Manufacturing of a Gearbox

Team 12

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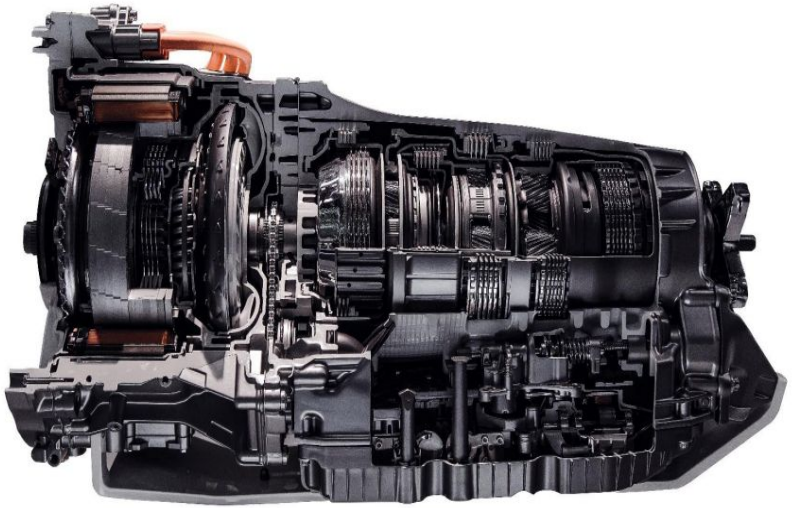
Why a gearbox is necessary

Without a gearbox, the engine of a vehicle would have to be directly connected to the wheels. This would severely limit the vehicle's speed and acceleration, as the engine's rotational speed (RPM) and torque output would not always be well-matched to the speed and torque required by the wheels at any given moment. For example, when starting from a stop, the engine would need to produce a high torque output to overcome the inertia of the vehicle and get it moving. However, once the vehicle is moving, the engine would need to produce less torque to maintain a constant speed.

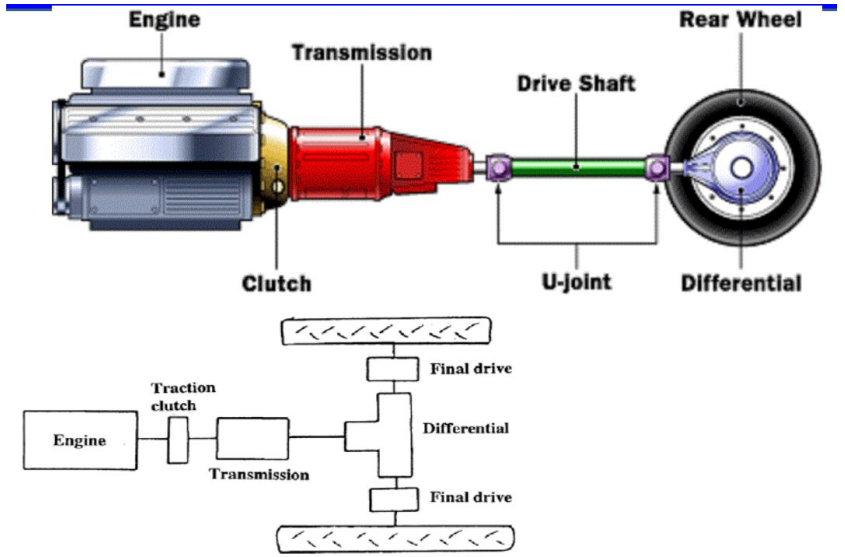
What is a Gearbox

A gearbox, also known as a transmission, is a crucial component of an automobile that enables power to be transmitted from the engine to the wheels. The gearbox is responsible for changing the speed and torque of the engine to match the driving conditions, allowing the vehicle to move forward or backward and navigate different terrains.



Gearbox - Uses

The primary function of a gearbox is to transfer the power generated by the engine to the wheels of the vehicle. However, the gearbox also plays an important role in ensuring the smooth operation of the vehicle, allowing for efficient use of fuel and reducing wear and tear on the engine.

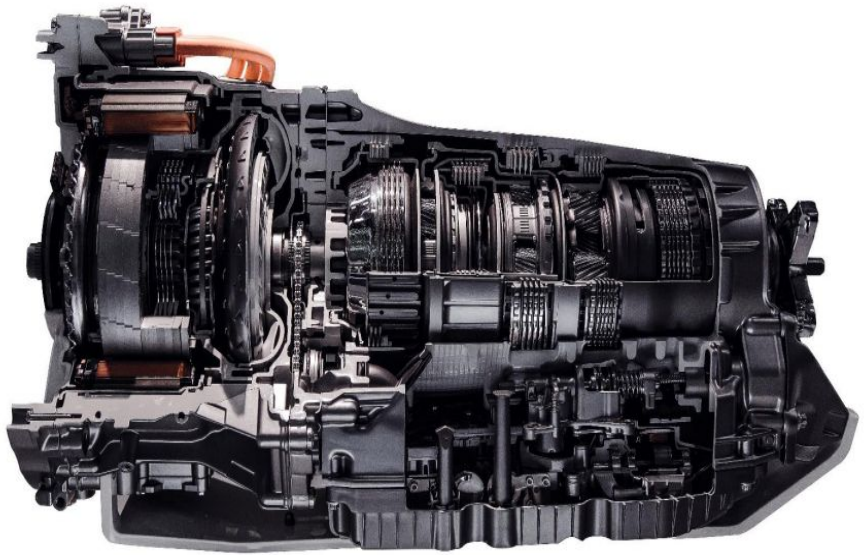


Gearbox - Uses

Additionally, a gearbox allows for the selection of different gears, which in turn provides the driver with control over the speed and acceleration of the vehicle. This allows for a greater range of driving conditions to be accommodated, such as uphill driving or highway cruising.

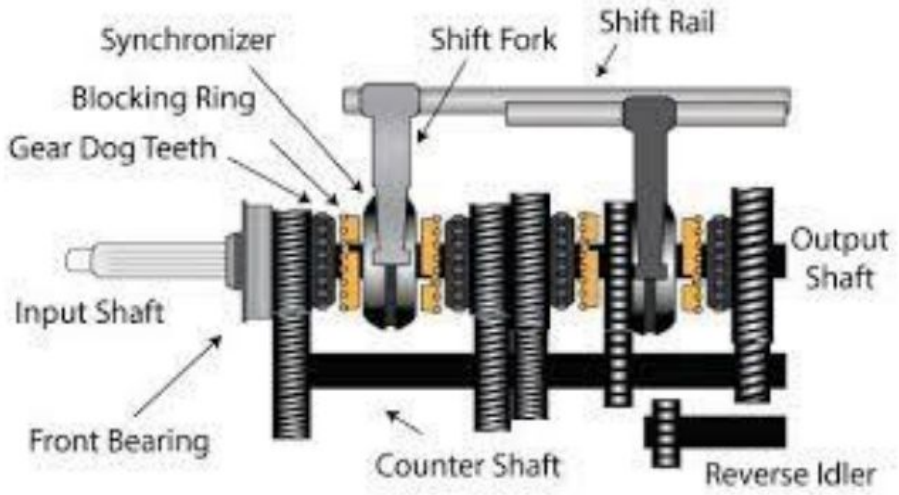
Comprehensive List of Components

1. Input Shaft
2. Output Shaft
3. Main Shaft
4. Counter Shaft
5. Gears
6. Synchronizer
7. Shift Forks
8. Clutch Pack
9. Dog Ring
10. Housing
11. Bearings
12. Seals
13. Gaskets
14. Shims
15. Oil Pump
16. Oil Filter
17. Oil Cooler



Components in our Assembly

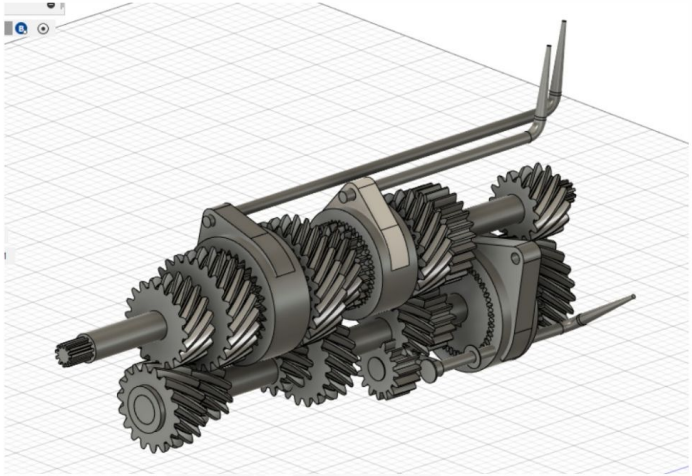
For the purposes of this project, we have chosen to focus on the manufacturing of a simplified gearbox, consisting of only the most vital components, such as gears, shafts, shift rails, synchronizers, syncromesh and the housing. It should be noted that commercial gearboxes typically have a much larger number of components. In this particular case, we have excluded the clutch assembly and focused solely on the transmission.

