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Research Article

Development of low-cost self-propelled multi-purpose power unit

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ABSTRACT
The self-propelled multipurpose power unit was developed in the laboratory of Farm Machinery and Power Engineering, JNKVV, Jabalpur for small farmers. The prime mower is powered by a 5hp diesel engine. The V-belt drive is provided for the transmission of power from the engine to the traction wheels. An adjustable accelerator wire is connected to the governor for adjusting the engine speed according to the requirement. The worm gear reduction unit is located at the axle having a speed reduction ratio of 20:1. A telescopic type frame is provided to support the end of the adjustable output shaft with the help of a bearing. The handle is modified to vary the height from 1.0 to 1.3 m from the ground. The additional lug cage wheel is connected to the transport wheel to increase the traction. Noise and Vibration isolators are provided between the engine and chassis to reduce the noise level and vibration. The noise level of the power unit was suitable for 8 working hr. The range of noise with load conditions is 60, 65, 70 (dB) and without load conditions 74, 79, 86 (dB), this limit of noise is under the permissible limit 90db. Vibration range according to optimum rpm 1200, rated rpm 1500 and maximum rpm 1800 so the output range of vibration in Handle 130 µm and chassis 217 µm, Handle 127 µm and chassis 198 µm, Handle 121 µm and chassis 193 µm.
Keywords: Power unit, Sound level meter and Vibration meter.

INTRODUCTION

The presence of a large number of marginal and small landholding farmers (80%) (D. Mahendra). India approves the importance of power tiller as the most suitable farm power source for field operations, because of its compact size, low cost, and versatility. A power tiller is a walking-type small tractor used for agricultural operations in most of the world. It is mainly used for field preparation sowing and other operations like Inter-culture, mower & harvesting in small agricultural fields. This power unit has gained popularity among farmers due to its rugged and reliable operation. The smallholding farmers faced many problems including poor access to modern inputs and credit, poor infrastructure, inadequate access to markets, land and environmental degradation, and inadequate research and extension services. A study about the use of Power Tiller among small farms indicated that there was a 70 % increase (Faleye T. *et. al.*) in yield. The suitability of these small prime movers can further be increased to a greater extent, if it turns out to be suitable for some left outfield operations like water lifting, winnowing, cleaning & grading operation then this unit may become the complete self-propelled multipurpose unit. In general, the available power units are developed for a specific kind of work so small and marginal farmers may not be able to purchase different machines for different operations. The solution to such a problem can be provided by the development of a small multipurpose power unit that may be a worthwhile endeavour in this context. This unit must be able to perform most field operations from tillage to post-harvest operations. The availability of multipurpose power units for marginal and small farmers may avoid the year-round maintenance of bullocks and also the high investment in tractors. This machine must be simple in design and can be fabricated & repaired by village artisans. The structure of a power unit must be so simple that it provided better manoeuvrability and better floatation for Kharif crops. The present study will be carried out for modification of the following objective by providing effective and easy power engaging & disengaging system and Modification to achieve better traction and operation comfort.

Design Consideration of Power Unit

To fulfil the above-mentioned design criterion, modification of a telescopic frame for hitching of different cutting tools and operating rotary machinery by the spliced output shaft was taken for modification in respect of the following components;
Telescopic frame
Engine
Power transmission.

power engaging & disengaging system
V-belt and pulley
Speed reduction unit
Axle
Traction wheels
Ball bearing and bushes
Output shaft
Handle and Hitching point
Telescopic frame

Telescopic frame modification is particularly important in frame of walking-type power unit lightweight reduce cost and ease of transportation. Operation and propelling power must be strong enough to resist the shock load during operation. With lightweight construction, there is considerable deflection and which leads to self-alignment necessary.

The following points were considered while modification the frame:

A proper size frame may provide the required strength and toughness so there may be no bending and twisting during operation, although flexibility is always needed field operation.

Provision to separate output shaft power according to the position of operating rotary machinery may be given.

Size of MS angle was determined based on the following assumption related to developing a power unit for intercultural operation calculation.

Determination of size of MS angle

Assumptions for the design of frame:

The number of cutting tools, no. = 3
width of the cutting tool (base), cm = 25 top
(Cutting section), cm = 10 bottom
depth of cutting, cm = 7
ground clearance, cm = 45
soil resistance, cm = 0.7 kg/cm2
row to row spacing, cm = 40

Furrow cross-section:

Cross-section of furrow was assumed trapezoidal with top width 25 cm bottom width 10 cm

Area of furrow cross-section = Top width + bottom width × depth
2

$= \frac{25+10}{2} \times 7$ = 122.2 cm2

Draft = Soil resistance × furrow cross-section
= 0.7 × 122.2 = 85.75 kg

The tool bar is subjected to torsion and bending moment due to induced draft. Three tines are to be arranged in tool bar in single row. The design is based on stress produced in the tool bar.

Draft per tine = 85.75 kg
Total draft = 85.75 x 3 = 257.25 kg
Torque on the tool bar by each tines = draft × ground clearance
= 86.75 × 45 = 3858.75 kg-cm
Total torque on the row tool bar = 3 x 3858.75 = 11576.25 kg-cm

In addition to torque, bending moment would also be produced. The tool bar can be taken as simple supported beam on the frame in between the last two tines.

