Discussion Group: 3

ME3200 Machine Design Project

Semester 5

Gear Box for A Mushroom Substrate Mixer

Initial Design

By

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1 Initial Design of the Mushroom Substrate mixer

1.1 Introduction

Mushroom cultivation is mostly done at household level as a small business. It is a profitable business if done correctly. So, in this project aim is to design a gearbox for a mushroom substrate mixer. Because lot of machines made for paddy particles. I am going to design a machine for sawdust.

Oyster mushroom can be cultivated in any type of lingo cellulose material like straw, sawdust, rice hull. There are lots of growing mixture can be use. In Sri Lanka For 50 kg mixture use Saw dust (strew paddy) (20kg), Rice bran (3kg), Cao (400g), Soya flour (400g), MgSO4 (40g).[1]

In the industry there are lot of mushroom mixture machine, made for paddy. As my specimen I use Satrise-STM 2 machine. This machine use motor as a prime mover. following are the design parameters.

Container length	2100mm
Container wight	800mm
container thickness	20 gauge
Central shaft	40mm diameter *2100mm length
Blade length	600mm *10
Container hight	1100mm

Table 1- Design parameter

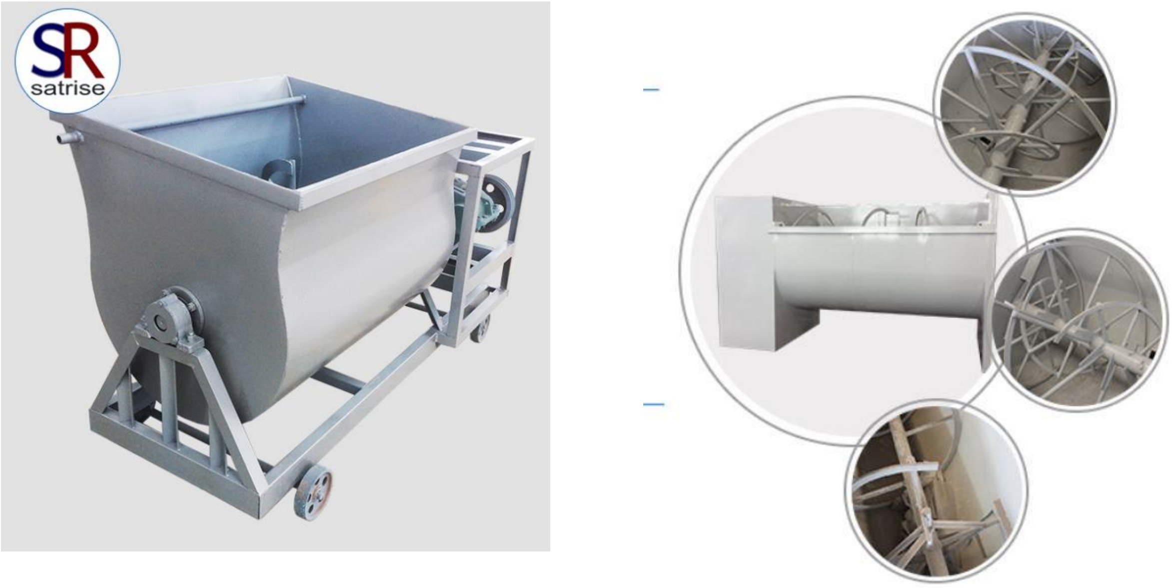

Figure 01-Substrate mixer

Product Parameters

Model	Specification	Power	Capacity	Weight
STM-1	1750*920*1260mm	2.2/3KW	100kg/time	260kg
STM-2	2100*850*1100mm	4kw/3phase	500kg/time	320kg
STM-3	2800*850*1100mm	4kw/3phase	500kg/time	380kg
STM-4	2800*900*1100mm	5.5kw/3phase	300kg/time	460kg
STM-5	2800*1200*1600mm	7.5kw/3phase	500kg/time	500kg
STM-6	4300*1800*2300mm	18kw/3phase	900kg/time	750kg
STM-7	4500*1800*2600mm	18kw/3phase	1300kg/time	750kg
STM-8	1200*700*700mm	4kw/3phase	500kg/time	220kg
STM-9	1200*700*850mm	8 horsepower	900kg/time	220kg

Figure 02-product parameters

My plan to design to use my gear first gear (hight speed low toque) wood sawdust mixture. Because there can contain some moisture content. So first we want to mix that moisture content.

