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Research Article

Design of a Manual Table-Top Grinder (MaTToG)

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Abstract: The Manual Table-Top Grinder (MaTToG) described in this paper is designed with a set of bevel gears intersecting at right angles with a velocity ratio of 5:1.This is to ease the drudgery encountered when using the existing manual screw grinder. It has advantages over the existing Manual Screw Grinder and the Electric Blender. The MaTToG is designed so that the power output is five times the power input while it is being cranked manually. The specifications on the design and drawings conform to approve international standards. This design can be used to grind fruits, seeds, vegetables, nuts, cooked meats or cooked fish etc.
Keywords: Bevel-gear, Velocity ratio, Output, Table-top, Screw grinder.

INTRODUCTION

The need for grinding/blending of food substances such as seeds, fruits etc. in their dry or fresh state necessitated this design. The ease of grinding these substances although in a small scale has become almost a daily affair to many household[1]. This need has been met by the invention of the Manual Screw Grinder and the Electric Blender. However, these inventions have their shortcomings. The shortcomings of the Manual Screw Grinder is quite low since it requires much power input to function, while the Electric Blender has not been optimally put into use because of the erratic power supply in Nigeria. The efficiency of the Manual Screw Grinder as well as electricity requirement which is epileptic has been identified as disadvantage to the use of the earlier inventions especially in rural areas in Nigeria. Therefore, the *MaTToG* described in this paper tried to overcome those shortcomings and can be used in rural as well as urban areas without electricity[2-4].

The existing models and types of grinding machines which this work tries to modify are as follows.

1. *Manual Screw Grinder:* This makes use of a screw shaft to convey food substances to be ground to two meshing cutting surfaces where they are ground. This is for grinding fruits, vegetables, nuts, cooked meats or cooked fish. It is made of Cast-Iron construction with a clamping device.
2. *Manual Blade Bolt-Down Meat Grinder:* This is (*Weston Tinned Bolt-down Manual Meat Grinder*) made of stuffing funnels, stuffing star, flange, two carbon-steel grinder plates, a carbon-steel cutting knife, nylon bearings, wood-grip handle and hopper opening. It is bolted to work surface for permanent and steady use.
3. *Electric Blender / Grinder:* This is made of a plastic or stainless steel container, blades and an electrically powered motor. It combines attractive, streamlined form with a functional product and meets standards for industrial design that were current for its time. It is used for grinding dry and fresh fruits, seeds, vegetables and roots; more so it can be used for blending mixtures. The Multipress Electric Blender is safe, efficient, and easy to use.
4. *The manual table top grinder (MaTToG):* The **MaTToG** described here is modification to the existing models mentioned above. The major components are as follows.
   i. *A Miter gear***:** This is a set of bevel gears intersecting at right angles. It has a velocity ratio of 5:1. This will give n^{th} teeth for the driver gear as the driven gear assumes $(n/5)^{th}$ teeth. This implies that the output velocity will be five times the input velocity. This will be made of mild steel.
   ii. *The Shafts for the Gears:* One shaft will extend from the driver gear to form the

handle for the operator. This handle will be gripped by plastic. The other shaft will extend into a hopper where the cutting blades will be attached. The shafts which will be made of ***food grade stainless steel*** will respectively pass through a bearing to aid the rotation. The entire compartment will be properly sealed to prevent leakage.

iii. *The Base:* This will be casted with Cast Iron. It will have comparatively much weight so that there will be no need for clamping. The base will also serve as the gear room.

iv. *Transparent Hopper:* This will be made of a calibrated transparent plastic container. It will be detachable so that the food substance that has been ground can be turned out. However, for mass production, a permanent mold will be made for it.

v. *Cutting Blade:* This will be made of ***food grade*** stainless steel. It has to conform to WHO and NAFDAC regulations on food standards.

DESIGN PARTS

The design parts for the device include, The bevel gears, The Hopper for mass production, The Base, The Shafts and Handle, The Cutting Blade and the design for casting of the base.

A. Design considerations

*Human factor consideration***:**

Human factor considered in this design include (a) **Psychological factor** and (b) **Biomechanics.**

(a). The *Psychological factor* involves the control of the consciousness attached to the precision nature of the design. This psychological factor or control involves the sequential movement of several relatively separate, independent movements in sequence.

(b). The *Biomechanics* of human, deals with the various aspects of physical movement of the hand and body member. This will not be treated here in detail. The abilities for people to perform various types of rotary motions depend essentially on the nervous system, and the metabolic process.

*Design speeds***:**

The speed of this device especially the input speed is considered for human factor. A convenient average revolutions and personal operation of the existing type at various places visited before the design was conceptualized was used for this work.

Human physiological controls involve the type of movement. The types of movement that will be encountered in the present design are as follows:

Continuous movements: **-** Involves movement of the arms continuously during cranking of the input handle.

Manipulative movement: **-** Involves holding the hopper (or work holding) properly in position to avoid displacement of the base. It is a control mechanism.