The max bending moment

$$\text{Mmax} = \frac{\text{Wl}}{4}$$

Where,
W = Total wt. on the frame = 257.25 kg;
l = Total length = 70cm;

Mmax = (257.25 x 70) / 4 = 4501.88 kg-cm.

Equivalent torque due to torsion and bending moment

$$\text{Te} = \sqrt{\text{M}^2 + \text{T}^2}$$

Where,
Te = Equivalent torque;
M = Max Bending Moment; and
T = Torque on the tool bar.

$$\text{Te} = \sqrt{4501.88^2 + 11576.25^2} = 12420.80 \text{ kg cm}$$

The maximum shear stress developed on the tool bar can be obtained by using the formula.

Fs / R = T / J ---- eq1

Where,
F_S = Shear stress at any section;
R = Distance of the section from neutral axis;
T = Equivalent torque produced; and
J = Polar moment of inertia.

Assuming maximum working stress of 500 kg/cm2 at the centre of tool bar, for angle section having each side measuring d cm.

J = d4/9.6,
R = d/2

Where,
d = width of the section

Substituting than values in equation

fs/ R = T / J ……….. eq2
500 / (d/2) = 12l20.80/(d4 / 9.6)
d3 = (12420.80x9.6) / (500x2)

$$d = \sqrt[3]{[(12420.80\text{x}9.6)\text{I}(500\text{x}2)]} =$$

4.92 cm = 5.5 cm.

Thus, on the basis of calculations, tool bar is to be made of angle section each side measuring 5 cm.

Rectangular structures are to be fabricated for frame out of angle section of 50×50×5 mm. thickness are 5mm selected as it standard matching with ms available of 50 mm.

Engine

Engine is main power sources for the power unit.

Power = 5hp;
Speed (n) = 1200 rpm.

Calculate torque on engine output shaft

$$\text{hp} = \frac{2\pi\text{NT}}{4500}$$

Where,
hp = Horse power;
N = rpm; and
T = Torque (kg cm).

$$\text{T} = \frac{5 \times 4500}{2 \times \pi \times 1200} = 2.98 \text{ kg cm}$$

Design of power transmission from prime mover to wheel

A 5HP engine with 1200 rpm has been taken. The required rpm of feed shaft is 18 rpm (assumed).

Therefore, to reduce the rpm, drive pulley is replaced with larger diameter pulley and decrease the diameter of traction wheel. The size of driven pulley and traction wheel is decided by calculation as given below.

$$Ne \times De = Np \times Dp \qquad \text{-----------eq3}$$

Where,

Ne = no. of revolution per minute of pulley of the engine;

Np = no. of revolution per minute of pulley of transmission system;

De = dia. of pulley of engine cm; and

Dp = dia. of pulley of transmission system, cm.

$1200 \times 10 = Np \times 30$

Np = 400 rpm

Since speed ratio = 20:1

No. of revolution of traction wheel (N) = 20 rpm

The forward speed of power unit was calculated as:

$$\text{Forward speed } S = \frac{\pi\, dN60}{1000} \qquad \text{-------eq4}$$

Where,

S = speed of power unit, km/h;

D = diameter of traction wheel, m; and

Diameter of traction wheel = 640mm.

$$= \frac{3.14 \times 0.64 \times 20 \times 60}{1000} = 2.4 \text{ km/h}$$

Consider 10% slip, and then speed will be 2.16 km/h.

Calculate drawbar horse power (DBHP)

BHP of engine = 5 hp

DBHP = 80% of BHP

DBHP = 0.80 × 5 = 4 hp

Calculate drawbar pull

speed will be 2.46 km/h.

$$DBHP = \frac{(PULL(kg) \times SPEED(m/min)}{4500}$$

$$\text{Pull (kg)} = \frac{DBHP \times 4500}{SPEED(m/min)} = \frac{(4 \times 4500)}{2500/60} = 432 \text{ kg}$$

Length of open belt

Length of open belt is calculated as

$$= \pi \frac{(De+Dp)}{2} + \frac{(De-Dp)^2}{4c} + 2C \qquad \text{------- eq5}$$

Where,

c = distance between center of two pulley = 36 cm

$$= \pi \frac{(10+30)}{2} + \frac{(10-30)^2}{4 \times 36} + (2 \times 36) = 137.5 \text{ cm} = 140\text{cm}$$

Thus, a V belt of B140 is selection for transmission of power.

Determination of diameter of axle:

The axle is a rotating member which transmits power from one point to another point.