Some country use hardwood pellets. In that situation we can use first gear to chop it into small particles like wood sawdust.

Figure 03 - Hardwood pellets

My second gear I plan to use after including other substances. Because there is a weight change in this mixture.so want more power to mix. 100kg mixture want to add 19kg substances.

My third gear (low speed hight toque) plan to use after including water to the mixture. Water requirements for a 100Kg substrate are 50L.

In my reverse gear is used to cleaning purpose. It should always be washed after working with this device so that all the mixture partial attached to the floor of this device is clean and free of any material. most mixture machines used today. the drum is cleaned manually. Therefore, it is important to have a reverse gear in the mixer. And another problem is how to get rid of this mixed mixture. This is when the need for a reverse gear arises again.

2 Prime mover selection

When we going to select prime mover want to consider maximum load. So, in my case study that in use in my third gear as a maximum.
Assume the mixture container in cylindrical one and center mixing blade like metal bar.

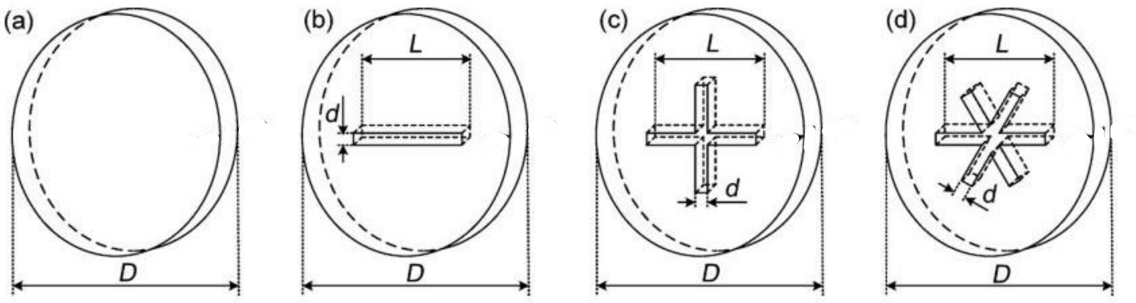

Figure 4

Also, we assume center metal bar section like following.

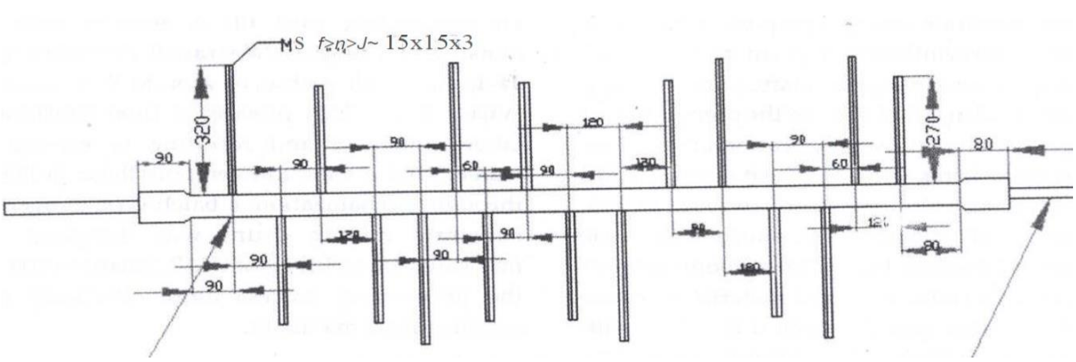

Figure 5

First, we calculate mass of the one bar. For that there is some assumption. I get blades are a constant cross section steel metal bar.

$$mass\ of\ the\ bar = \ \rho_{matal}Al$$

$$\text{Mean radius of blade} = 0.4$$

The density of stainless steel is approximately 7,500kg/m3 to 8,000kg/m3[1]

$$mass = \frac{8{,}000\text{kg}}{\text{m3}} \times (0.02 \times 0.05) \times 0.4$$

Assume there are 10 blades in the machine.

$$mass = \frac{8{,}000\text{kg}}{\text{m3}} \times (0.02\text{m} \times 0.05\text{m}) \times 0.4\text{m} \times 10 = 32\text{kg}$$

$$Substrate\ mass = saw\ dust + other\ indrediant + water$$

$$Maximum\ substrate\ mass = 400 + 19 \times 4 + 50 \times 4 = 676kg$$

$$Total\ mass = 676 + 32 = 708kg$$

Considering the critical moment of blade in third gear the mass in the mixture is maximum. Using paddy mixture machine date in internet. We can get the requested rpm for the mixture.