Repetitive movement: **-** This is the repetition of the same movement as will be with the control of the input cranking handle. It involves the pronate type of hand posture.

Sequential movement: **-** Involves movement encountered while holding the input clamp handle and at the same time (simultaneously), the hopper (or work holding).

Energy lost in all of the above movements is related to the amount of work done.

As part of the design considerations, the cranking handle has the following design specifications:

For an Assumed load of 200N:
L = 95mm preferred, L = Arm movement
D = 25mm, D = diameter of grip
R = 190mm or 200mm for RPM lower than 100, R = turning radius

(From Mil – STD – 1472D)

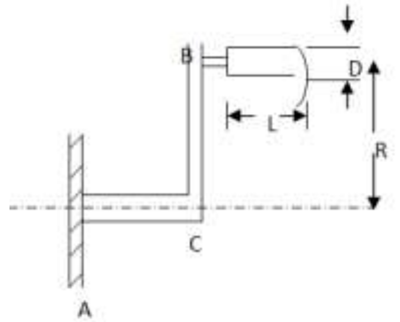

Fig. 1: Design recommendation for crank handle.

Power requirement In the diagram above, a force P acts on the axis of the shaft at point C, a distance R. The turning moment transmitted by the shaft is

T = Pr (i)

From the assumptions of Sanders & McCormick, that a grown up man of average power 0.05kW can conveniently apply a hand force of 210N at a speed of 40rpm at a distance of 0.20m from the axes of the shaft and tangential to the shaft.

i.e. T = 210 x 0.20 = 42Nm.

The Power required to turn the handle based on the maximum applicable load is given as

$$P = \frac{2\pi NT}{60}, \qquad \text{(ii)}$$

Where N=speed of rotation, T=Torque on the shaft, Nm and P=Power required, kW

Therefore, P= 2 x π x 40 x 42/60= 176W =0.176kW

Operation and maintainability: - The device is easy to operate and maintain.

GEAR DESIGN ANALYSIS.

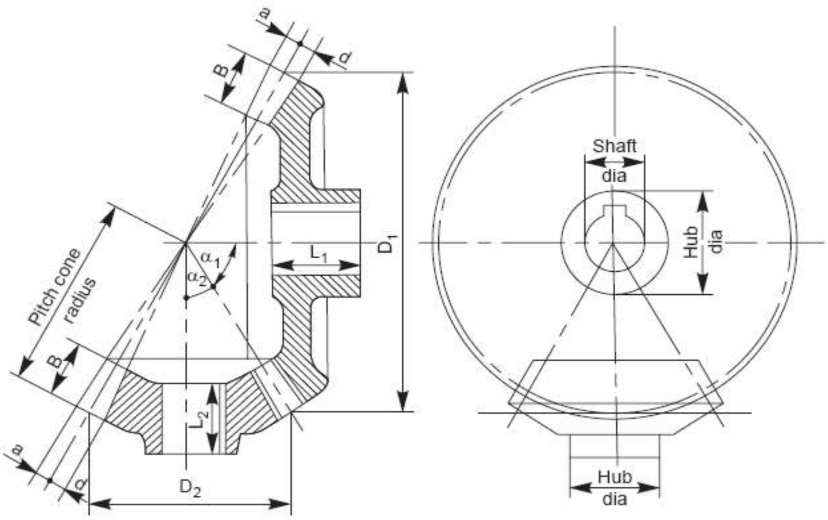

Fig- 2: Bevel gearing

Assumptions for the design analysis.
Pressure angle, θ = 20^o
Velocity ratio needed = 5:1
Number of teeth, T,
T_g= 100, T_P = 20

Where
T_g is number of teeth of gear and
T_p is number of teeth of pinion.
Assuming an input power, P of 150W and output power of 750W.
Angular velocity, N_g of 70 rpm
Assuming an overhang of 100mm (gear)
Angular Velocity, N_p = 350 rpm
Assuming an overhang of 50mm (pinion)

Relevant equations for the design

Velocity Ratio,
$$VR = \frac{velocity\ \ of\ pinion}{velocity\ \ of\ gear} = \frac{N_g}{N_P} = \frac{D_g}{D_P} \quad (1)$$

Where
D_g is diameter of gear and
$D_p$is diameter of pinion.