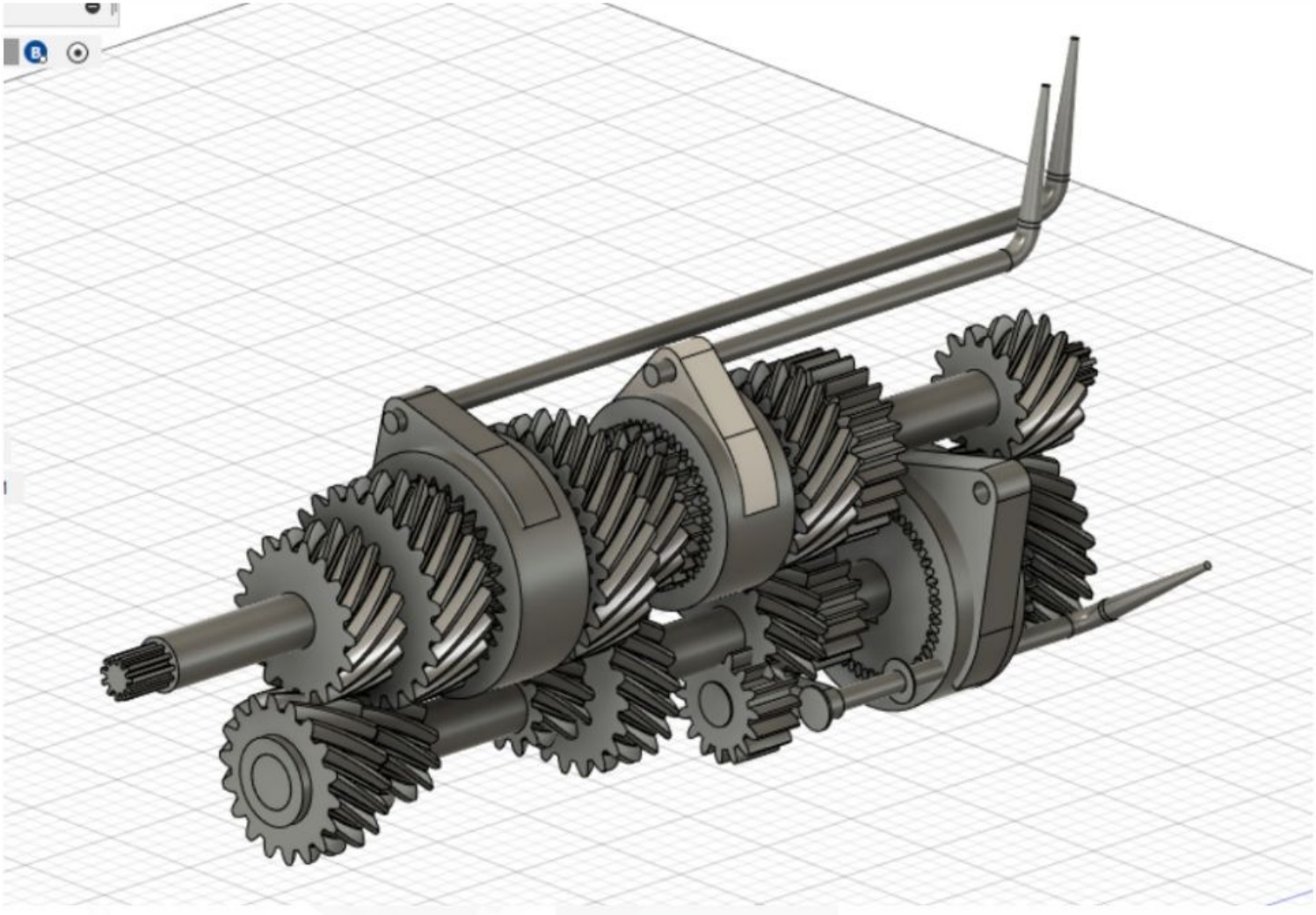


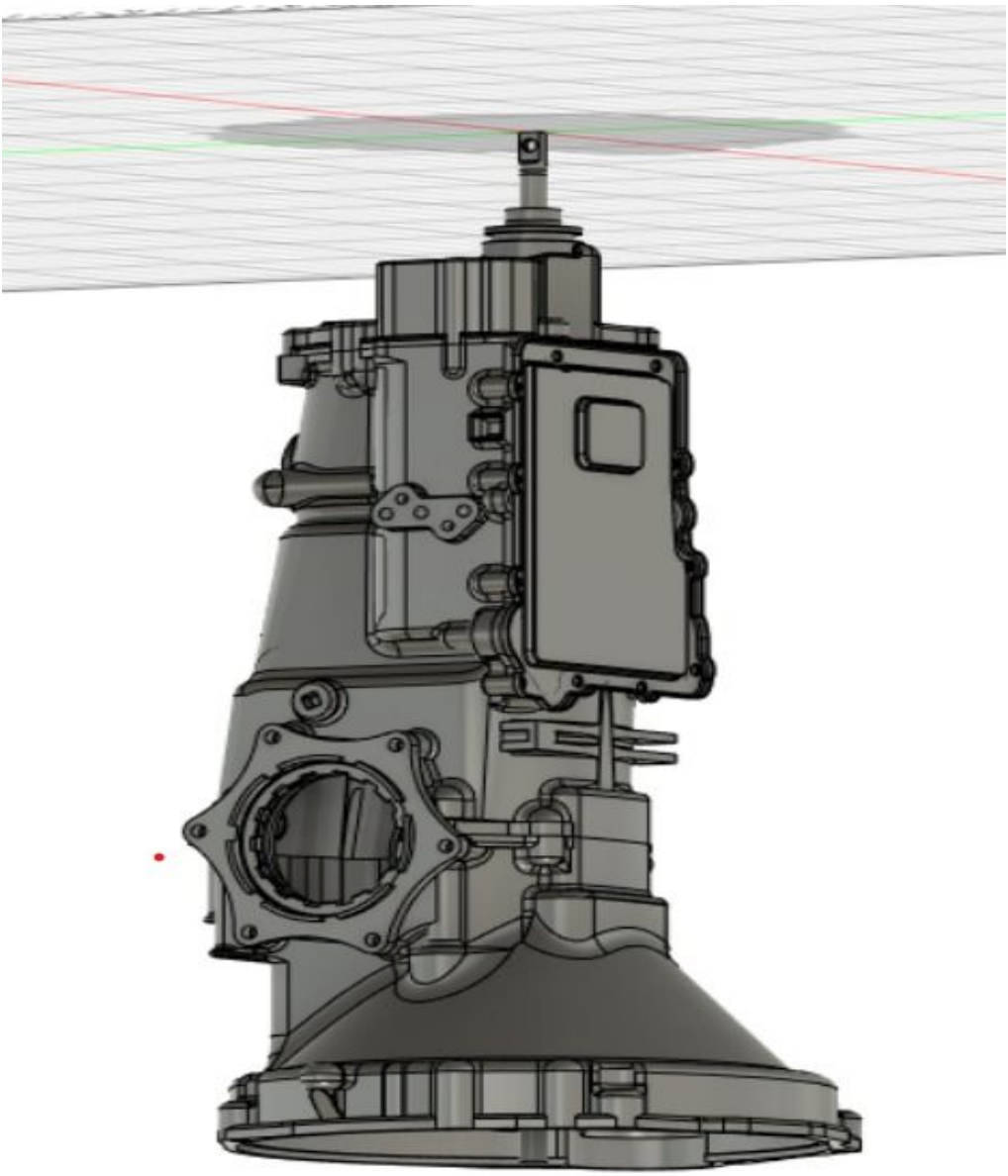
Components in our Assembly

The components we have taken in our model is

1. Shafts (Drive, Lay, Driven)
2. Various gears (Helical & Spur)
3. Synchronizer
4. Dog Ring
5. Shift rails
6. Bearings
7. Housing







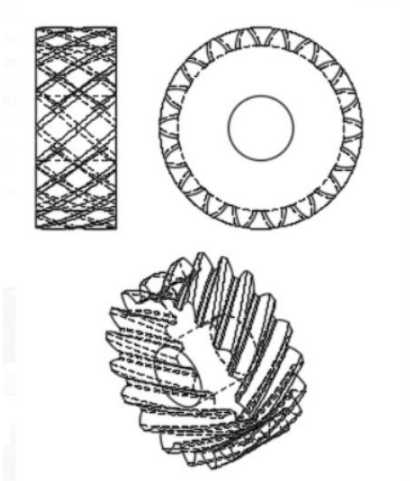
Components - Gears

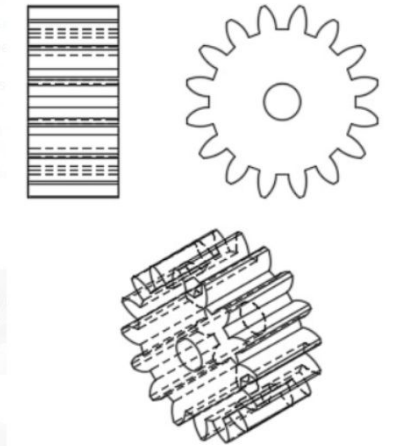
Gears are the most crucial components of a gearbox as they are responsible for transmitting power from the engine to the wheels. They come in various sizes and shapes, and their teeth are designed to mesh with other gears to transmit rotational force.

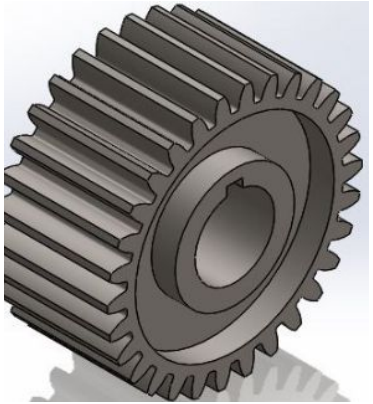
Components - Gears

There are 10 gears used on the shafts here we have chosen two gears (helical and spur) present on the drive gear and as change gear

Different pairs of meshing gears provide different gear ratios.





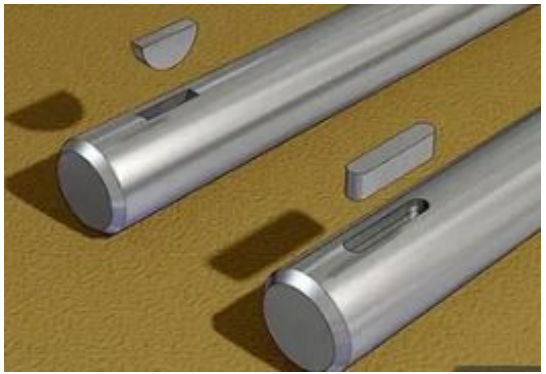


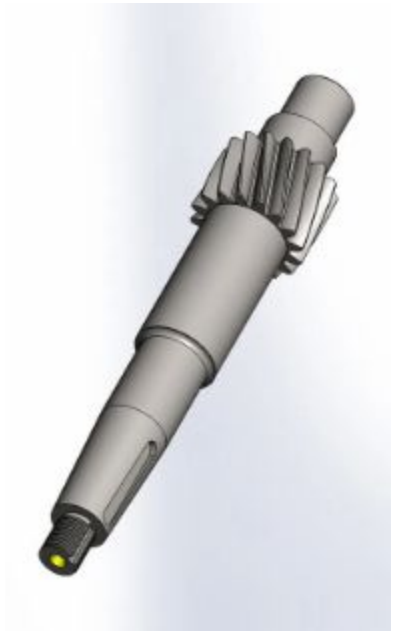
Components - Shafts

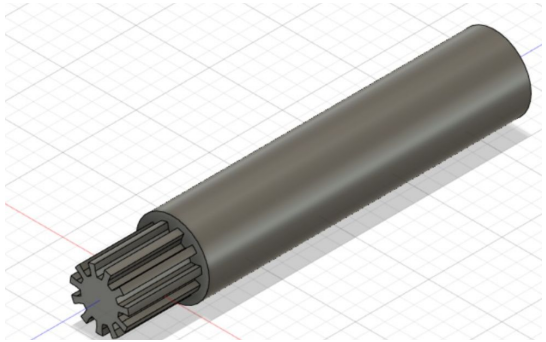
Shafts provide a means of supporting the gears and transmitting rotational force. They are designed to withstand the torque generated by the engine and are often made of hardened steel to ensure strength and durability.