Power = 5 hp;

Rpm of the axle = 20; and

Maximum permissible shear stress = 600 kg/cm2.

$$Hp = \frac{2\pi NT}{4500}$$

Where,

Hp = Horse power;

N = rev. per minute; and

T = torque in kg cm.

$$T = \frac{5 \times 4500}{2 \times \pi \times 20} = 179.04 \text{ kg m} = 17904 \text{ kg cm}$$

$$T = \frac{\pi\, f_s\, d^3}{16}$$

Where,

T = torque;

fs = max. Permissible shear stress; and

d = dia-meter of axle.

$$d^3 = \frac{T \times 16}{\pi \times f_s} = \frac{17904 \times 16}{\pi \times 600} = 159.3 \text{ m} = 1.59 \text{ cm}$$

d = 2 cm

Selection of V - belt and pulley

V belt drive has been selected for the design as it has following advantageous features.

Noiseless and quiet running.

No lubrication.

Acts as cushions shock.

Alignment requirements are less critical.

The v-belt drive, by slippage overcome the over loads and thus acts as a safety too.

If required, direction of shaft rotation can be easily reversed by crossing the belts.

The speed reduction is provided in three stages. In first stage engine speed reduction from 3000 to 1200 rpm by a built-in spur gear. In second stage reduction is done by means of v-belt drive between engine output shaft and gearbox input shaft and in the third stage engine gears are used to reduction speed to 20:1 gears ratio.

Selection of bearings

When there is a relative motion between two machine parts, one of which supports the other, the supporting member is called bearing. Bering plays important role in working of machine. A bearing helps a machine in many ways viz. carrying and distribution load, reduction friction to minimum, safeguard revolving, oscillating or reciprocating parts from wear due to friction etc. It helps in assembly of two parts from wear due to friction. Apart from providing support the bearing reduces friction between the moving parts, which would otherwise cause a loss of available power. Selection of bearing for farm machines is made with the following requirements.

Self – alignment often required dare to high deflections of light weight construction.

As machine has to work on soil, so adequate seals are to be used to avoid dust setting.

It should be easily available, simple in construction and low cost.

Roller bearing offers the following advantages over journal bearings

Roller bearing have an advantage where starting torque are high because of the rolling action of the balls, or rollers.

Roller bearing give warning (by becoming noisy) when failure occurs in journal bearing, the failure is sudden.

Roller bearings can take a combination of radial and thrust load.
Clearance in roller bearing need be much less than in journal bearing, providing accurate positioning of machine parts.
Roller bearing can take high over lads for short period.
In the present design, ball bearings of sizes (6206) (inner 3 cm outer dia. 6 cm) & 6506, 7205 are used and housed in ring blocks of appropriate sizes.

MATERIALS AND METHODS

The present self-propelled power unit was initially developed as power weeder for intercultural operation and later on it was further developed as multipurpose Power unit to perform secondary tillage and sowing operation. The machine is sequentially modified to full fill the need of small and medium farmers for different field operations. A new modified unit was initiated to overcome problems of existing machines and for development of output shaft which can accommodate the input shaft of different machines with the help of suitable coupling and linkages for operation of rotary unit, mower, grader etc. The self-propelled power unit is very use full and economical unit. This work of modification and fabrication was conducted in the workshop of department of Farm Machinery and Power Engineering, College of Agriculture Engineering, JNKVV, Jabalpur. The materials for fabrication of various components were selected considering requirements as given in Table 1.

Table 1. General specification after modification of self-propelled multipurpose power unit

Name of parts	Material used	Major specification
Frame and hitch	M.S. Angle & square section	50×50×5mm 50×50×5mm
Diesel engine		5hp,1200 rpm(output) air cooled diesel engine
Gear (speed reduction unit)	Spur gear Warm gear	40 teeth 8 teeth
Idler linkage system	Mild steel (flat)	Outer frame angle 50×5mm Linkage 20×3mm Idler wheel dia. 20mm
V-pulley	Cast iron	Engine shaft pulley outer dia75mm. Input gear shaft pulley outer dia. 300mm.
V-belt	Rubber fabric-cord	B (single) length 140 cm
Axle	Mild steel	Length 300 mm Dia. 25 mm
Bearing	Chrome alloy Steel ball bearing	6205 6505 7207
Bearing block	C.I.	Length 11cm Width 11cm Thickness 3cm
Acceleration wire		1m
Conduit pipe		Dia. 25 mm Length 500 mm
Output shaft	Mild steel	Length – 300 mm Dia. - 20 mm
V-pulley	Cast iron	Input outer shaft pully
Bearing	Steel ball bearing	205US
Stander finish item	Split pins, bolts and nuts	Spring washer set

Fabrication of telescopic frame

Modification in frame of the unit is urgently required to have the unit for versatile use. It must be rigid but light for easy transport. It must be strong enough to resist the sudden shocks transfer by the cutting tools. The weight must be light enough so downward load coming on the wet soil may not cause a severe sink age in kharif season. Keeping these points under consideration the square bar section of 50×50×5mm is selected as it fulfills all above requirement. Fig 2

Fabrication of hitch bar for attachment of various implement

The hitching mechanism was designed for easy attachment and better maneuverability. Various tools can be attached with the power unit by providing square box. The box was made out of hollow square bar of 40 mm sides. This square box slide forward and backward inside the hollow square section (50×50×5) of mounting frame. In the square box, circular holes (10mm dia.) are made at a regular interval of 20mm (3 hole) along the length of machine, the corresponding provision is also made in the seed drill for varying the length of hitch bar to obtain good performance at different operating depths. Fig 2