“A substrate mixer drum was developed and tested for pre-wetting of substrate in batch mode (Fig. 2). The capacity of substrate mixing drum was 30 kg dry weight of wheat straw/paddy straw. The initial moisture contents of air-dried wheat and paddy straws were at 10.7%and 9.6%, respectively. The effect of drum rotation speed and mixing time on substrate moisture content is shown in Figure 3. The highest moisture content (75.1%) was obtained for wheat straw for the 35rpm rotational speed and 15 min mixing time, whereas the minimum moisture content (40.2%)was found in 15 rpm drum speed and 5 inmixing time. This might probably be due to highest rotational speed imparting the mechanical actions like shredding, trampling, rubbing etc.”[2]

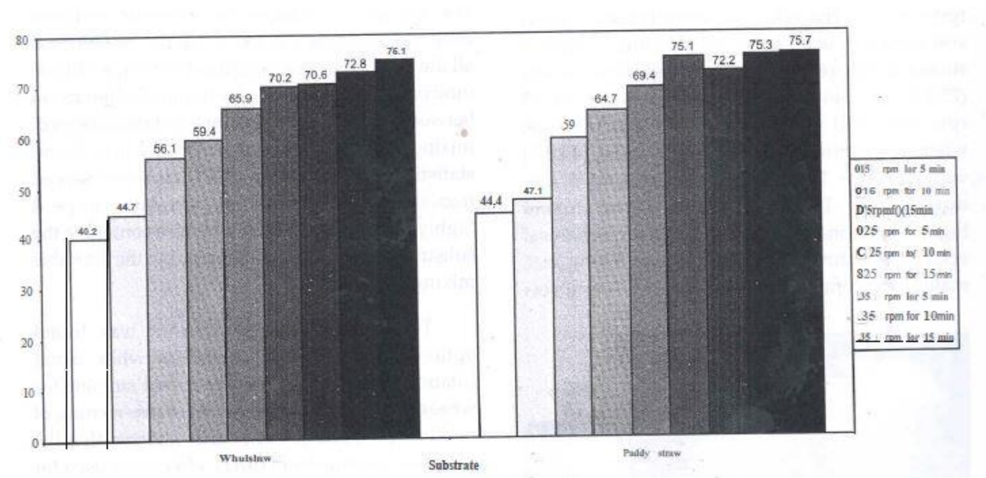

Figure 06

For the batter mixture, want to include water moisture content is 75.1%. There for it want to reach speed 35 rpm.

Also, we can assume haff of the mass acting as a point mass at the diameter of the cylinder.

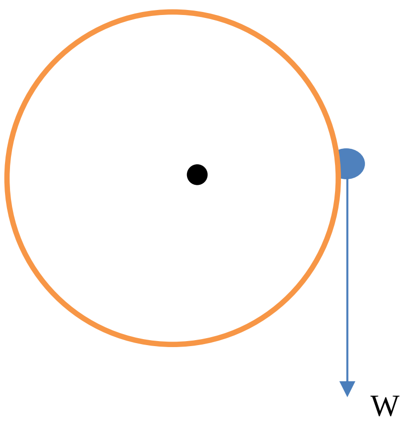

Figure -07

We can calculate requested toque using above assumption like in figure 07.

$$\tau = W \times R$$

$$\tau = \frac{708}{2} \times 9.81 \times 0.4 = 1389.096\, Nm$$

There is maximum rpm 35rpm

$$anguler\ velocity = 35\ \times \frac{2\pi}{60} = 3.6652\, rads^{-1}$$

$$Mix\ power\ want\ to\ mix =\ \tau \times \omega = 1389.1Nm \times 3.6652rads^{-1}$$

$$= 5091.31Kw$$

Considering power loss and other things as a service factor (1.4)

$$5091.31 \times 1.4 = 7127.834kw = 7.128kw$$

So according to above calculation a 7.5 kW motor is enough to do this mixing process.