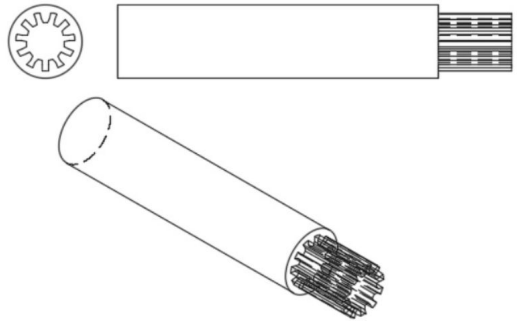
Components - Shafts

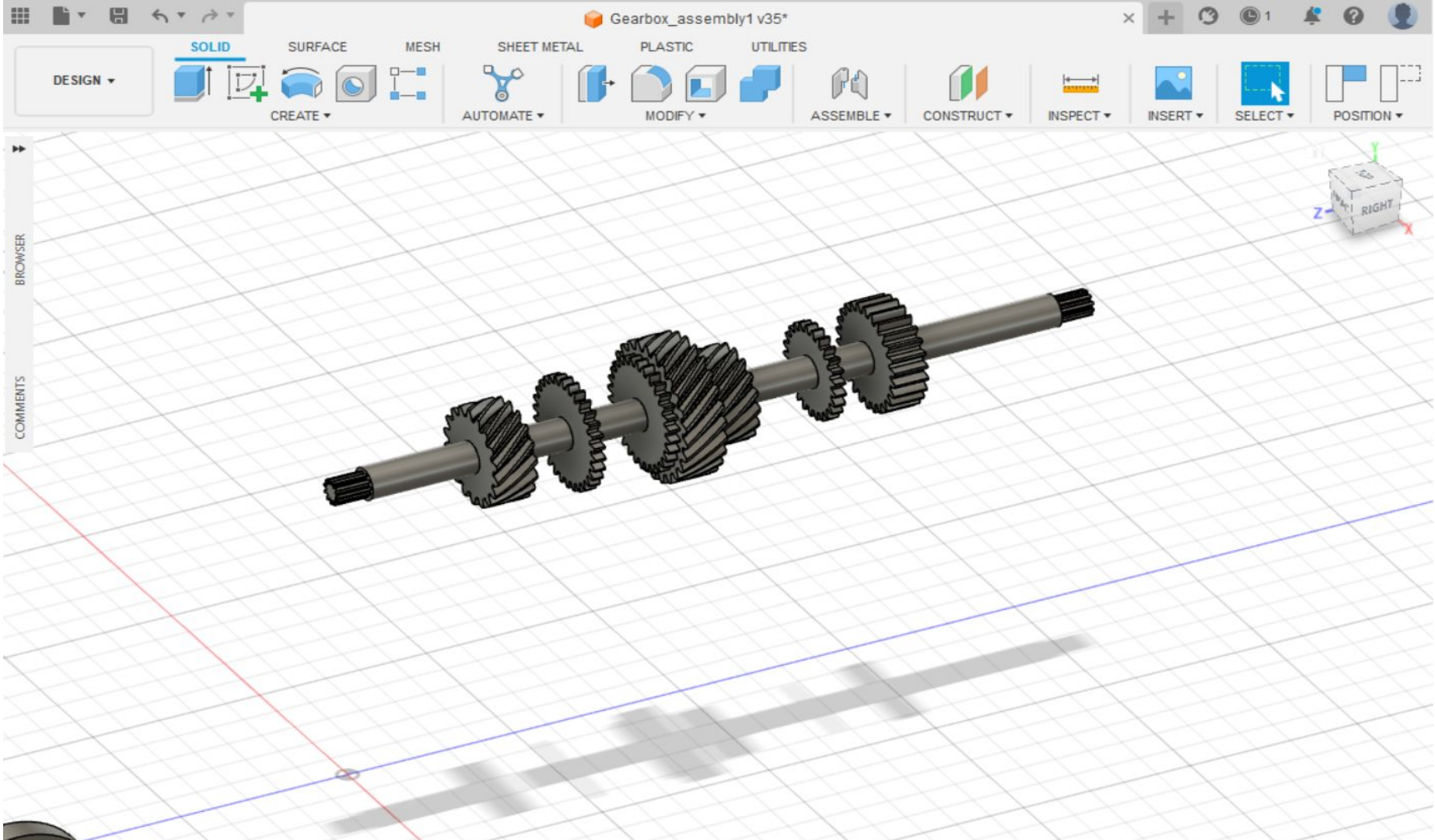
There are 3 shafts, the lay shaft, the drive shaft and the driven shaft. Each have gear attachments at either ends.









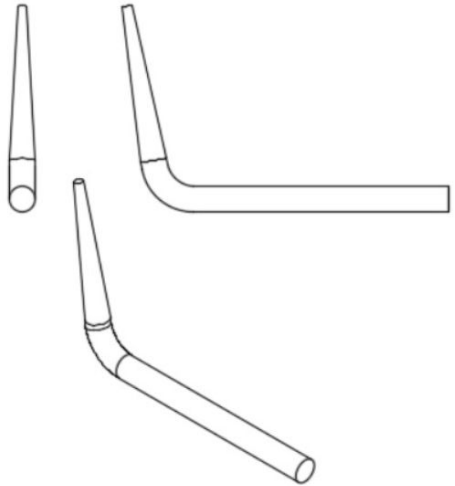

Gearbox_assembly1 v35*
DESIGN
SOLID
SURFACE
MESH
SHEET METAL
PLASTIC
UTILITIES
CREATE
AUTOMATE
MODIFY
ASSEMBLE
CONSTRUCT
INSPECT
INSERT
SELECT
POSITION
BROWSER
COMMENTS
RIGHT

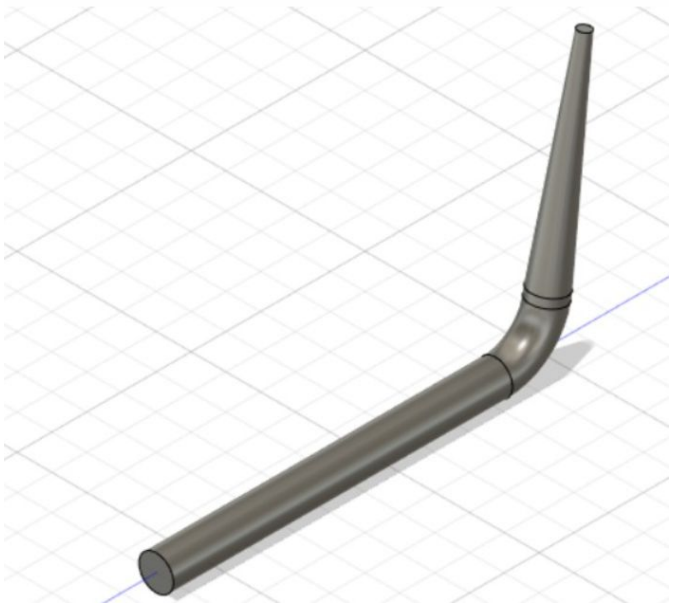
Components - Shift Rails

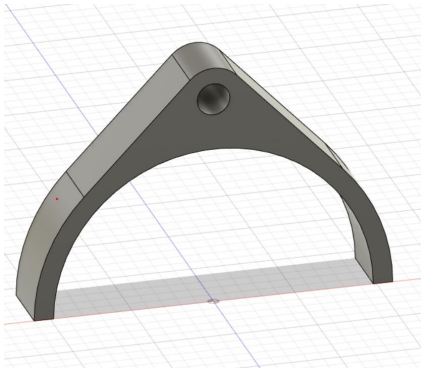
The shift forks are mounted on the shift rails and are operated by the shift lever in the vehicle's cabin. When the driver moves the shift lever, it pushes or pulls the shift forks, which in turn move the synchronizers and engage the gears.

Components - Shift Rails

The end of the shift rail is attached to gear locking mechanism and other end to the gear selection handle



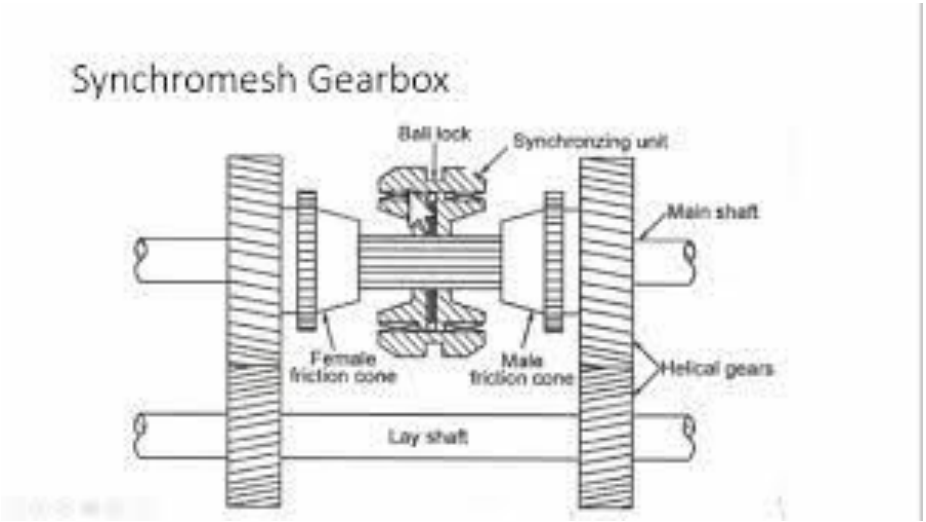




The Shift Fork is used to attach the Shift Rail

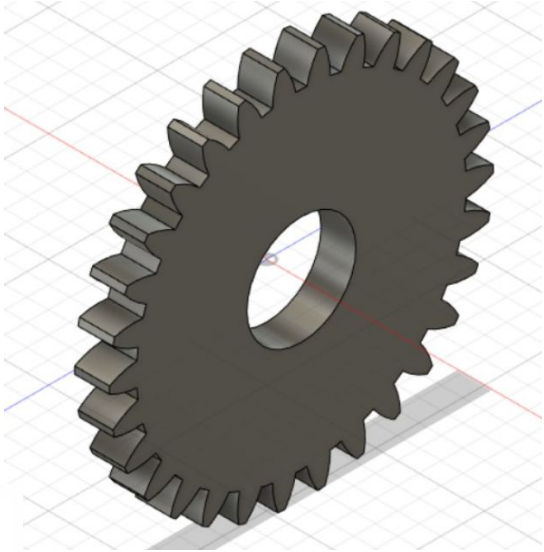
Components - Synchroniser

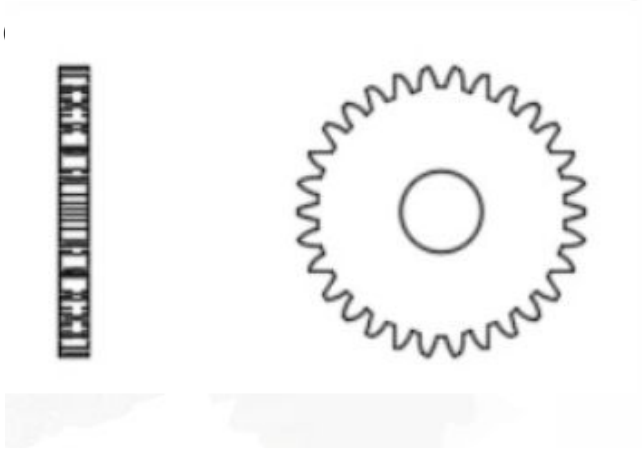
A synchronizer is a component that helps to match the speed of the gears to the speed of the output shaft during gear changes. This helps to ensure smooth and precise shifting, and reduces wear and damage to the gears and other components.



Components - Synchronizer

Given is a simplified version of the synchronizer given as a single component achieving the same function. The inner region will be welded to th hub



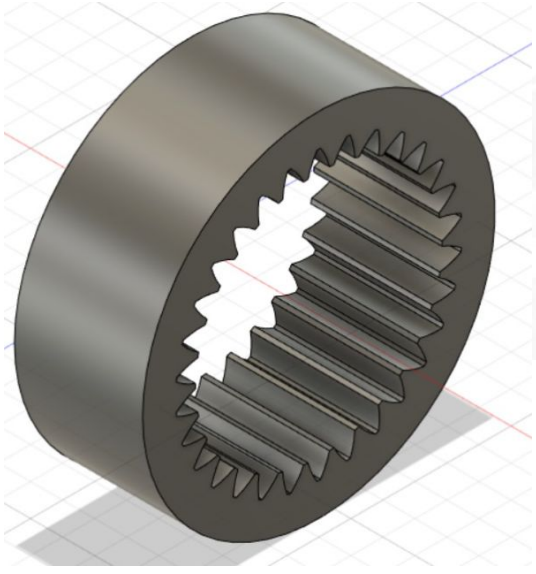


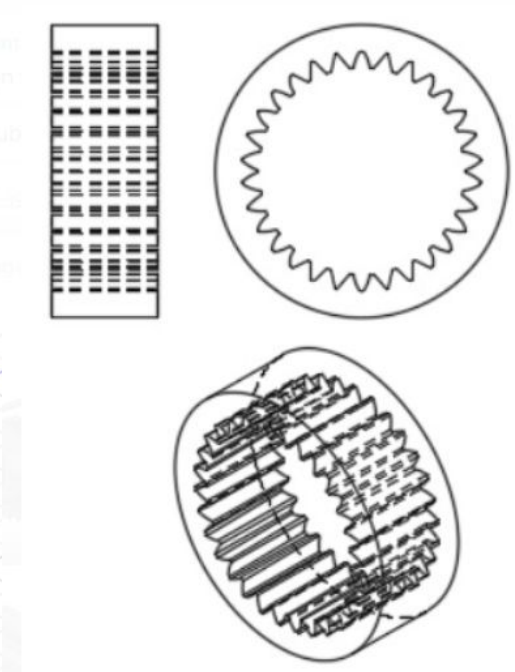
Components - Dog Ring

A dog ring is an engagement mechanism used in manual transmissions that has teeth or "dogs" on its outer surface that engage with similar teeth on the inner surface of the gearbox's gears. It is used to lock the gears in place once the new gear has been selected.