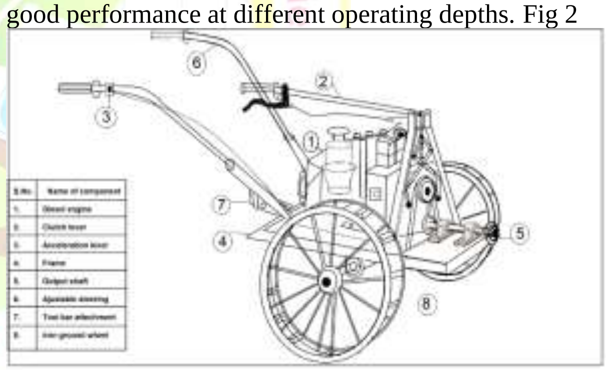


Fig 1. Schematic diagram of multipurpose power unit

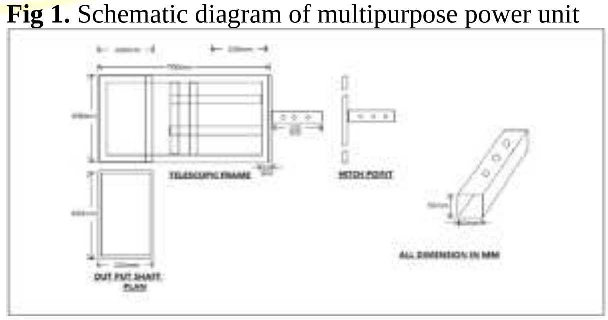


Fig. 2. Different components of telescopic frame and Hitch bar for attachment of different tools

Fabrication of output shaft and linkages

The output shaft of engine was facilitated with multi-grooves 'V' pulley. The output shaft Accommodate the input shaft of different machines with the help of suitable coupling and linkages. Mild steel round shaft of 20mm dia. and 300mm length was used for the fabrication of the axle. The axle was suitably turned on a lathe machine and finished to get accommodated in the spider bearings. The Steel ball bearing 205 Us are used in the axle. The revolution of output shaft can vary from 1000 rpm to 2000 rpm depending upon toque requirement of output reciprocating machinery.

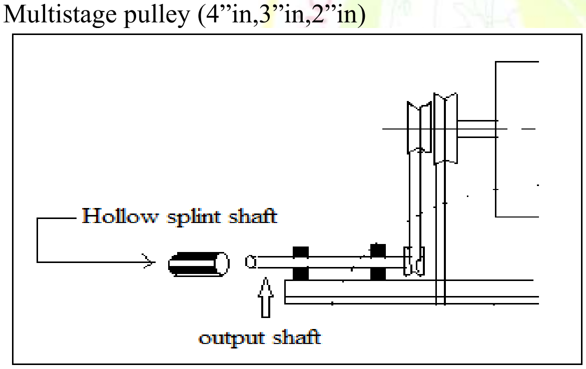
An universal joint is used to connect two shafts whose axes intersect (bevel gear) or at an angle other than the right angle to transmit rotary power from one shaft to another and to the other parallel shaft. The outer section of universal joint was attached with hollow square angle (25×25mm) and inner section of solid bar (20×20mm). The length of universal joint may vary from 400 to 700 mm depending upon the inclination of output and input shaft. The multi stage pulley mainly used to converting of RPM according to rational speed of output rotary machinery through by pulley. The drive cast iron pulley 2in, 3in, 4in, size are attached in output shaft.

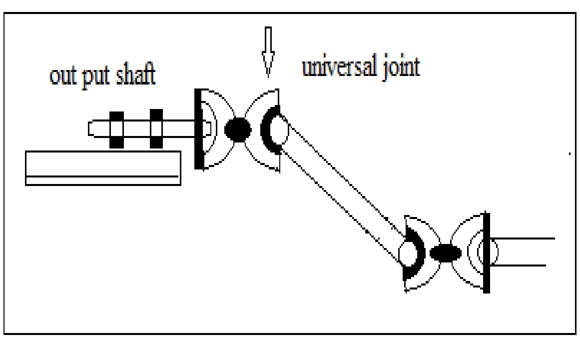
Three type of linkages provide in output shaft:-

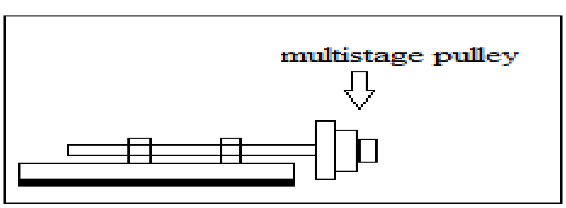
Hollow splint coupling (6 splint)

Universal joint linkage

Multistage pulley (4"in,3"in,2"in)