Figure 08- selected motor

Marelli - High Efficiency 132 Frame 7.5kW 3ph 4 Pole Face Mounting AC Motor for 400V x 50Hz 3 phase supply. Use with Variable Frequency Drives, or a fixed frequency mains supply at 50Hz.

SPECIAL PRICE AVAILABLE FOR STOCK ONLY

Fixed mains supply output: 7.5kW (10HP) x 1465RPM at 400V x 50Hz 3ph.
Inverter Supply Output: 15:1 Speed Control range from 147RPM to 2198RPM for 5Hz to 75Hz, with suitable de-rating at the lower speeds.

Full Load Current - 14.8A at 400V.
Power Factor is 0.82 when mains connected at 50Hz.
Efficiency is 89.3% at full load.
Terminal Box for 2 x M25 Glands.

259mm Wide x 505mm Long x 332mm high overall in its IP55 enclosure.
Face mount on M10 tapped holes at 165mm PCD with 130mm diameter register in the 200mm diameter flange.
Shaft is 38mm dia x 80mm with 10mm wide key.
Weight is 62kg.

Rated at 40C Ambient.
Ventilation space required at rear cooling air intake.

Part number is - MAQ132SB4-B14 (MAQ 132 SB4-B14)

Figure 09 - motor parameters

3 Power transmission methods

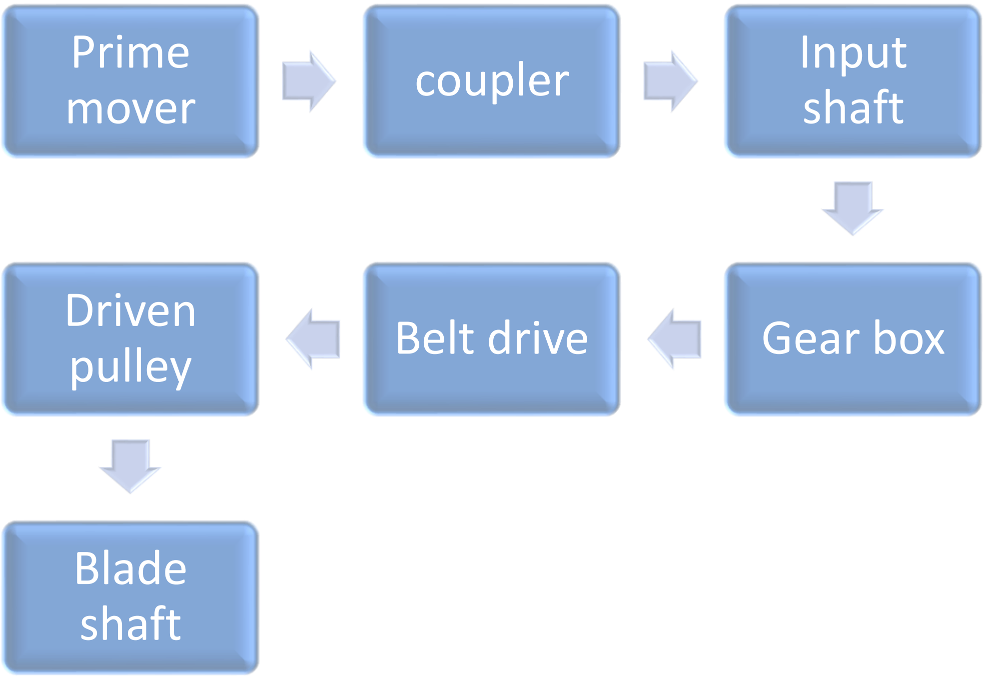

Figure 10- Power Transmission methods in flow chat

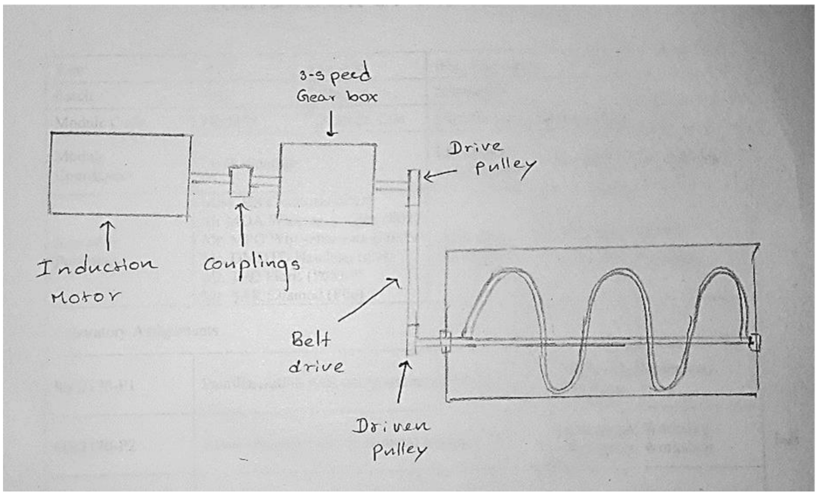

Figure 11-Power Transmission methods in actual chart

Also bearing used for smooth gear reducing. There are two bearing use in drum.

3.1 Coupling selection

Coupling is needed to join motor and gearbox because motor and gearbox are designed as two different parts and we need a method to connect the two shafts. Rigid coupling is used due to high efficiency (no slip) resulting excellent torque transmission, low cost of production and high precision.

Figure 12 - Rigid Couple [3]

3.2 Keyed shafts

