



Keywords

Mechanical,
Shaft,
Design,
Agricultural,
Machineries and Analysis

Received: September 19, 2014

Revised: November 07, 2014

Accepted: November 08, 2014

Forms and design analysis of mechanical shafts used in agricultural machineries: A Review

Emmanuel Adeleke Fagbemi^{1,*}, Agbolahan Okeeseni²,
Baldwin Omonigho², Ebike Iseru³, Teddy Akpovwovwo³,
Emmanuel Kayode Awolola⁴

¹Research Operation Department, Rubber Research Institute of Nigeria, Benin City, Nigeria

²Works and Services Department, Rubber Research Institute of Nigeria, Benin City, Nigeria

³Mechanical Engineering Department, University of Ibadan, Nigeria

⁴Mechanical Department, Osun State Ministry of Works, Osogbo, Nigeria

Email address

emmanuel.fagbemi@yahoo.com (E. A. Fagbemi)

Citation

Emmanuel Adeleke Fagbemi, Agbolahan Okeeseni, Baldwin Omonigho, Ebike Iseru, Teddy Akpovwovwo, Emmanuel Kayode Awolola. Forms and Design Analysis of Mechanical Shafts Used in Agricultural Machineries. *International Journal of Agricultural Sciences and Natural Resources*. Vol. 1, No. 5, 2014, pp. 103-106.

Abstract

This reviewed paper looked at mechanical shaft as one of the major components in any agricultural rotating machines, agricultural products processing equipment, and other agricultural machineries such as oil expeller for processing oil producing agricultural seed, dehulling machines of seeds, and tractors. Types of mechanical shafts considered are, line, jack, flexible, axle, and stub shafts. Also discussed are the functions of mechanical shafts which are not limited to transmission of power and torque, design considerations which are not limited to length of the shaft and material selection. Finally design analyses for shaft power, diameter, and shaft stresses enumerated and defined.

1. Introduction

Mechanical Shaft (A drive shaft, driven shaft, driving shaft, propeller shaft (prop shaft), or Cardan shaft) is a mechanical component used in agricultural machineries for transmitting torque and rotation, usually used to connect other components of a drive train that cannot be connected directly because of distance or the need to allow for relative movement between them [2,5]. A shaft is a rotating or stationary component which is normally circular in section and designed to transfer torque from a driving device to a driven device [5]. If the shaft is rotating, it is generally transferring power and if the shaft is operating without rotary motion it is simply transmitting torque and is probably resisting the transfer of power or relative movement between them.

Drive shafts are carriers of torque: they are subject to torsion and shear stress, equivalent to the difference between the input torque and the load. They must therefore be strong enough to bear the stress, whilst avoiding too much additional weight as that would in turn increase their inertia [1, 2].

To allow for variations in the alignment and distance between the driving and driven components, drive shafts frequently incorporate one or more universal joints, jaw couplings, or rag joints, and sometimes a splined joint or prismatic joint.

Cardan shafts are used in some diesel locomotives (mainly diesel-hydraulics, such as British Rail Class 52) and some electric locomotives (e.g. British Rail Class 91). They are also widely used in diesel multiple units. Cardan shafts are also often used in marine

applications between the transmission and either a propeller gearbox or waterjet. On a power-driven ship, the drive shaft, or propeller shaft, usually connects the transmission inside the vessel directly to the propeller, passing through a stuffing box or other seal at the point it exits the hull. The automotive industry also uses drive shafts at testing plants.

Shafts are subject to combined loading including torque (shear loading), bending (tensile & compressive loading), direct shear loading, tensile loading and compressive loading. Therefore, the design of a shaft must include consideration of the combined effect of all these forms of loading. The design of shafts must include an assessment of increased torque when starting up, inertial loads, fatigue loading and unstable loading when the shaft is rotating at critical speeds (whirling) [1,2].

2. Forms of Shafts

Since shafts take on several different configurations and are used for many different purposes, the forms of mechanical shafts are discussed thus:

2.1. Line Shaft (or Power Transmission Shaft)

Line Shaft is a shaft connected to a prime mover which transmits power to a number of machines – now mostly superseded by machines having individual motors.



Figure 2.1. Line Shaft

Source:
http://upload.wikimedia.org/wikipedia/commons/thumb/1/16/Line_shaft.jpg/400px-Line_shaft.jpg

Figure 2.1: shows that the overhead line shafts run continuously and individual machine can be stopped only by moving the flat drive belts from the driving pulley onto a free-running pulley. Note the large timber construction of the building, allowing significant flexing of the structures under load.

2.2. Jack Shaft

Jack Shaft is a short shaft used to connect a prime mover to a machine or another shaft. It may also be a short shaft

placed as an intermediate shaft between a prime mover and driven machine. Figure 2.2 shows a Jack Shaft function as part of a drive system to provide a decrease in rotational speed from the electric motor (at top left) to the jack shaft, then a second reduction in speed between the jack shaft and the two driven components (not visible).