Pitch Angle θ
$$\theta_G = \tan^{-1}(\frac{Tg}{T_P}) \quad (2)$$
$$\theta_p = \tan^{-1}(\frac{T_P}{T_g}) \quad (3)$$

Module, $M = \frac{Dg}{Tg}$ (4)

Parts of the gear system
Addendum, a = 1M (5)

Dedendum, d = 1.2M (6)

Clearance = 0.2M (7)

Working depth = 2M (8)

Tooth thickness = 1.5708M (9)

Torque, $T = \frac{60P}{2\pi Ng}$ (10)
Length of the pinion cone, L =31.62M (11)

Mean radius of the gear, $R_m = (L - \frac{b}{2})\frac{D_h}{2L}$ (12)

Tangential force onR_m, $W_T = \frac{T}{R_m}$ (13)

Axial force on the shaft,
$W_{RH} = W_T \tan\theta\ Sin\theta_G$ (14)

Radial force on the shaft,
$W_{RV} = W_T \tan\theta \cos\theta_G$ (15)

Bending moment due to W_{RH} and W_{RV} M_1
$M_1 = W_{RV}$ X overhang – W_{RH} X R_M (16)

Note: negative shows that the gear is rotating in opposite direction to the pinion.
$W_{RHP} = W_{RVG}$ and $W_{RVP} = W_{RHG}$ (17)

Bending moment due to W_T,
$M_2 = W_T$ X overhang (18)

Resultant bending moment,
$M = \sqrt{M_1^2 + M_2^2}$ (19)

Equivalent twisting moment
$T_e = \sqrt{M^2 + T^2}$ (20)

Determination of diameter of the shafts,

For gear, $D_G = \sqrt[3]{\frac{16T_e}{\pi E}}$ (21)

(Where E = 45N/mm^2 is the elasticity modulus for mild steel).

Shaft design for pinion
Power Output = 750N

Torque, $T = \frac{60P}{2\pi N_P}$ (22)
Length of the pitch cone, L

Mean radius of the pinion,
$R_m = (L - \frac{b}{2}) \frac{Dp}{2L}$ (23)

Tangential Force on R_M, $W_T = \frac{T}{R_m}$ (24)

Axial Force on the Shaft $W_{RHP} = -W_{RHG}$ (25)

Radial Force on the Shaft,
$W_{RVP} = - W_{RHG}$ (26)

Bending Moment Due to W_{RH} and W_{RV}, M_1

$M_1 = W_{RV}$ X overhang – W_{RH} X R_M (27)

Bending Moment due to W_T,
$M_2 = W_T$ X overhang (28)

Resultant Bending Moment,
$M = \sqrt{M_1^2 + M_2^2}$ (29)

Equivalent Twisting Moment,
$Te = \sqrt{T^2 + M^2}$ (30)

Diameter of the Shaft, $D_p = \sqrt[3]{\frac{16Te}{\pi E}}$ (31)

Table -1: Analysis of design calculations.

COMPONENT	VALUES
Pitch Angle θ	11.31^o
Module, M	1.5mm
Addendum, a	1.5000mm
Dedendum, d	1.8000mm
Clearance	0.3000mm
Working depth	3.000mm
Tooth thickness	2.3562mm
Determination of diameter of shaft (Gear)	
Torque	16363.63Nm
Length of the pinion cone	47.43mm
Mean radius of the gear	65.62mm
Tangential force on R_m	249.3696N
Axial force on the shaft	89.00N
Radial force on the shaft	17.80N
Bending moment due to W_{RH} and W_{RV}	- 4060.18Nmm*
Bending moment due to W_T	24936.96Nmm
Resultant bending moment	25265.33Nmm
Equivalent twisting moment	26054.42Nmm
Diameter of the shaft (gear)	14.34mm say 15mm
Determination of diameter of the shaft (pinion)	
Torque	16363.6Nmm
Length of the pitch cone	47.43mm
Mean radius of the pinion	13.12479mm
Tangential Force on R_m	1246.77N
Axial Force on the Shaft W_{RH}	-17.80N*
Radial Force on the Shaft	- 89.00N*
Bending Moment Due to W_{RH} and W_{RV}	4450Nmm
Bending Moment due to W_T	62,338.5Nmm
Resultant Bending Moment	62497.13Nmm
Equivalent Twisting Moment	64603.86Nmm
Diameter of the Shaft (pinion)	19.4mm, Say 20mm

** negative shows that the gear is rotating in opposite direction to the pinion.*

Table -2: Bearing selection.

	GEAR SHAFT BEARING	PINION SHAFT BEARING
Number	202	204
Bore	15mm	20mm
Output Diameter	35mm	47mm
Width	11mm	14mm

Table-3: Material selection.

COMPONENT	MATERIAL
Gear	Mild steel
Pinion	Mild steel
Shaft (Gear)	Mild steel
Shaft (Pinion)	Food grade stainless steel
Blade	Food grade stainless steel
Base/Gear room	Cast iron
Beverage container	Food grade plastic (transparent)

Casting

For economy of production, casting design takes into considerations those factors in moulding and coring that would lead to the simplest procedure. Elimination of expensive core, irregular parting lines and deep grafts in the casting were seriously thought of. Combination of the fore going factors with the selection of the right metal for the job was an important facet of the casting design.

The choice of cast iron material is on its unique damping characteristics, desirable in producing bases for machines; hence it minimizes vibration due to its weight. It also aid in strength, stability and rigidity. The casting method was chosen on consideration of kind of metal to be cast, purpose and product, scope of production, availability of moulding processes etc.

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