Components - Hub

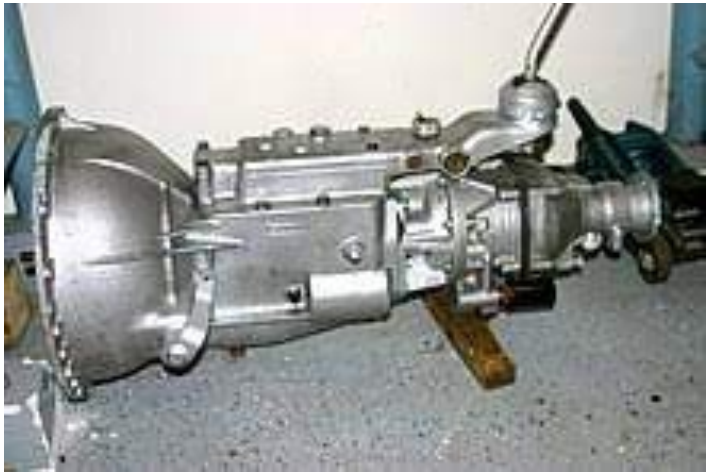
These are components that help to lock the gears in place when engaged, allowing for power to be transmitted between the shafts.





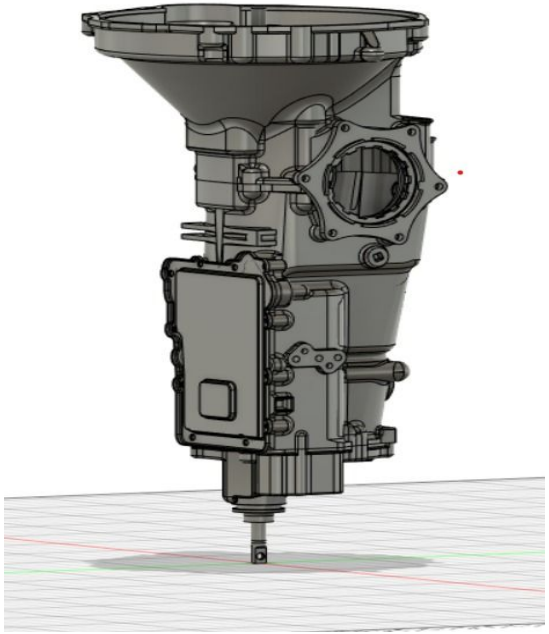
Components - Housing

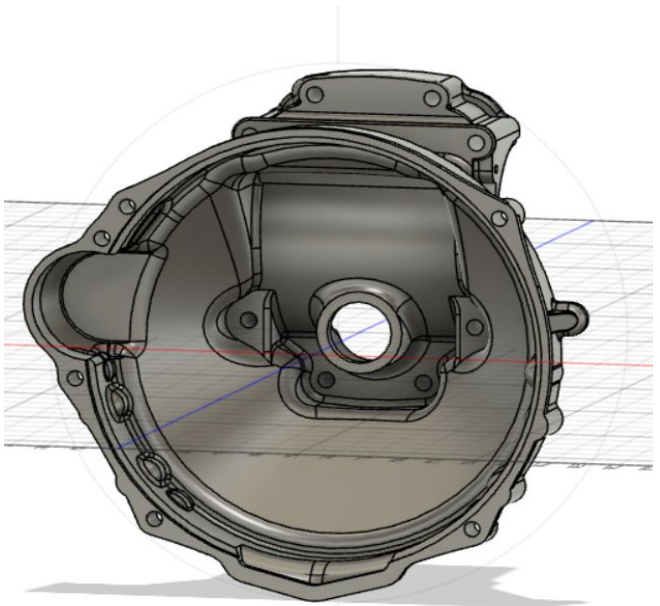
The gearbox housing is the outer casing or shell that encloses and protects all of the internal components of the gearbox. The housing also provides a mounting point for the gearbox and helps to dissipate heat generated by the gearbox during operation. Additionally, the housing contains ports for oil or fluid to circulate through and provide lubrication to the gears and other components.



Housing / Casing

We had sourced the model from the internet for the housing. It contains the required spacing/ oil holes/ sumps/ screw holes and other complex components





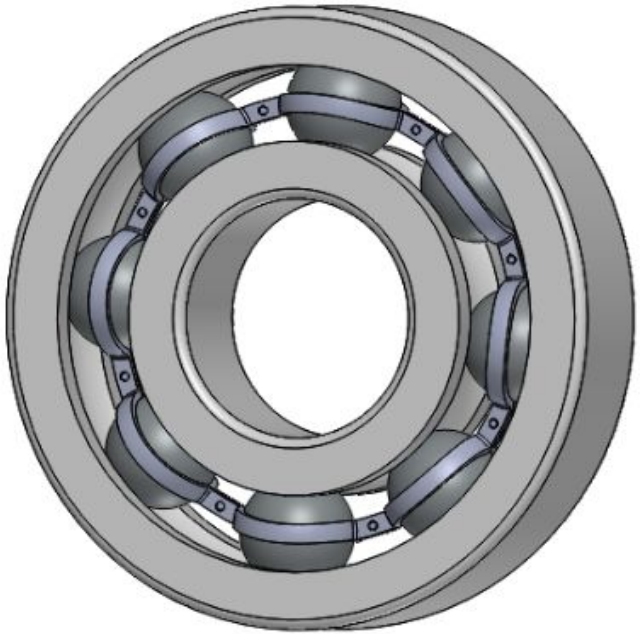
Bearings

Bearings are important components in a gearbox that help to reduce friction and support rotating shafts. They consist of two rings, an inner ring that is mounted on the shaft and an outer ring that is mounted in the housing. The space between the two rings contains rolling elements such as balls or rollers, which reduce the friction between the rings and allow them to rotate smoothly

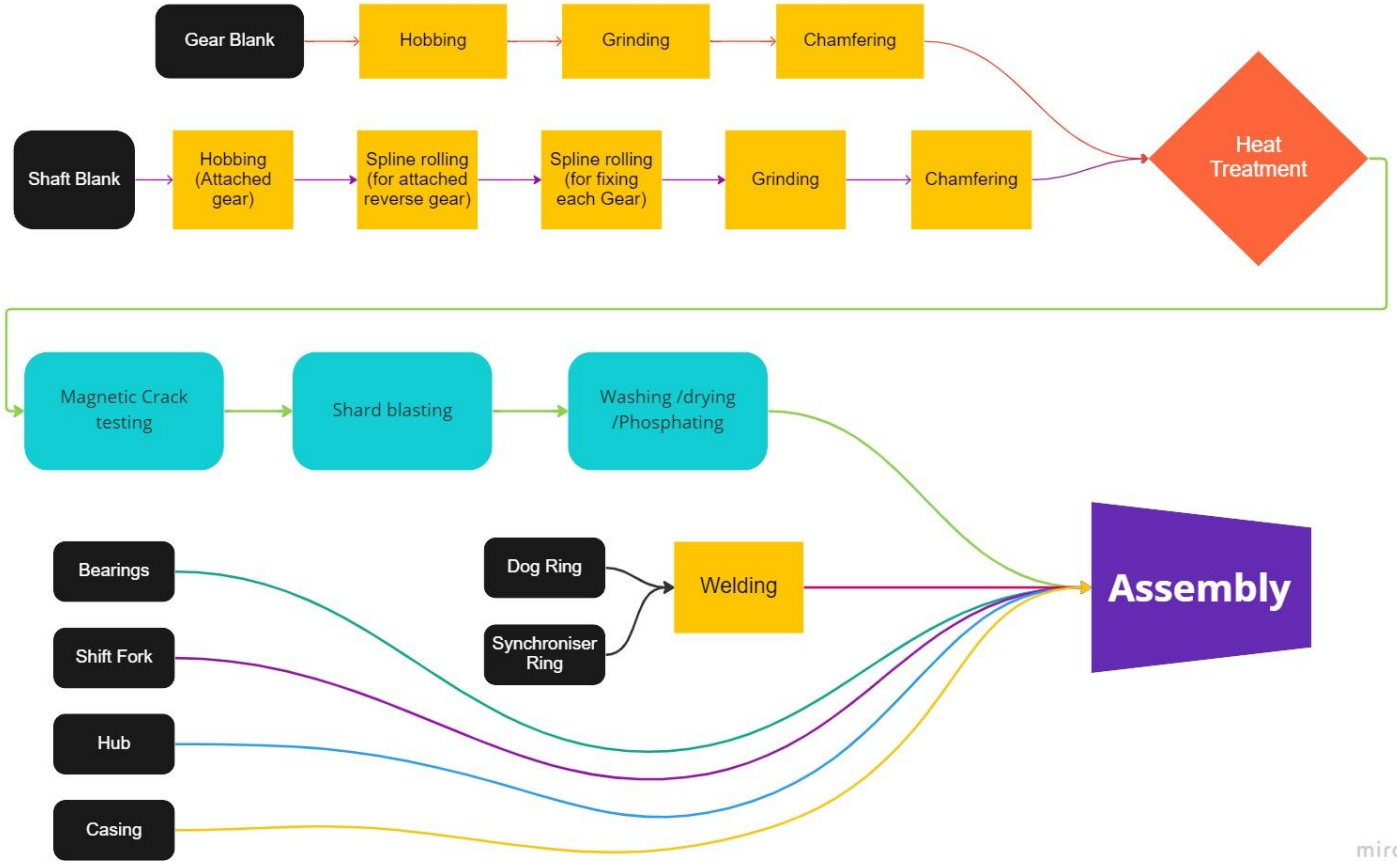
Bearing

Bearings used:

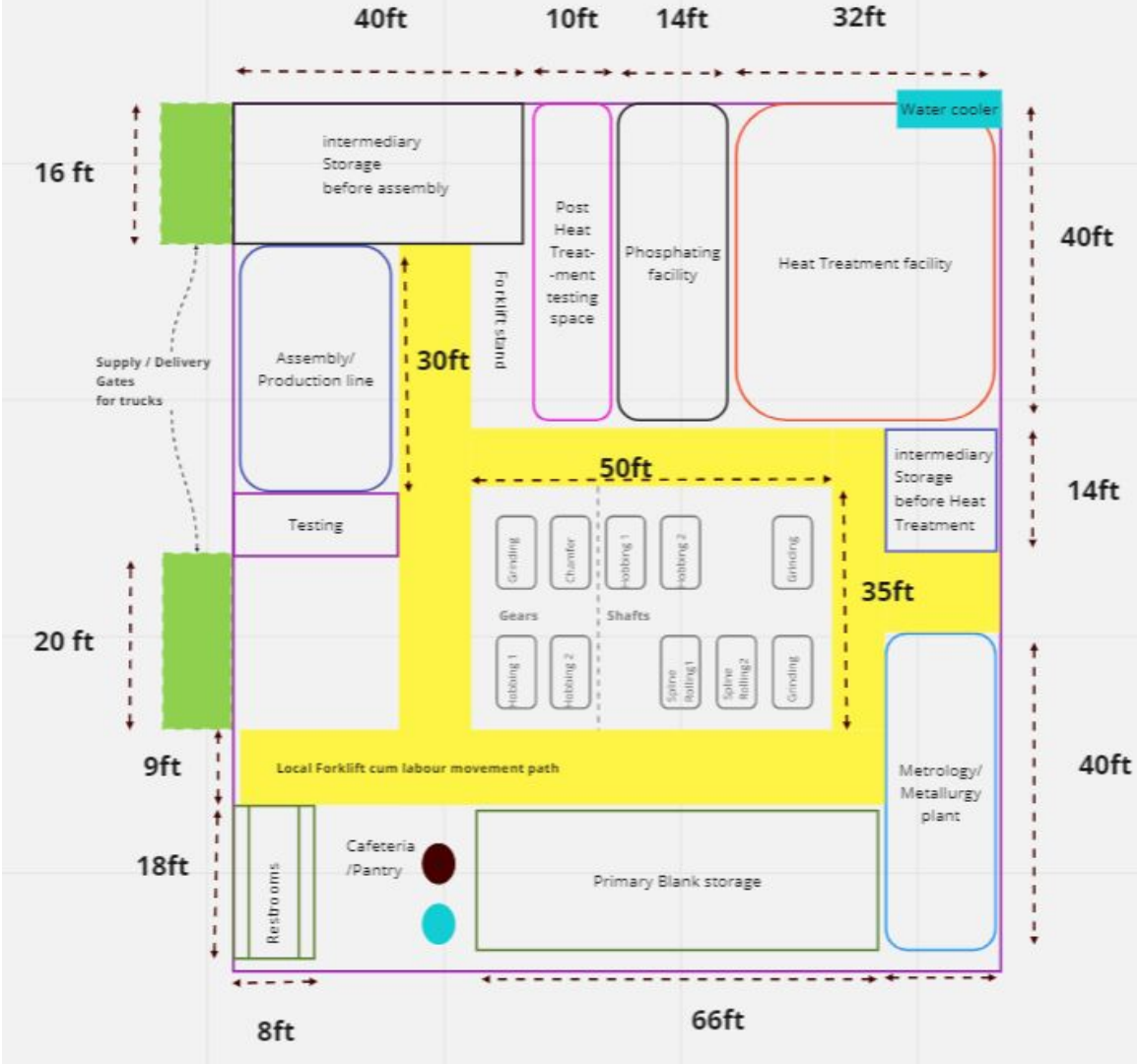
- Deep Groove Ball Bearings.
- Cylindrical Roller Bearing.
- Tapered Roller Bearing.
- Needle Roller Bearings.

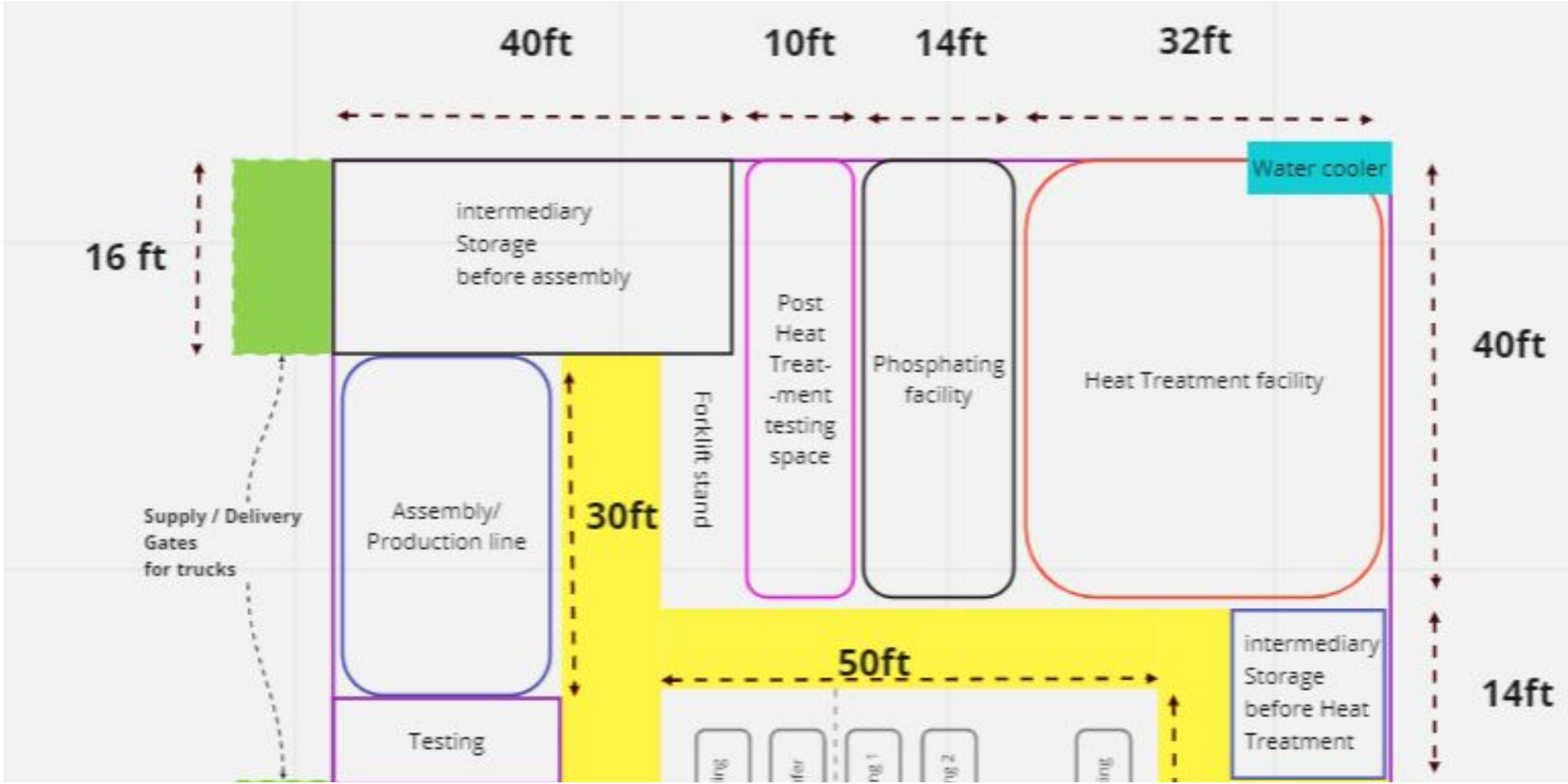


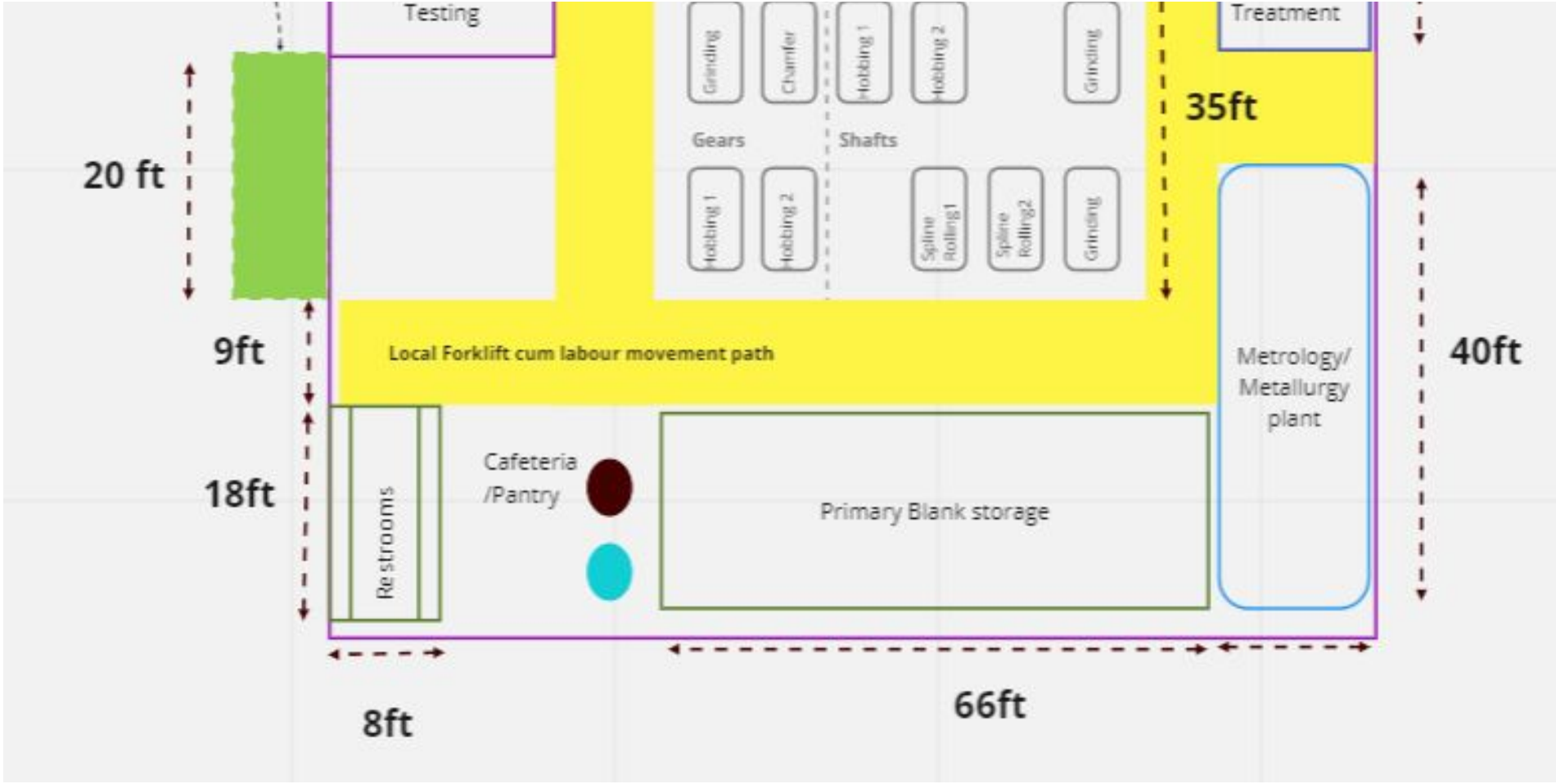
Process Layout



Plant Layout




40ft
10ft
14ft
32ft
16 ft
intermediary
Storage
before assembly
Post
Heat
Treat-
-ment
testing
space
Phosphating
facility
Water cooler
Heat Treatment facility
40ft
Supply / Delivery
Gates
for trucks
Assembly/
Production line
30ft
Forklift stand
50ft
intermediary
Storage
before Heat
Treatment
14ft
Testing


Testing
Grinding
Chamfer
Hobbing 1
Hobbing 2
Grinding
Treatment
35ft
Gears
Shafts
Hobbing 1
Hobbing 2
Spline Rolling1
Spline Rolling2
Grinding
20 ft
9ft
Local Forklift cum labour movement path
Metrology/ Metallurgy plant
40ft
18ft
Re strooms
Cafeteria /Pantry
Primary Blank storage
8ft
66ft

Materials considered

Gear Box may be produced using:

- Gears-Steel Grades- 20MnCr5, SAE 8620, SAE 1045 etc
- Shafts-Steel Grade- EN8D
- Shifter Forks- EN8D,Polymer, Investment Casting
- Rails-Bright Bars- EN1A
- Transmission Casing- Grey or S.G. Iron Casting

  Essentially all of it is Forging or Castings. To manufacture these- Pig Iron, Coke & CRCA scrap & alloying elements are used as Raw Materials.

- Casing - Aluminium (Mostly Billet, Injection Molding is used)

Manufacturing & Fabrication- Gearbox Casing

Material : 6061 – T6 Aluminum

Processes :

- Lost foam aluminum casting
- CNC machining
- Dimension inspection.
- Material testing (NDT).
- Quality assurance and after-sales service.

Lost Foam Aluminium Casting - Casing

Procedure followed :

- Foam gearbox is built from the required design. (draft=0.6°)
- 0.95cm thick layer of sand has to be formed.
- The foam is removed using acetone.
- Casting heated for 2hrs at 900°C in a furnace.
- Metal heated in Intermediate frequency furnace is poured. (@ 647°C)

CNC machining follows

Surface Finishing - Casing

- Polishing:
  - Chemical Treatment

- Shot blasting:
  - to remove something on the surface
  - large air gun or spinning paddles throw the shots.