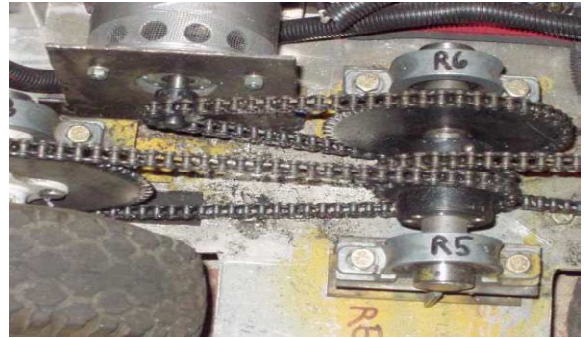


Figure 2.2. Jack Shaft.

Source: <http://www.teamkiss.com/lunch/jackshaft.jpg>

2.3. Flexible Shaft

Flexible Shaft permits the transmission of power between two shafts (e.g. motor shaft and machine shaft) whose rotational axes are at an angle or where the angle between the shafts may change. In general, flexible shafts are not used to transmit high powers or high speed.



Figure 2.3. flexible Shaft.

Source:
http://www.szwholesale.com/uploadFiles/Japanese%20flexible%20shaft_

2.4. Axle Shaft

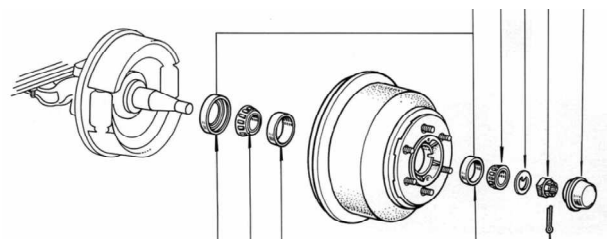


Figure 2.4. Axle

Source: Toyota Dyna & Coaster Repair Manual, 1978, page 5-7

Generally, axle shaft is a stationary member used as a support for rotating members such as bearings, wheels, idler gears, etc.

2.5. Spindle Shaft

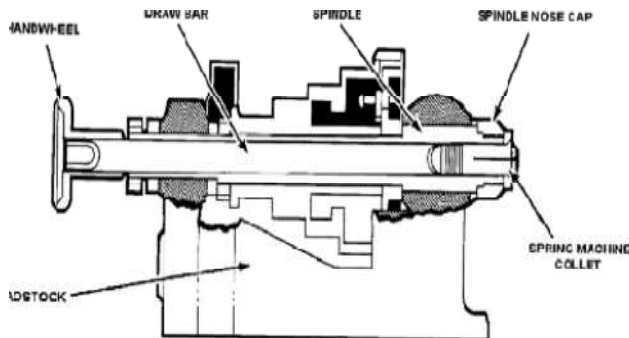


Figure 2.5. Spindle

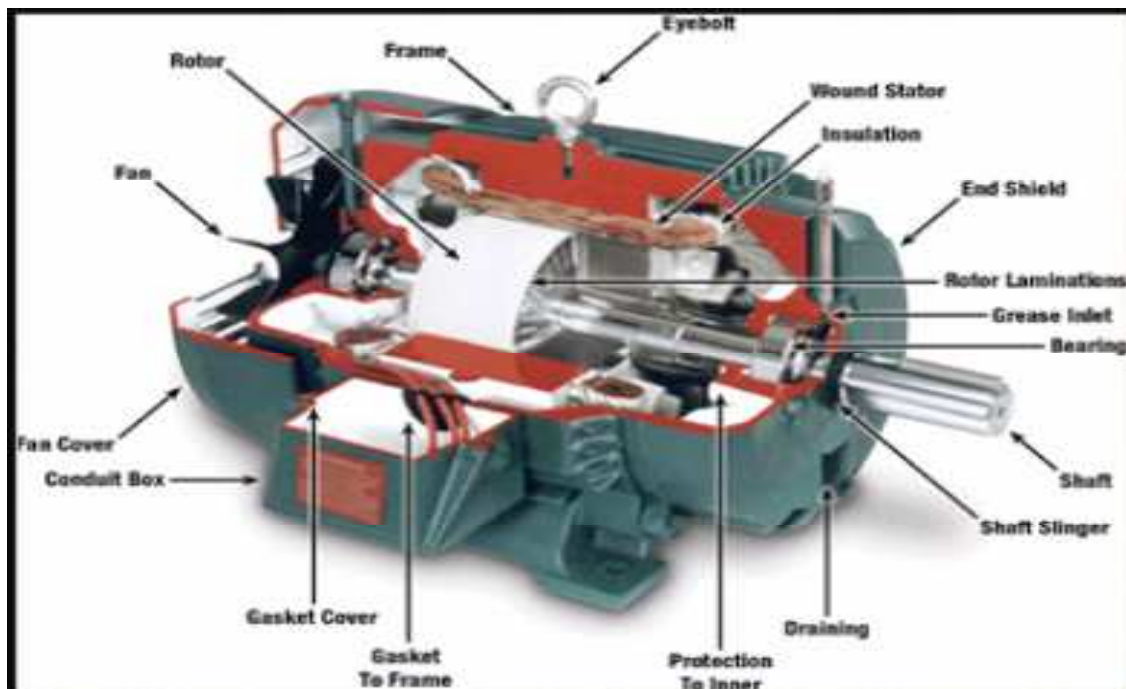
Source:

<http://www.google.com.au/search?client=safari&rls=en&q=headstock+spindle+pictures>

Spindle is a short shaft, usually of small diameter and rotating, e.g. valve spindle for gate valve. However the headstock spindles of a lathe, which is quite large and usually has a hole right through its centre.