Keyed shafts are used to fix the pulleys to the shafts as they are cheap to manufacture, good for medium torque transmissions and importantly it is easy to disassemble which will be useful with regular maintenance of belt drives. Axial forces are minimum as spur gears are used (Helical gears will generate axial forces as gear teeth are angled) in the gearbox. Therefore, keyed shafts will be best suited to connect the pulley shafts.

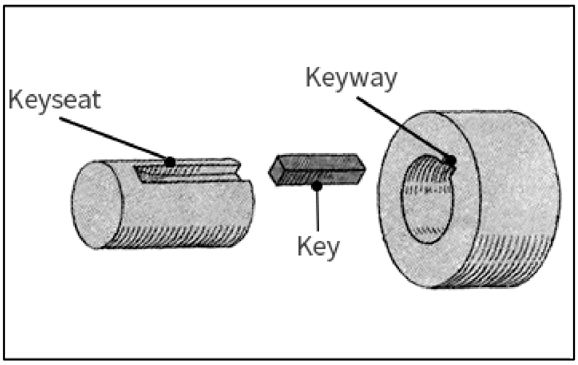

Figure 13 - Keyed Shaft [4]

3.3 Bearing

4 Gearbox and layout

4.1 Gearbox type selection

Gearbox types such as sliding mesh, constant mesh and synchro-mesh are the types that are available in the industry. Most of the automotive and locomotive applications use constant mesh and synchromesh type gearboxes because it allows them to shift gears while moving thus achieve higher speeds. In earlier stages of automotive industry, sliding mesh type gearboxes are used.

Sliding mesh gearbox is selected because the mechanism is very simple and easy to design and cheap to manufacture. And, in this type of gear box fluctuating loads are less in a sliding mesh as only one gear is meshed at a time. Although efficiency of constant mesh and synchronous mesh type gear box has higher efficiency than sliding mesh gear box, designing, manufacturing, and assembling is difficult in constant mesh and synchronous mesh type gear boxes.

The major issue of sliding mesh gear box is the fact that speeds of the input and output shafts should matched when changing gears. Otherwise, gearwheels do not align and crash into one another. This will not be a problem as our application does not require to change gears will in the move.**[5]**