Quality Assurance Plan - Casing

QA steps:

1. failure testing
2. statistical control (6σ)
3. Total quality control (RMSS)
4. Quality awareness.

- Dimension testing :
  - Either manually – cheaper.
  - Or using a reliable Coordinate Measuring Machine (CMM). – accuracy, expensive.
- Non-Destructive testing using UT-machine.

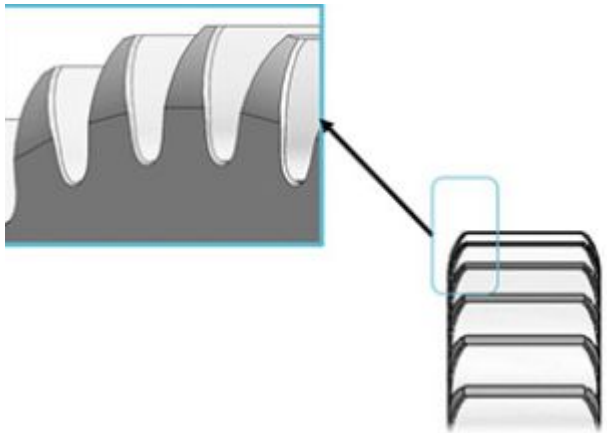
Process - Gears

Hobbing of Gear blanks

- **Hobbing** is a machining process for gear cutting, cutting splines, and cutting sprockets on a **hobbing machine**, which is a special type of milling machine.
- The teeth or splines of the gear are progressively cut into the material (a flat, cylindrical piece of metal) by a series of cuts made by a cutting tool called a **hob**.

Chamfering

- Machining of gears, also with coarse **burr** from the previous gear hobbing process.
- Chamfering is used in hobbed Gears to remove usually a 45 degree edge, and it’s also a useful tool for deburring and smooth running.



Grinding

Grinding is an abrasive machining process that uses a grinding wheel or grinder as the cutting tool to finish parts requiring high surface quality and dimension accuracy.

Spline Rolling

Spline rolling is a metal forming process used to manufacture shafts with gear-like teeth on the end. The process involves cold-forming the teeth onto a pre-machined shaft, resulting in improved tooth strength, surface finish, and dimensional accuracy.

Heat Treatment

Heat treatment is a process used to improve the properties of gears and shafts by altering their microstructure through heating and cooling. This process can increase the strength, durability, and wear resistance of the components. It involves heating the metal to a specific temperature, holding it at that temperature, and then cooling it at a controlled rate. Different heat treatment techniques can be used depending on the desired properties of the gears and shafts.

Magnetic Crack Testing

Magnetic crack testing, also known as magnetic particle inspection, is a non-destructive testing method used to detect surface and subsurface cracks in metallic materials. The process involves magnetizing the material, applying magnetic particles to the surface, and inspecting it under UV light to detect any indications of cracks or defects. This method is reliable, cost-effective, and widely used in industries such as automotive, aerospace, and manufacturing to ensure the safety and reliability of metallic components.

Cracks as small as 0.01 inches can be found

Shard Blasting

Sandblasting is a process that uses compressed air or water to propel abrasive materials onto a surface to clean, shape, or smooth it. The abrasive material used can vary depending on the surface and desired outcome, and can include sand, glass beads, and aluminum oxide. Sandblasting is commonly used to remove paint or rust from metal surfaces, clean concrete or stone surfaces, and prepare surfaces for coatings or adhesives.

Surface roughness can be reduced upto less than 5 micrometer

Washing/Drying/Phosphating

Washing involves cleaning components to remove contaminants, while drying is done to remove any moisture present on the components after washing. Phosphating is a process that creates a thin layer of phosphate on the components to improve their corrosion resistance and increase their adhesion to paints or other coatings. These processes are crucial for ensuring the components are clean, dry, and properly coated for optimal performance and durability.

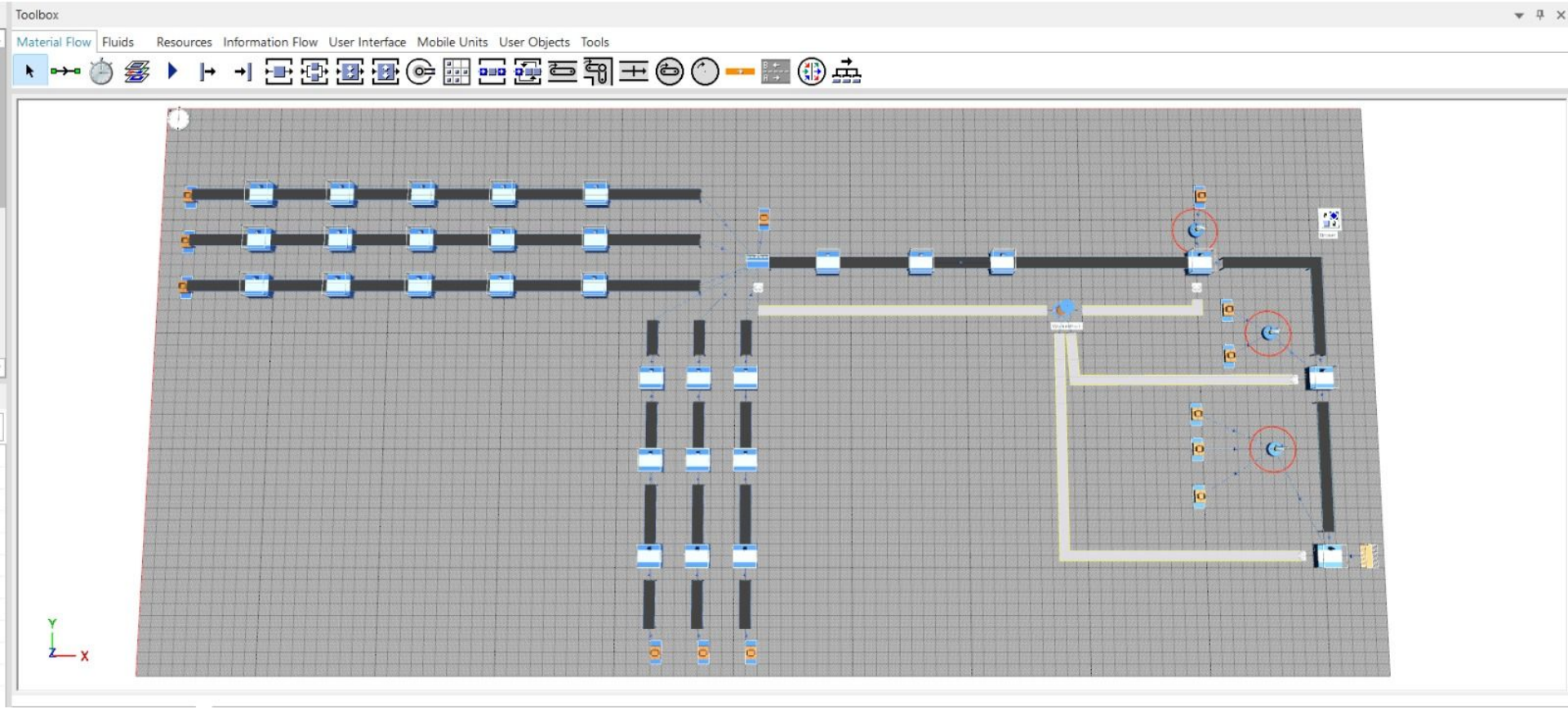
Phosphating can have a layer of upto 2-3 micrometer thickness

Welding

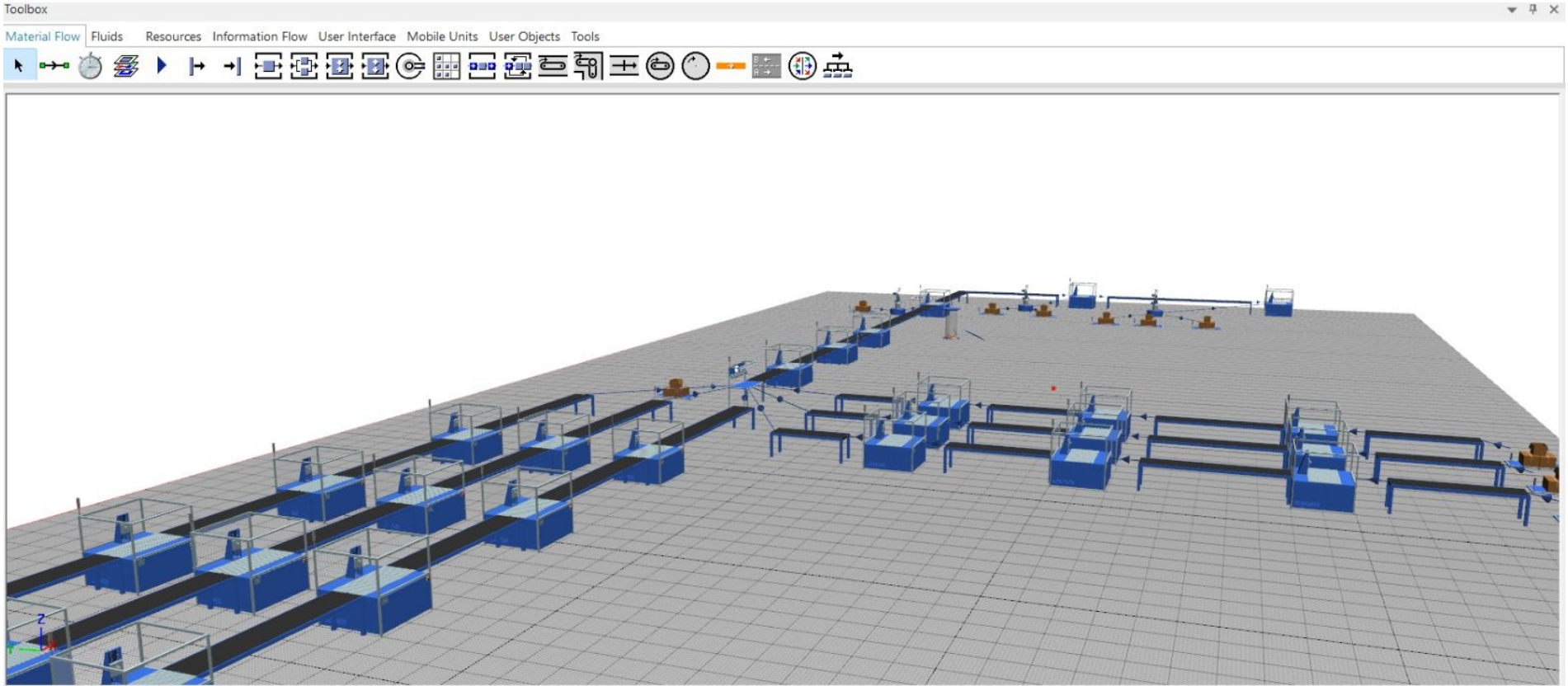
The process involves positioning the dog ring and the synchroniser with the gear together and then welding them in place using the TIG welding technique. The welding creates a strong and durable joint between the two rings, which allows for the smooth and efficient operation of the gearbox. After the welding is complete, the joint is inspected to ensure that it is of high quality and meets the required specifications before the components are assembled into the gearbox.