2.6. Stub Shaft

Stub Shaft is a shaft which is integral with an engine, motor or prime mover and is of suitable size, shape and projection to allow its easy connection to other shafts.



Source: http://www.naw.co.za/motors_files/diagmotor.gif

Figure 2.6. Electric motor showing stub shaft

3. Shaft Design

3.1. General Considerations

When designing shaft, the following must be considered;

1. To minimize both deflections and stresses, the shaft length should be kept as short as possible and overhangs minimized.

2. A cantilever beam will have a larger deflection than a simply supported (straddle mounted) one of the same length, load, and cross section; therefore straddle mounting should

be used unless a cantilever shaft is dictated by design constraints.

3. A hollow shaft has a better stiffness/mass ratio (specific stiffness) and higher natural frequencies than a comparably stiff or strong solid shaft, but will be more expensive and larger in diameter.

4. Try to locate stress-raisers away from regions of large bending moment if possible and minimize their effects with generous radii and relief.

5. General low carbon steel is just as good as higher strength steels (since deflection is typically the design

limiting issue).

6. Deflections at gears carried on the shaft should not exceed about 0.005 inches and the relative slope between the gears axes should be less than about 0.03 degrees.

7. If plain (sleeve) bearings are to be used, the shaft deflection across the bearing length should be less than the oil-film thickness in the bearing.

8. If non-self-aligning rolling element bearings are used, the shaft's slope at the bearings should be kept to less than about 0.04 degrees.

9. If axial thrust loads are present, they should be taken to ground through a single thrust bearing per load direction. Do not split axial loads between thrust bearings as thermal expansion of the shaft can overload the bearings.

10. The first natural frequency of the shaft should be at least three times the highest forcing frequency expected in service, and preferably much more. (A factor of ten times or more is preferred, but this is often difficult to achieve).

3.2. Shaft Power

Power is the time rate of change of energy, power = torque angular velocity

$$P_{wr} = \omega \times \text{torque} \quad (1)$$

3.3. Shaft Diameter

$$d^3 = \frac{16}{\pi s_s} \sqrt{[(K_b M_b)^2 + (K_t M_t)^2]} \quad (2)[7]$$

Where;

d = Diameter, M_b = Max. Bending Moment,

M_t = torsion moment = T_R ,

K_t = combine shock and fatigue factor as applied to torsion; range from 1.5-2.0 for rotating shaft ASME code

$K_b = 1.75$ selected, K_b = combine shock and fatigue factor as applied to bending; range from 1.0-1.5 for rotating shaft ASME code

$K_b = 1.45$ = selected, S_s = Shear Stress (constant) = 45 MPa [8]

3.4. Shaft Stresses

3.4.1. Bending Stress

$$\sigma = k \frac{Mc}{I} \quad (3)$$

Where, k = stress concentration factor, M = bending moment, c = distance from neutral axis to the outer most

fibre, and σ = bending stress.

3.4.2. Torsion Stress

$$\tau = k \frac{Tr}{J} \quad (4)$$

Where, T = Twisting Moment/Torque acting upon the shaft, r = Distance from neutral axis to the outer-most fiber, J = Polar Moment of Inertia of shaft about the axis of rotation, and τ = Torsion Shear Stress.

4. Conclusion

In developing countries today, machines and equipment are designed and fabricated locally for processing agricultural products and manufacturing purposes, such machineries or equipment to mention but view are; Oil Expeller, Seed Sheller, Dehulling Machines, and Hammer Mill. All these machines and equipment has shaft as major component to transmit power, torque and accommodate members like gear, bearing and pulley. Types and area of applications of different shafts has been explained in this paper to help engineers in designing an efficient machines or equipment and as well increases life span of these equipment.

References

- [1] Robert L. Norton (2000): *Machine Design- An Integrated Approach*, 2nd Edition, Prentice Hall.
- [2] Orhan h. Yildiran: *MECE 304 Mechanical Machine Elements Shafts - Shafts and Shafts Components*, Lectures Notes, McGraw – Hill Companies.
- [3] REXNORD – Failure Analysis, Installation and Maintenance (*Gear, Shafts, Bearings, and Seals*).
- [4] www.pump-zone.com: Cynods Nyberg, *EASA Understanding Factors that Causes Shaft Failures*
- [5] Drive shaft: *Wikipedia, the free encyclopedia* (retrieved 2013)
- [6] (PVT) LTD, Ramnagar, New Delhi.
- [7] R.S. khurmi and J.K Gupta, 2004, *Theory of Machine*, Eurasia Publishing House (PVT) LTD, Ramnagar, New Delhi-110055.
- [8] R.S. khurmi and J.K Gupta, 2008, *Machine Design*, Eurasia Publishing House. 509-557