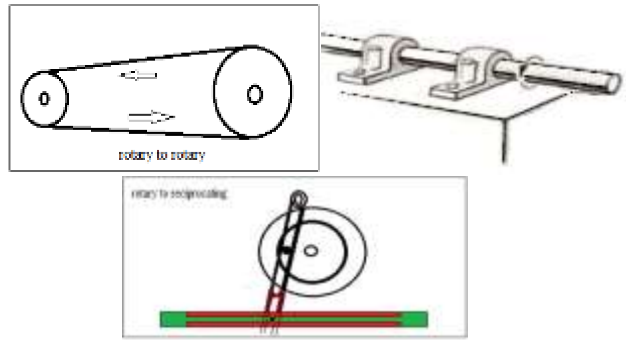


Fig. 3. Line digram of multi-stage pulley

Fabrication of Traction Wheel

Two cage wheels as traction wheel are fabricated for batter gripping and contact between wheel and soil surface, each of 640mm dia. and 80mm width, and 25mm lug height. Four mild steel flats of 2560 × 80 mm size were bent and welded to form two rims. Washers were bolted at the outer periphery it with other traction wheel. The additional wheel attached with original ground wheels are used as traction wheels in the field with lug height 25mm, lug spacing 80mm and lug angle 900. Dog clutches (Paul and ratchet) are provided at both end of axle. This helped in turning by keeping the inner wheel free. (Show in fig 4)

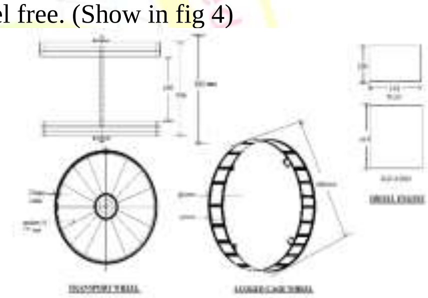


Fig. 4. Lugged Cage Wheel

Fabrication and Installation of Power Drive System

The self-propelled unit comprises of 5hp diesel engine, speed reduction unit (gear box) and V - belt pulley arrangement. These are arranged as to keep the machine balanced. The worm type gear reduction unit was located at the axle having gear reduction ratio of 20:1.

The speed reduction was done in 2 stages. First stage gave reduction of engine speed from 1200 to 400 rpm with the help of v belt pulley. The bigger pulley fitted at the end of gear box input shaft and smaller pulley fitted on output shaft of the engine. The dia. of corresponding pulleys are 30 cm and 10 cm respectively. These pulleys were connected to a V-belt of size B 46. Second stage reduction was in the worm gear reduction unit. The output shaft of gear was extended in both sides and used as the axle for the traction wheels. Two V-pulleys, one V-belt and two idler pulley linkage system was used to transmit the power from engine to the traction wheels. One U clamp of flat mild steel was fabricated and arranged in such a manner so that it could move on driven idler pulley touching its surface of the V-belt. It was used for increases the angle of contact on the idler pulley and maintains the desired tension as the belt stretches for engaging and disengaging power transmission unit. The detail construction of clutch system is given in fig 5. The outer linkage flat iron of size made of MS angle 40×4mm according to width and thick are used. The vertical bar was connected to horizontal bar with the help of nut and bolts and fixed on frame. The clutch lever was made of 20mm dia. and 50 cm length. Clutch lever was fitted along with the help of spring. Under the normal condition, both idler remained in engaging position due to spring pressure and the power transmission through from driven pulley to tight the belt and rotation of one causes rotation of the other output shaft of the gear reduction unit. When the clutch handle was push down, the u clamp at the engaged idler with belt and disengaged the power supplied from engine output shaft. The linkage clutch was brought back to the engaged position by bringing back the handle to its normal position.

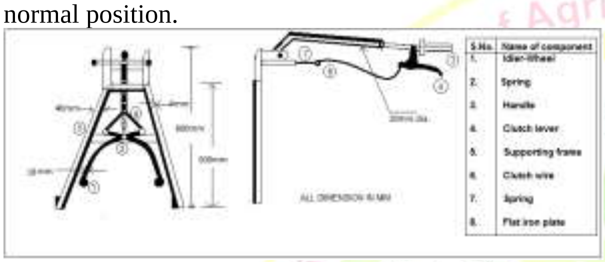


Fig. 5. Line diagram of power engaging and disengaging system

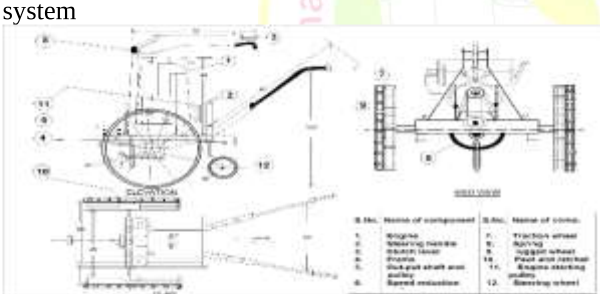


Fig. 6. Schematic diagram of multipurpose power unit

Vibration Isolators

Vibration levels depend on the terrain conditions and engine speed of the machine. It was observed that as the engine speed increases, RMS (root mean square) value of vibration also increases and it was highest on the top surface of the engine followed by the chassis, seat, handle, base of handle bar end gear box. The vibration at the top of the engine was the highest since the major reason of the vibration of the machine is the unbalanced inertia force of the engine. Four vibration isolators were mounted between the engine and chassis. With this, excitation of the unbalanced inertia force of the engine gets transmitted to the chassis through the isomer only because of the high percentage of molecular diffusions in the case of rubber isomer, the mechanical energy would be consumed and dissipated as heat, and the instantaneous vibration would be attenuated rapidly. 25 mm thick isolator was placed between two metal plates. Dimension of isolator (60 x 60 x 25) mm.