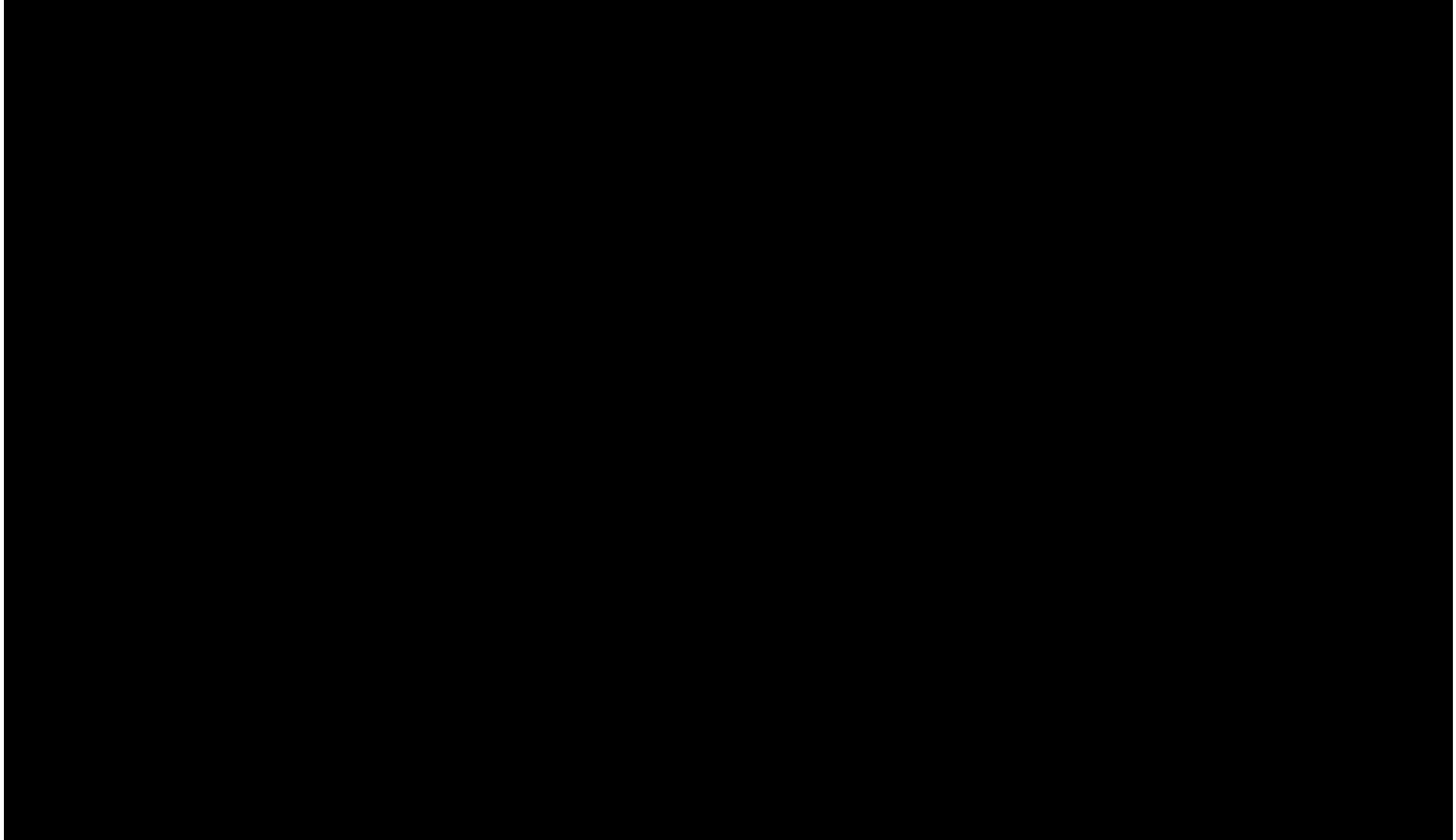
The weld strength can be upto 50000 psi

Plant Layout- Top View

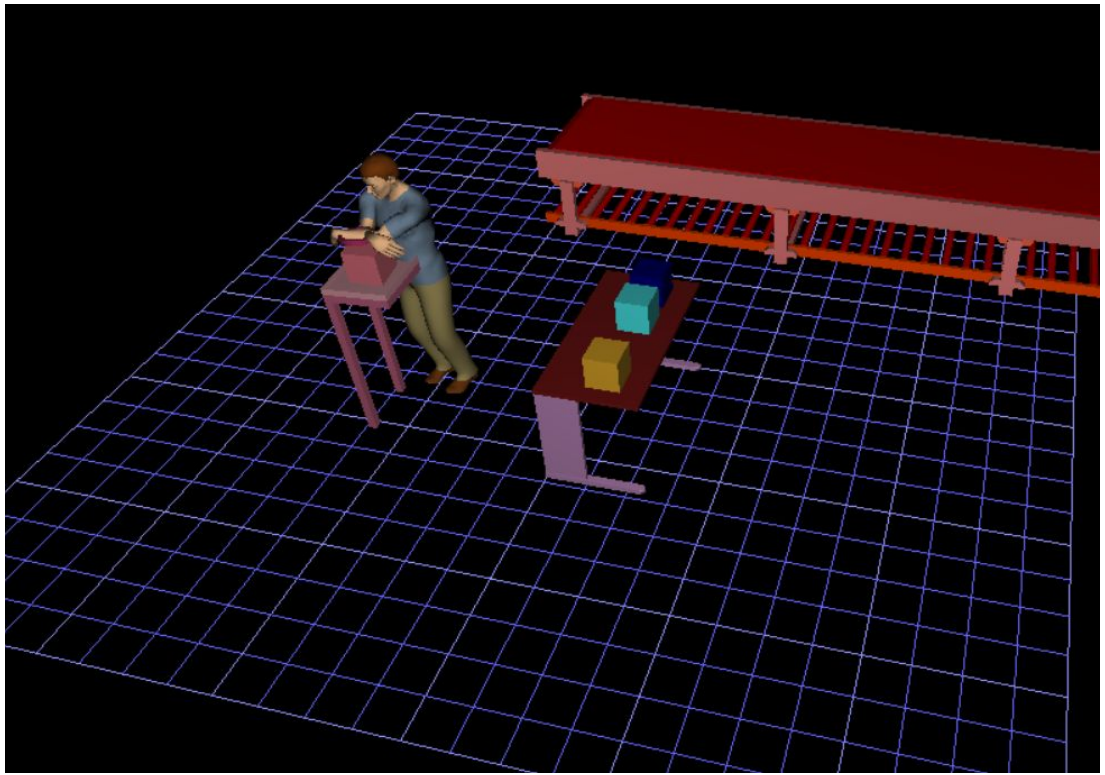


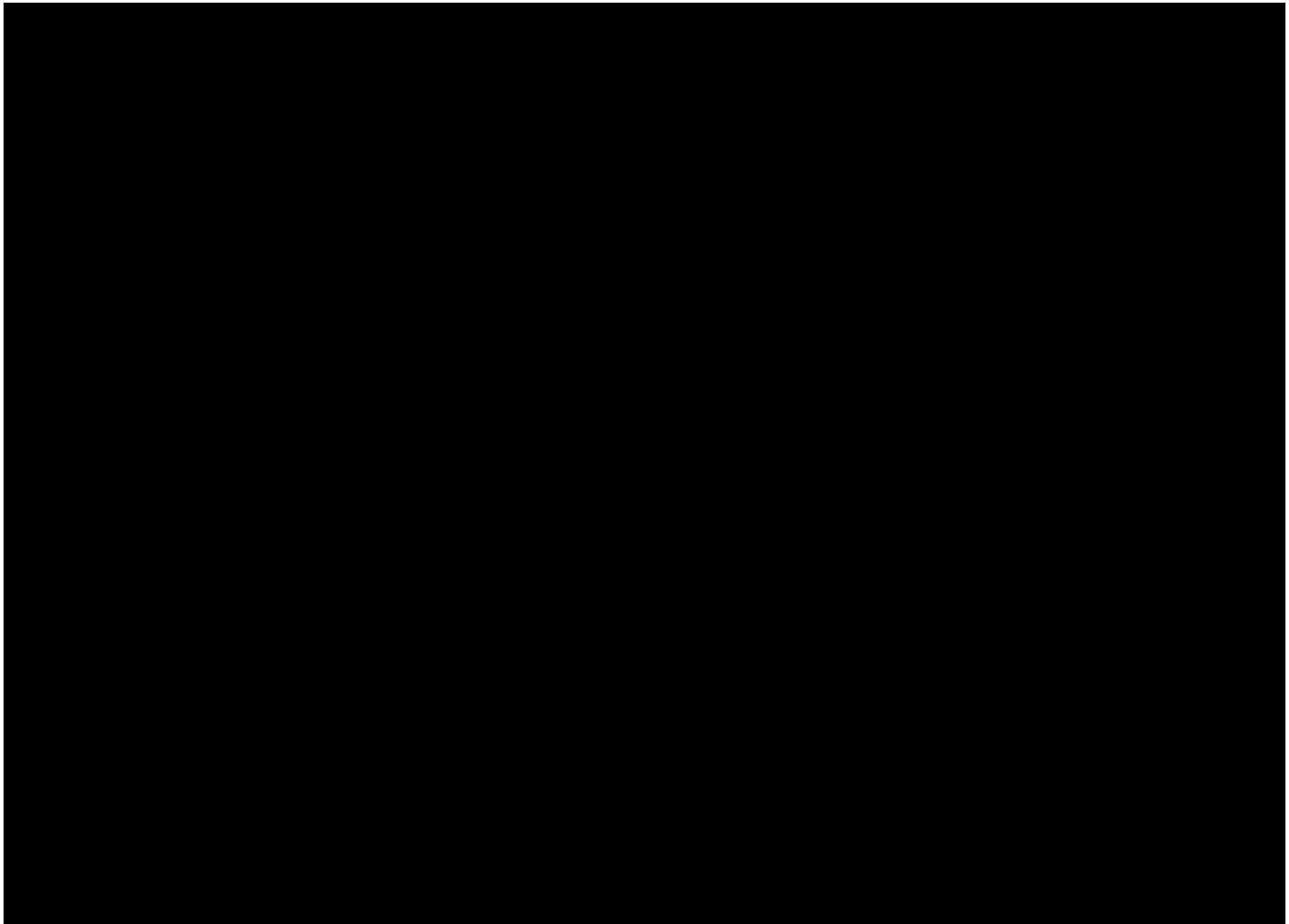
Plant Layout - Side Top view





Technomatrix Jack Simulation





Time Analysis

Gear:

Per piece time

Hobbing	– 20 seconds
Chamfering	– 20 seconds
Grinding	– 30 seconds

Local Bottle neck= 30 seconds

=1920 sets per day

Run time = 2 shifts = 2 * 8hours = 960 minutes

Shaft:

Per piece time

Hobbing –25 seconds

Spline rolling –10 seconds

Grinding –45 seconds

Local Bottle neck 2= 45 seconds

= 1280 Sets per day

Run time = 2 shifts = 2 * 8hours = 960 minutes

Heat Treatment and Dependencies:

Run time = 3 shifts = 3 * 8hours = 1440 minutes

Number or Gearbox sets Treatable at 1 Cycle: 163 Sets

Time Required for each cycle = 4 hrs

Time Required per piece:1.469 min

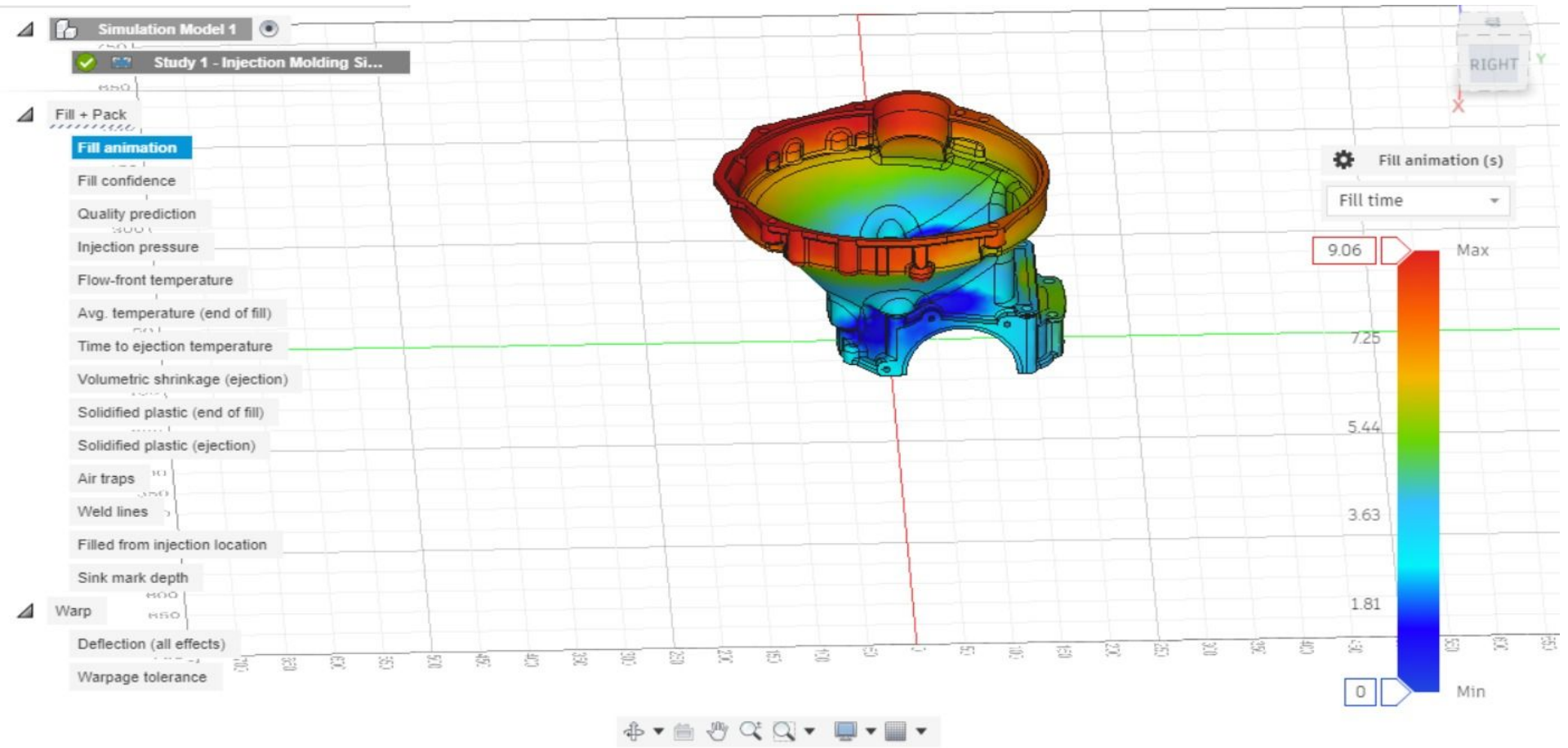
Phosphating:

Time required per 80 pieces: 1 hr

Time required per piece: .75 mins

Local Bottle neck 3: 980 sets per day

Injection Molding Sim - Casing(Only Clutch Housing)



Injection Molding -Time Analysis

Time for:

- Clutch Housing - 9.06 secs
- Main Housing - 23 .25 secs
- Rear Housing - 16.78 secs
- Other parts - 6 secs

Bottleneck Time for injection of Casing - 23.25 secs

Time Analysis - Gearbox

Workstation Names	Local Bottleneck Time taken per Piece(Seconds)	Max. Production per day (Sets)
Gear	30	1920
Shaft	45	1280
Heat treatment	88.1	980
Injection Molding	23.25	2482

Material and costs - Gears

Assumption: Total number of gearboxes produced per day = 980 Gearboxes

Gear blank material: 98% pure **20MnCr5**

Total Cost for gear blank (10 sizes) per gear box(800 per apiece): 19,60,00,000

For a depreciation of 15%: Machine costs(per 3 years): 30,00,000

Build running cost: 10,00,000

Labour Salaries[14]: 2,00,000

Cost for gears required in each Gearbox: 8052 /-

Material and costs - Shafts

Shaft blank material: 98% pure **20MnCr5**

Total Cost for blank (3 different) per month(1000 apiece): 7,35,00,000

Depreciation Cost(machines'): 15%

Machine costs(per 3 year): 50,00,000

Build running cost(Pmo): 10,00,000

Total Labour Salaries(Pmo)[20 nos]: 3,00,000

Cost for Shafts(3) required in each Gearbox: 3058 /-

Process cost - Heat Treatment

Labour costs (Per month)[21 nos]: 6,00,000 //since 3 Shifts
Machinery cost(per 3 years):1,20,00,000
Build running cost: 20,00,000

Total Heat Treatment Process cost(per gear box): 638/-

Material and costs - Outsourced products (For each gearbox)

Outsourced material cost(Per gearbox): 8000(6 bearings) + 5000(sensors)+2000(Other) = 15000/-

Includes Housing ,sensors ,Synchromesh ,washers ,bearings ,etc

Costs of Quality Management:

(I) Post Heat Treatment/Shard Blasting and Phosphating : 10 apiece

Magnetic Crack Test: 5 apiece

(II) Metallurgy and Metrology lab Costs- (8 pieces destroyed out of 980)

Running cost: 2,00,000

Highly Skilled Labour [10 nos]: 10,00,000

Current value per set= 8052+3058+638+15000=26,748

Total Quality maintenance Cost(per gearbox):

[3000000+8*(26748)]/980/25 = 131/-

Cost for Assembly, Final Testing and Packaging:

Cost of Assembly Scara and Conveyor belt cost(per 5 years):30,00,000

Labour Salaries(Per month)[20 nos]:3,00,000

Build running cost:5,00,000

Final Leak test(per piece): 10

Total Assembly and Testing cost(per gear box): 154/-

Final Cost of Production

=8052+3058+638+15000+131+154

=27033 /-

For a Production pace of 972 Gearboxes per day with an average 25 days/mo, 2 shifts of 8 hours per day Except for Heat Treatment Facility of 3 shifts of 8 hours per day.

Costs Analysis - Gearbox

Type	**Costs Involved(in Rs.)**
Gears	8052
Shafts	3058
Bearings(6 Nos.)	8000
Sensors(Heat, Load, Oil check)	5000
Heat Treatment	638
Quality Maintenance	131
Assembly and Testing	154
Other costs	2000
Total	**27,033**

Selling Price

Typical Gearbox Price of PSA Avtec Sold to Citroen cars :

Per piece : 31,800 /- // Direct import, no Marketing costs

Average Gearbox in Indian Market:

Per piece : 30,500 /- // Negligible marketing costs

Our Price:

Per piece : 30,500 /- => Markup of 12.8%

Break-Even Point

For a Labour only setup:

Total Fixed cost : 10,00,000+10,00,000+20,00,000 = 40,00,000

Total Variable cost : 2,00,000+3,00,000+6,00,000 = 11,00,000

Labour only production curve:

$$COST = 40,00,000 + P*11,00,000/30$$

Break-Even Point

For a Completely Automated setup:

Total Fixed cost : 1,30,00,000+1,30,00,000+18,55,00,000 = 3,45,00,000

Total Variable cost : 1,00,000+1,00,000+2,00,000 = 6,00,000

Semi-Automated production curve:

$$COST = 3,45,00,000 + P*6,00,000/30$$

Future Plan

Considering the Profit we get that is,

30 *(30,500-27,033)=1,01,929,800/-

Looking into the market state at average loans an Manufacturing Industry pay we can estimate our company holding about 20,00,000/- per month

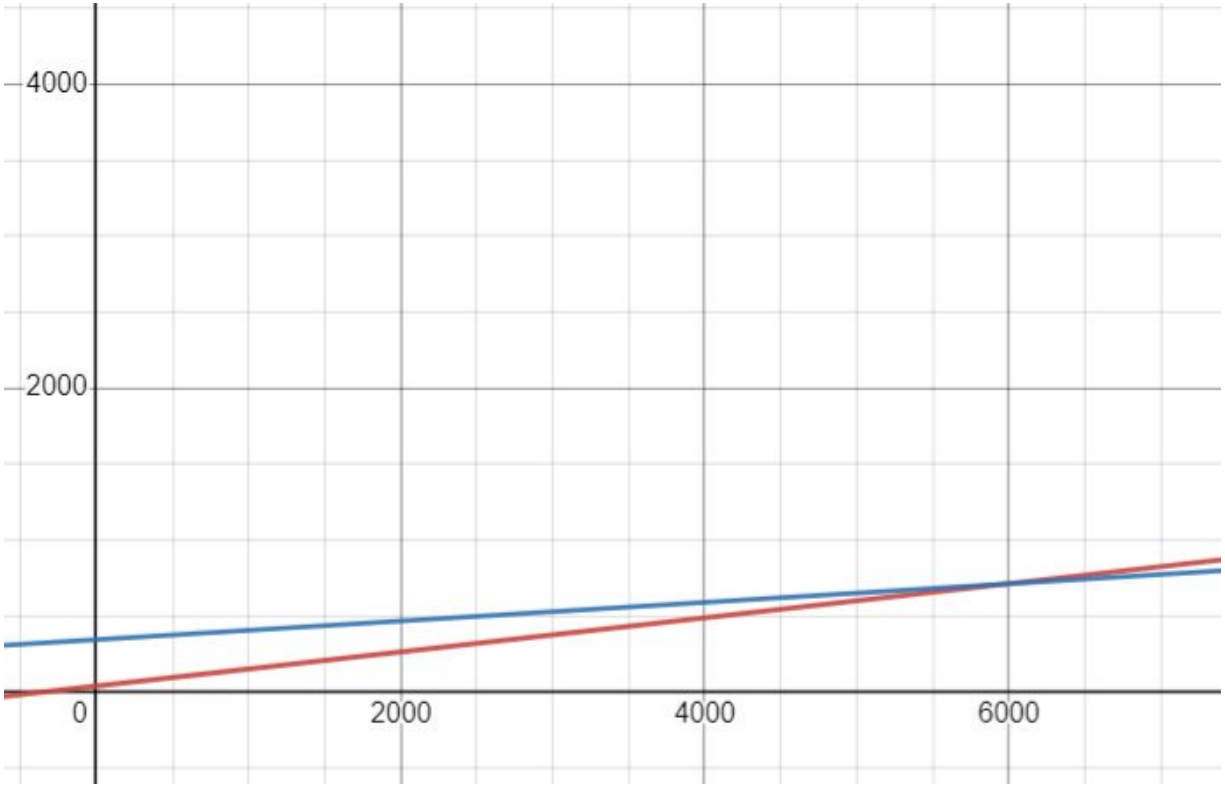
So our Estimation of Completely Converting into Automated setup:

=(Automated fixed cost -Labour fixed cost)/Annual holdings

=(3,45,00,000-40,00,000)/(20,00,000*12) = ***1 year 4 months***

Break-Even Point Graph

We can clearly see that at Fully automated setup one should Produce at least ***5988*** Gearboxes per day



Difficulties faced

- Downloading and obtaining license for technomatrix jack software was tricky. The user interface proved to be challenging
- There were many wide estimates from different sources for the cost and time analysis on the internet.
- Some components like the housing was too complex to be made in CAD.
- There are many components in a commercial gearbox and choosing what to include for this project was hard.

Individual Contributions

All of us worked together on the Cad model. We split the components equally amongst ourselves and made the models in a shared file on fusion. We made the line models together. We discussed together and made the plant layout diagram. We split the slides in the final presentation and combined them in google slides.

Thank You