4.2 Layout

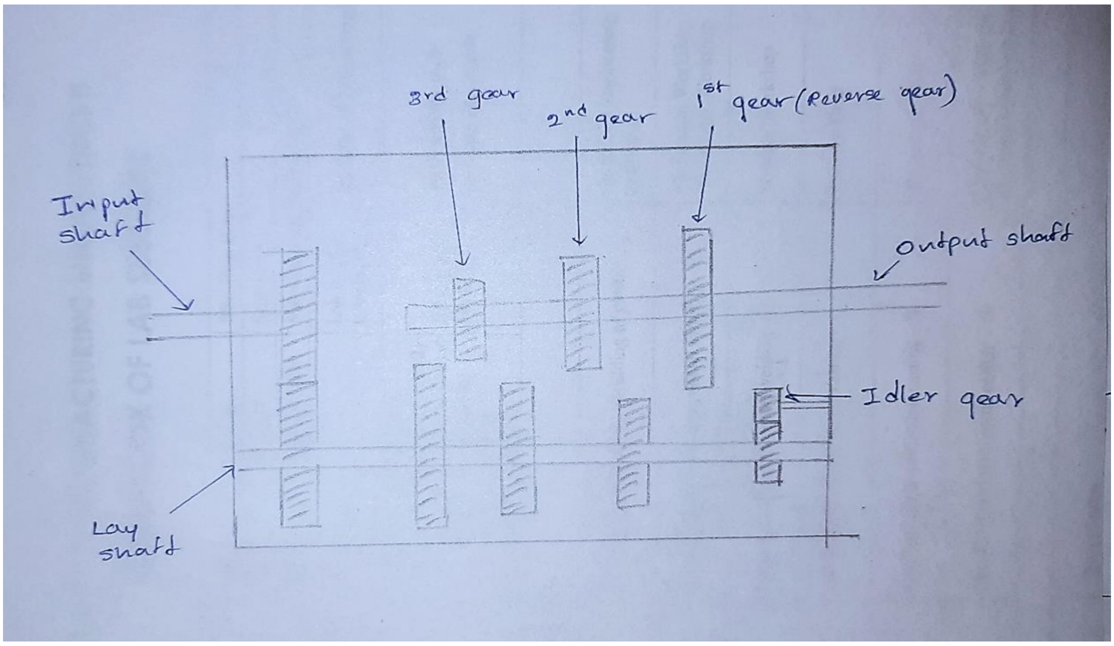

Figure 14 - Layout

4.3 Gear Shifting Layout

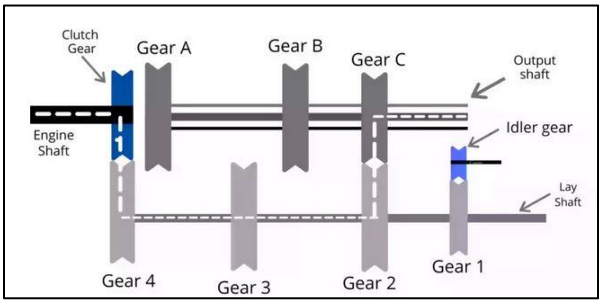

Figure 16 - First Gear[6]

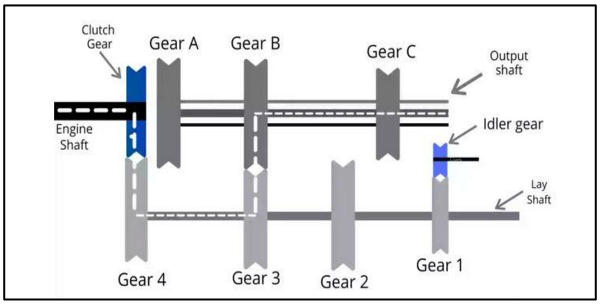

Figure 17 - Second Gear[6]

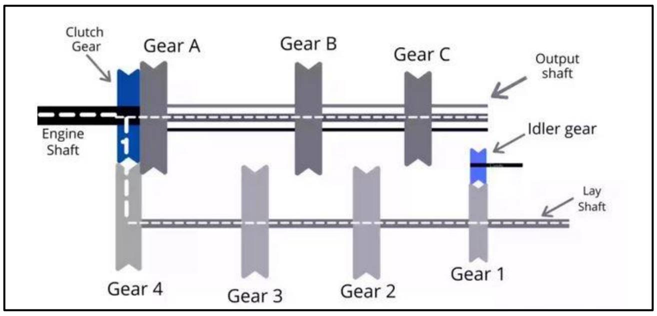

Figure 18 – Third Gear[6]

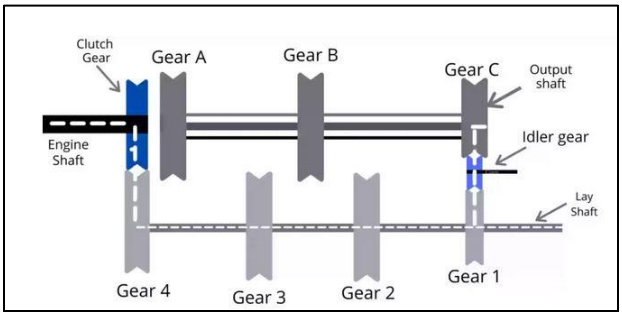

Figure 19 - Reverse Gear[6]

First, second, third and reverse gears are shown above respectively. In forward gears on output shaft will mesh with gears on lay shaft as usual. In reverse gear on the output shaft will mesh with idler gear and reverse gear on lay shaft will always be meshed with the idler gear.