Measurement of the effective noise level

Recording instrumentation

Instruments used in this study were: METRAVI SL-4005 sound level meter with sound level: Lo = 35-100 db or Hi = 35-135 and the flat frequency, weighting 6.0, time weighting slow or fast. Response in human threshold of hearing range sound level meters with 20 - 146 dB dynamic range and 0.1 dB accuracy.

Location of measurement point

The Policies normally specify noise limits for outdoor areas of noise sensitive areas. It is therefore preferable to choose a point outdoors to take measurements. It should be chosen so a maximum level of the noise source is obtained.

Microphone placement

The test site was prepared and maintained according to ISO (ISO 5131, 1996) and SAE (SAE J1174, 1985) sound measurement standards.

The test area are free from obstacles and consisted of a flat open space free from the microphone is holding 1.2 m above the ground surface and 5 m away from the center of the power unit in (Fig-7) path way in a horizontal position and pointed in the direction of travel. The background noise was at least 30 dB lower than that for the power unit.

Equipment checkpoints

When measurements of noise are being made in the field, (from a factory premises, entertainment noise or background noise) certain procedures should be employed to ensure an accurate measurement is obtained. Some of these procedures also apply to analysis of tape-recordings in the farm.

Some pieces of equipment require a minimum 'warm-up' time before their performance is optimum. The manufacturers' recommendations are the best guide.

A battery was being checked in the field before and after it is used.

A calibration check was made both before and after the measurement. Calibration checks varied slightly, but variation was not significant.

The picker was operated at the recommended travel speed 2.5 km/hr of prime mover at full accelerator. The test is observed in three stage ideal rpm, rated rpm, maximum rpm to accelerated by lever adjusting (1200, 1500 and 1800 rpm) of the engine.

Noise at By-Stander Position

The measurement of the noise of power unit at bystander position shall be conducted in accordance with (ISO 5131, 1996):

The measurement was made with the power tiller stationary on a soil surface,

The engine of the power unit operated at the manufacturer’s rated speed and all mechanisms shall be functioned as in normal field work.

The weighted sound pressure level was measured and reported

Fig. 6. Sound level meter (Digital)

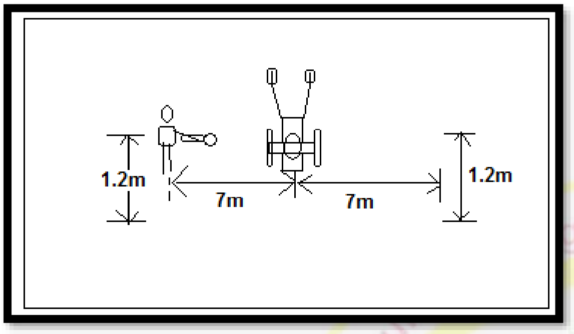


Fig.7. Dimensions of the measurement area

Measurement of the effective vibration

The experiment was conducted to evaluate the performance of vibration of multipurpose power unit implemented in the College of Agriculture Engineering. We have used ACD – D 83 instrument to measure the vibration for developed power unit to check it is suitable or not as for operator handle structure, causes increased vibration at operating knobs. Proper insulation between engine and handle reduces the vibration greatly when transmitted to hands. The use of hand tractors in farmlands and countryside where the terrain has plenty of roughness is one of the main sources of increased vibration.

Description vibration meter modal ACD – D 83

All machines with rotating/moving parts or carrying currents vibrate. The maximum life and performance can only be achieved by operating machines within these specified limits.

The vibration meter is primarily to suit the above purpose. The regular measurement of various machines can be taken to judge their mechanical status. The instrument can be used for very wide range of measurements. It can measure 0 to 2000 microns DISPLACEMENT in the range of 600 R.P.M to 60,000 R.P.M.

The displacement of mechanical vibration of components/assemblies of the power unit measured with the help of suitable vibration measuring instrument on the components of machines.

The power unit shall be parked on a level soil surface. The power engine is started optimum rpm is adjusted, rated rpm and maximum rpm of engine and its operated at rated engine speed at load and no-load position of power unit. The maximum horizontal displacement (HD) and vertical displacement (VD) in microns shall be measured by mounting the measuring device in relevent positions.

The data shall be recorded in accordance with vibration meter.

Fig.7. Vibration meter

Drive wheel skid

The travel distance of the ground drives wheel in a given no. of revolutions increases due to skidding of the wheel. It is the difference between ideal distance a wheel should move and the distance actually moved by the wheel.

$$\text{Slippage (\%)} = \frac{N_1 - N_2}{N_1} \times 100$$

N_1, N_2 Distance covered with & without attachment respectively.

