a tractor 110 hp was 74.5 LE/h. the IRR is 72 % and NPV of 4579 LE. The pay back period was 2.1 years.

- The modification success to decrease the bruising from 7.98 to 7.88 by 1.25 % and decrease the un-harvested tuber from 1.76 to 1.69 % by 0.07%. These values can be translated to extra economical losses that could be added on the using of excess high power of the tractors.

## **ACKNOWLEDGEMENT**

The author wishes to express his sincere thanks and appreciation to ***Dr. SAMY MOHAMED YOUNIS***, Professor of Agricultural Engineering, Faculty of Agriculture, Cairo University, for his continuous supervision, advice, encouragement and guidance.

The author wishes to express his deep and sincere thanks to ***Dr. MOHAMED IBRAHIM GHONIMY***, Associate Professor of Agricultural Engineering, Agricultural Engineering Department, Faculty of Agriculture, Cairo University for his valuable assistant in particular.

The author wishes to express his deepest thanks to the staff members of Agricultural Engineering Department, Faculty of Agriculture, Cairo University especially ***Dr. AHMED EL-RAIE and Dr .MOHAMED OMRAN***.

Also, the author wishes to express his deep and sincere regards to the members of Agricultural Engineering Sector – Ministry of Agriculture for their valuable assistance.

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## NOMENACLUTRE

Symbol	Meaning
$A$	Blade area
$A_0$	Harvested area
$A_1$	Tuber projected area in x axes
$A_2$	Tuber projected area in y axes
$A_3$	Tuber projected area in z axes
$A_c$	Cutting area
$a$	Dimension of the tuber in x axes
$a_{max}$	Max. dimension of horizontal axes of the tuber
$a_1, a_2, a_3$	The dimensions of the tubers
$AC$	Area of the minimum circle can surround the shape.
$AP$	Projection area.
$b$	Blade width
$b$	Dimension of the tuber in y axes, m;
$b_1, b_2, b_3$	Constants for volume equation
$b_{beam}$	Beam width
$b_{max}$	Max. dimension of vertical axes of the tuber
$b_{s,i}$	Width over which a cluster of tubers lies;
$C$	Oil price
$C_b$	Bearing load rating capacity
$c$	Dimension of the tuber in z axes, m.
$DC$	Radius of the minimum circle can surround the projection of the shape.
$DE$	Radius of a circle its area equal of the projection of the shape.
$D_{beam}$	Outer diameter
$d_{beam}$	Inner diameter
$d_{shaft}$	Shaft diameter
$d_s$	Diameter of the shaft
$E$	Modules of Elasticity for steel blades
$e_{max}$	Max. distance between cam center and max. stroke point.
$e_c$	Eccentricity
$F$	Applied force

Symbol	Meaning
$F_f$	Force due to friction between the root and the cutting edge.
$F_s$	Shearing force for the key
$FC_d$	Digger performance rate
$F_r$	Radial load acting on the bearing
$F_a$	Axial load acting on the bearing
$F_c$	Digging force
$F_C$	The maximum reading of the dynamometer at digging angle of $40^\circ$
$F.S$	Factor of safety
$F_{follower}$	The max. load on the arm
$f$	Coefficient of sliding friction between the root and the cutting edge of the share.
$f_p$	Potato tubers firmness for Spunta variety
$fc$	Fuel price
$G_1$	Normal components of the inertia force
$h$	Tubers height
$h_w$	Weld size
$h_k$	Height of the key
$h_s$	Depth of under-cutting
$h_e$	Depth at which a cluster of tubers lies at the extreme ends of the share
$I$	Bending Moment of inertia
IRR	Internal rate of return
$i$	Interest rate
$J_1$	Normal components of the inertia force
$K_b$	Combined shock and (0) fatigue factor applied to bending moment
$K_t$	Combined shock and fatigue factor applied to torsional moment
$k_{pt1}, k_{pt2}, k_{pt3}$	Tubers stiffness in x, y, z axes respectively
$k_b$	Blade stiffness
$k_{pt}$	Tubers stiffness

Symbol	Meaning
$k_s$	Soil stiffness
$k$	Ratio between the acceleration of the vibrating blade to the gravitational acceleration
$L$	Blade length from the blade edge to the supporting point
$L_c$	Labor cost
$L_r$	Beam length
$L_k$	Length of the key
$M_b$	bending moment applied on the blade
$M_{b\max.}$	The max. bending moment on the beam
$m_b$	Blade weight
$m_{pt}$	Average tuber weight
$m_s$	Soil weight
$M_t$	Torsional moment
$M_b$	Bending moment
$N$	Number of labors
$N_{fb}$	Blade natural frequency
$N_s$	Soil natural frequency
$n_{beam}$	The beam, rpm
$n$	yearly working hours
$N_{pt}$	Tubers natural frequency
$n_{t1}$	Number of teeth of the drive
NPV	Net present value
$Oc$	Oil consumption
$P$	Blade force per unit length
$P_b$	Bearing equivalent dynamic load
$P_c$	Purchase price
$P_t$	Tractor power
PBP	Pay back period
$Q$	Force acts in the direction of motion of the soil layer
$r_1$	Tuber max. radius
$r_2$	Tuber the base radius

Symbol	Meaning
$r$	Crank radius
$r_c$	Coefficient of repair and maintenance
$S$	Surface area
$S_v$	Salvage value
$S_y$	Yield strength
$S_{\text{allow}}$	Allowable shear strength of the key material
$T$	Over all parameter for drawbar pull
$T_c$	Total cost
$T_m$	Max. torque on follower
$T_t$	Transmitted torque for the key
$T_{\text{beam}}$	Beam thickness
$t$	Blade thickness
$t_c$	Total consumed time
$U$	Unit draft of soil
$V$	Predicted volume of the tuber
$V_m$	forward speed of the machine
$V_0$	speed of oscillations
$v_1$	speed of the drive (for sprockets and idlers)
$v_2$	The speed of the driven(for sprockets and idlers)
$v_{ho,}$	The initiation of cutting corresponds to that instant when the horizontal component of the oscillatory motion of the share
$w$	Blade width
$w_k$	Width of the key
$Y$	Anticipated length of time owned
$\delta_s$	force of the ridge axis relative to that of the share
$\sigma_s$	Shear stress
$\sigma_b$	Blade bending stress
$\sigma_{\text{allow}}$	Allowable stress of the blade
$\delta_b$	Maximum deflection of the reciprocating ruler
$\sigma_c$	Compression stress

Symbol	Meaning
$\sigma_{cr}$	Crushing stress
$\phi_r$	Angle of repose of the soil.
$\phi$	Angle of sliding friction between the root and the cutting edge of the share
$\omega$	Angular velocity of the crank
$\alpha$	Digging angle
$\alpha_c$	The digging angle
$\alpha_s$	Angle subtended by the share with respect to the horizontal.
$\mathcal{E}$	Angle which acts at with respect to the horizontal
$\lambda_c$	Ratio between the crank radius to the oscillating radius
$\tau_k$	Direct shearing stress for the key
$\tau$	Shear stress induced in the welded joint
$\Sigma l$	Total length of the welded joint of the arm end .
$\lambda$	Ratio between vibrating and forward speed
$\rho$	Ratio between the max. acceleration of the vibrating blade and the forward speed