4.4 Gear ratio selection

mass	708kg	508kg	432kg
toque	1389.01Nm	996.69Nm	847.584Nm
power	7.5KW	7.5KW	7.5KW
Service factor	1.4	1.4	1.4
Angular velocity	3.8588	5.3778	6.3238
Motor output rpm	1172.5	1172.5	1172.5
Motor output velocity	122.78	122.78	122.78
Full reduction	31.81	22.83	19.41
Gear reduction	2.12	1.522	1.294

Assume belt reduction =5 and lay shaft reduction =3

4.5 Gear type selection

Since sliding mesh gear box was selected, spur gear type is most suitable gear type . spur gears are very simple and compact therefore it is make easy to design , manufacturing and assembling . in other hand this type of gears changes the shaft speed with high accurate at a constant velocity. And another advantage of spur gear is reliability. Spur gears have a low risk of premature failure since they are durable and unlikely to slip during operation. the other major advantage of using spur gear in this application is cost effectiveness. The simplicity of design and manufacturing make less expensive to fabricate and purchase. in other hand efficiency of spur gear is very high. In number it is between 95%-99%.

5 Lubrication method selection

Lubrication of gears is an essential part of a gearbox. Adequate lubrication provides,

- Less friction
- Proper cooling
- Optimum performance
- High mechanical efficiency and reliability
- High lifespan and low maintenance

Most used lubrication methods for the gearboxes are grease lubrication, splash lubrication and spray lubrication [7].

Grease lubrication is the most suitable for low-speed gears. For proper lubrication right amount of grease is needed and it should have proper viscosity. For heavily loaded gears, grease lubricant is not recommended. Grease does not provide the required cooling for gears[7].

In **splash lubrication**, an oil bath is used, and oil is circulated in gears. The proper amount of oil level must be maintained in the oil bath. Otherwise, an extra power is needed for gears to pass through the oil bath and churning effect might be detrimental for heat transfer. This method only lubricates the gear teeth and if other locations need to be lubricated, separate oil jets need to be used with a pump [8] .In my case splash lubrication is most suitable.

Spray lubrication is also known as forced lubrication. Oil jets are designed and aimed at desired locations and dripped oil is collected in an oil bath. This is effective for high-speed applications. But there might be some locations that cannot be lubricated using this method. Designing of a pump is also required [8].

6 References

[1] “Density of Stainless Steel - thyssenkrupp Materials (UK).” https://www.thyssenkrupp-materials.co.uk/density-of-stainless-steel (accessed Sep. 20, 2022).

[2] T. Arumuganathan, R. Tewari, R. Kumar, and V. Khare, “Development and evaluation of substrate mixing drum for pre-wetting of substrates for button mushroom cultivation,” Dec. 2008.

[3] “Rigid Couplings,” *HMA Group*. https://hmagrp.com/rigid-couplings/ (accessed Sep. 21, 2022).

[4] J. Sabhadiya, “Shaft Key: Definition, Type, and Application,” *Engineering Choice*, Oct. 10, 2020. https://www.engineeringchoice.com/what-is-shaft-key/ (accessed Sep. 21, 2022).

[5] J. Sabhadiya, “What Is Sliding Mesh Gearbox?- Parts And Working,” *Engineering Choice*, Feb. 13, 2021. https://www.engineeringchoice.com/what-is-sliding-mesh-gearbox/ (accessed Sep. 21, 2022).

[6] “Sliding mesh gearbox: Definition, Diagram, Construction, Working with Pdf,” Dec. 25, 2020. https://mechcontent.com/sliding-mesh-gearbox/ (accessed Sep. 21, 2022).

[7] “Gearbox lubrication: What are the best methods?” https://www.motioncontroltips.com/gearbox-lubrication-best-methods/ (accessed Sep. 20, 2022).

[8] A. Stokes, *Manual gearbox design*. Oxford; Boston: Butterworth-Heinemann, 1992.