RESULTS AND DISCUSSION

This study deals with the study related to modification of existing self-propelled multipurpose power unit machine and the performance evaluation of developed output rotary shaft to operate various machinery and provide attachment of tillage tool bar for tillage operation under laboratory and actual field condition. It also contains the cost economics. The utility of the same machine may vary with the land holding. The machine can be used for 1000 to 1500 hour per year. A larger farmer can handle larger area. This small walking type tractor costing low may equally usable to the large farmers.

Identification of problems in existing machine and development of a modified power unit

In existing power unit, the alignment of frame was improper and it was fixed type. The MS angle size was 40 ×40×5 mm. This frame size was not suitable to bear the load of machine with attachment of tool bar and cutting tool for tillage. The reason of this was its rigidity which was not adjustable according to arrangement of another tool carrier. The handle was not adjustable for 5th to 95th percentile operator.

To eliminate this problem in the power unit a telescopic type frame is provided which also supported the end of output shaft with the help of fixed bearing housing. Bearing also reduced the vibration in the machine and kept shaft in such a way so axis of rotating is fixed. This MS angle 50 × 50 × 5 is used in the modified frame to bear the load and bending moment coming on frame. This is suitable for operating for 5th to 95th percentile operator the adjustable, height of handle is 1 m to 1.3 m from ground surface.

Fig 9. Alignment of frame in (A) existing model (B) modified model

Fig. 10. Handle height for 5th to 95th percentile operator

Power engages and disengages system:

The power from engine output shaft is transmitted to input shaft of gear reduction unit through belt. In existing power unit single idler pulley was mounted on the frame which moved a lever up and down by cable and bar to tight and slack the v-belt on pulley. There was the friction between belt and pulley resulting to high temperature and sticking of belt due to release problem. This system did not work effectively and when it was disengaged by lever power transmission was not completely disconnected. To eliminate this problem modified power transmission system was developed and the system engage and disengage become easy due to reduction in quantity of linkages resulted into less effort and more contact area cause reduction of slippage and heat generation in the belt. Now this system is working proper with less effort. Two idler pulley are used which resulted in to more contact area thus less heat generation between belt and pulley.

Fig. 11. Arrangement of power engaging & disengaging (A) existing (B) modified

Modification for better traction wheel

In existing unit iron wheels with 640mm diameter 83 mm wide was used inverted triangular shape lugs were used for easy transportation on the road. During tillage operation when power unit operated in the field the iron wheel did not provided proper grip between lugs & soil surface. Many time it skid over clods which caused instability of machine caused side wise turning. To eliminate this problem new traction cage wheel was designed and developed. The dimensions of new developed cage wheels were 640mm diameter, 80mm lugs spacing 25 mm lug height & lug angle 900. This cage wheel is attached to outer rim periphery of existing iron wheel with nut and bolts. This resulted in increased traction (increased grip between track and terrain) caused reduced slip in wet soil and reduced skid on clods increased to a great extent because of fact that contact is between wheel and soil increased caused better side wise stability.

Fig. 12. View of Traction cage wheel (A) existing (B) modified

Table 2. Observation on wheel slippage before and after attachment of additional lugged cage wheel

Theoretical distance covered in 10 rev. (m)	Actual distance covered in 10 rev. (m)	Existing unit Slippage (%)	Modified unit Slippage (%)
20.10	16.7	17	5
20.10	16	20	6
20.10	15.8	21	5
20.10	17	15	5
Average	16.3	20	6

The tractive efficiency of existing machine was 68 % that needed to be increased. This machine had high fuel consumption due to low field efficiency caused by more slippage; the average slippage value was 13.6 % at 14 % soil moisture content on dry basis. The tillage tool bar device was driven by traction wheel that was the reason of uneven tilling of implement. The average percentage of slip in power unit without lugged cage wheel was 20% and with attachment of developed lug cage wheel was reduced to 6% in (Table-2), the 6% slip is the permissible limit as per the test code 6183. The developed cage wheel also increased the field capacity 0.08 ha/hr. So developed lug cage wheel also increased the traction and proper griping between iron wheel and contract soil surface.

Development of different component of multipurpose power unit

Front output shaft:

Developed multipurpose power unit is a versatile power unit which can be used for field preparation, sowing and with the application of power on front output shaft operations like Inter culture operation, water pumping, mower & harvesting and winnowing/threshing in small agricultural fields could also be achieved easily the demonstration of this power unit among farmers visiting the college fascinated them to due to its reliability and versatility. The machine is sequentially modified to full fill the need of small and medium farmers for different operations. A new modification unit would be initiated to overcome problems of existing machines and developed output shaft which can accommodate with the input shaft of different machines with the help of suitable coupling and linkages to operate rotary machinery, mower, grader etc. The existing power unit was used only for sowing purpose and the provision for attachment of various implement was limited. In newly developed self-propelled multipurpose power unit various Implement can be attached easily to the chassis with the help of rectangular box type hitching mechanism and also can operate output rotary machinery for other inter culture operation.

Table 3. Linkages used for different operation

Operation	Linkages used
Water pumping	Universal joint
Winnower	V-belt pulley
Mower	V-belt pulley & axle
Sowing	Adjustable Hitch bar
Tillage	Tool frame hitch bar

Use of vibration isolator:

The vibration and noise in existing unit was high that caused drudgery to the operator and required regular maintenance. In modified developed power unit vibration isolator are provided in between engine and chassis to reduce the vibration and noise shown in fig (13). and measurement vibration in farm of displacement through by vibration meter shown reading in table (7 and 8) and noise level in db shown reading in table (5 and 6).

Noise measurement

The experimental value of noise measurement exposures of the developed self-propelled multipurpose power unit operators was measured during load and without load operations. Table-4 shows some information according to Occupational safety & health administration, USA has given a standard (OSHA, 1983) for occupational noise exposure. It mentions that the permissible daily (8-h) exposure to the operator is to be up to 90 db.

Table 4. Permissible daily noise exposure as per OSHA - 1983

Duration per day, hours	Sound level, (db)
8	90
6	92
4	95
3	97
2	100
1.5	102
1.0	105
0.5	110
0.25	115

Table 5. Noise measurement without load condition

Engine rpm	Noise level in (db)	Permissible limit
1200	74	90
1500	79	90
1800	86	90

Procedure to apply for noise measurement was according to Indian standard test code value shown in, Table 5.4 and Table 5. The (IS 12207: 1999) recommends that maximum ambient noise at operator's ear level should not exceed 90 db for continuous working of 8 hr. The obtained value of noise measurement reading of power unit is suitable for farmer's body during 8 hr working time.

Vibration measurement

The experimental value of vibration measurement of the developed self-propelled multipurpose power unit operators was measured during load and without load operations. The vibration was recorded by vibration meter, reading show in displacement (μm). The engine rpm are adjusted by tachometer. The purpose of this measurement was to assess exposure to hand-arm vibration in power unit operator. The hand-arm vibration measurement was done according to the standards ISO 5349-1 and ISO 5349-2. The obtained results indicated that the exposure level in three dimensions X, Y and Z consecutively result show that vibrations were the same in all three measurements. Measurements were performed on a vibrating surface as close as possible to the grip center of power unit handle and chassis. Vibration assessment was done according to ISO 5349 standard.

Displacement (μm) of vibration in three directions x y and z

Total hand-arm handle and chassis vibration: The actual test results of average total hand-arm and chassis vibration in load and without load operating of power unit users are in Table 7 and Table 8.

Evaluation of vibration: The value of vibration is specified in the relevant standards. Whole body vibration is evaluated by calibrated graph chart of ISO 2954-1975 value in displacement (µm) exposure limit of safe limit of whole-body vibration ranges. According to (IS 12207:1999)

Steering handle – 100 – 150 µm.

Chassis – 200- 300 µm.

Table 7. Vibration (in µm) measurement without load (standing) condition

Mode	Engine rpm	Measurement direction	Vibration in chassis (µm)	Vibration in handle (µm)	Permissible value ISO 2954-1975 In (µm)
Idle rpm	1200	X	226	153	Very Good 100 -150
		Y	230	156	
		Z	227	155	
Rated rpm	1500	X	217	130	Good 150 -200
		Y	219	133	
		Z	217	128	
Maximum rpm	1800	X	198	126	Slightly rough 200 - 400
		Y	202	127	
		Z	198	118	

Table 8. Vibration (in µm) measurement with load (movable speed 2.5 km/hr) condition

Mode	Engine rpm	Measurement direction	Vibration in chassis (µm)	Vibration on handle (µm)	Permissible value ISO 2954-1975 In (µm)
Idle rpm	1200	X	217	130	Very Good 100 -150
		Y	219	133	
		Z	217	128	
Rated rpm	1500	X	198	126	Good 150 -200
		Y	202	127	
		Z	198	118	
Maximum rpm	1800	X	197	121	Slightly rough 200 - 400
		Y	198	123	
		Z	193	115	

CONCLUSION

On the basis of above it can be concluded that the 5hp self-propelled power unit developed under the project is a low-cost power unit which can efficiently be used for various tractive and stationary work and such power unit is found to be most useful prime mover for small and medium farmers. Due to the change of power engaging system and reduction of linkages reduced the operator's drudgery. Due to the use of additional wheel the traction is improved under the wet land soil condition and on ploughed land having higher number of clods. Due to the use of isolator the vibration remains with the permissible level. This power unit can be used for variety of operation that too where ever it is needed.

As there is no complex component so it can be assembled and fabricated even by the local artisans.

Fig. 13. By-stander test for noise

Fig. 14. Vibration measurement at standing position

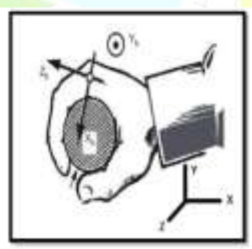


Fig 15 Axes of the acceleration components

Fig 16 Directions X, Y and Z in this study

Fig 17 Vibration in handle

Fig 18 Vibration in chassis

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