0.0.1 Design and development of the drive wheel and gearbox system

The following section is devoted to the design and development of the drive wheel and gearbox system, which is crucial for the mobility, stability, and functionality of the AGV. The drive wheel and gearbox system is crucial in ensuring smooth and precise motion control, load handling, and adaptability to various operational environments. This project utilizes SolidWorks, a state-of-the-art computer-aided design software, for modeling and simulation of the drive wheel and gearbox. The robust tools for parametric design, assembly, and motion analysis in the software allow us to create an efficient and optimized design. It further takes into consideration practical constraints in reality, such as material selection, cost, manufacturability, environmental impact, and safety and engineering standards. The objective of the project is to present a design that will not only be functional and reliable but also sustainable and economical. The successive sections outline the design process, engineering analysis, and critical decisions in view of the realization of the above-mentioned objectives in detail.

Key objectives included:

- To design the system in SolidWorks.
- Check for structural integrity at operational loads.
- Analyze gearbox performance for the required torque and speed to achieve the desired gear ratio.
- Simplify design for manufacturability and assembly.

0.0.2 Critical elements of agv design: drive wheels, gear mechanisms, and material selection

AGVs are driverless transport systems used in the manufacturing industry, warehouses, and logistics. According to Groover (2015) [**?**], in ”Automation, Production Systems, and Computer-Integrated Manufacturing” an AGV would have a navigation system, a drive system, and sensors to operate autonomously. The driving system is the major component of an AGV, which provides the stability of the robot, the load-carrying capability, and the accuracy of motion.

In AGVs, middle drive wheels are important for balance and drive. Jazar's study [**?**], ”Vehicle Dynamics: Theory and Applications”, presented in the year 2019, gave much importance to wheel type, selection of motor, and gearbox that affects energy efficiency in a robot, how much load a robot can carry, adaptation on various kinds of terrain. A gearbox allows for the delivered torque and speed to the wheel for smooth, accurate movement.

Research on gearbox design for robotics has highlighted the requirement for compact, high-efficiency mechanisms. Kauffenberger et al. (2018) studied gear mechanisms in small mobile robots and found that among them, spur gears are the most used due to their simplicity, high load capacity, and ease of manufacturing. Their study also discussed the trade-off between gear ratios and torque output, noting that planetary gear systems provide higher torque.

The design of the drive wheel is critical for traction, maneuverability, and load-carrying capability. Bloss (2017), in ”Mobile Robotics: Principles and Design,” has discussed the role of drive wheels in robots, and he mentioned that material, tread pattern, and diameter of the wheel have a direct influence on performance. The wheels for AGVs are designed to meet both lightweight and high durability to allow for continuous operation with various loads.

The CAD tools utilized for the design of robot systems are quite popular, due to their advanced modeling and simulation capabilities. Das and Jana 2020, in the work ”Application of CAD Tools in Robotic Design”, have shown the capability of solid works to model complex assemblies such as gearboxes and also to simulate their motions.

Material selection is one of the most critical aspects in mechanical design. Ashby [**?**], 2011, ”Materials Selection in Mechanical Design” described a criterion for material selection that was based on strength, weight, cost and environmental considerations. Since this project dealt with drive wheels it mostly utilized rubberized materials, hence a thick rubber material was chosen, while gears are made from hardened steel preferred for its wear resistance and strength, it was also considered in my material selection.

0.0.3 Engineering standards and lifelong learning

0.0.3.1 Engineering standards

Engineering standards provide a framework for designing, testing, and manufacturing mechanical components to ensure compatibility, performance, safety, and reliability. Several organizations, such as ISO, ANSI, ASTM, IEEE, and DIN, define standards applicable to AGV drive systems.

0.0.3.2 Importance of Engineering Standards in AGV Drive System Design

Standards are essential in development to ensure:

- *Interoperability*: Components such as wheels, bearings, and shafts must conform to international sizes and tolerances. According to ISO 9001, which ensures a structured design and manufacturing process for reliability.
- *Safety*: Gearboxes and drive systems must adhere to safety regulations to prevent failures that could endanger users or disrupt operations. According to ISO 14121 , which helps in evaluating and mitigating risks associated with moving components.
- *Manufacturing Feasibility*: Standardized materials and design practices facilitate efficient production and cost reduction. According to AGMA 2001-D04, which helps in designing gears that meet durability and performance requirements.
- *Quality Assurance*: Standards define testing protocols for evaluating the durability and performance of components. According to ISO 606, which ensures proper gear-chain compatibility in AGV transmission systems.

0.0.4 Methodology

The methodology followed for the project in brief is given below:

1. Determination of dimensions, number of all gear teeth , and gear ratio.
2. 3D Modeling: Detailed CAD modeling of wheels, gears, shafts, and housing on SolidWorks.
3. Simulation: motion analysis to validate the design.
4. Optimization: Refined design for performance and manufacturability.

0.0.4.1 Dimensions

Ring gear which is the bigger gear has a dimater of 190 teeth
The planet gear has a diameter of 90mm
The sun gear has a diameter of 10mm

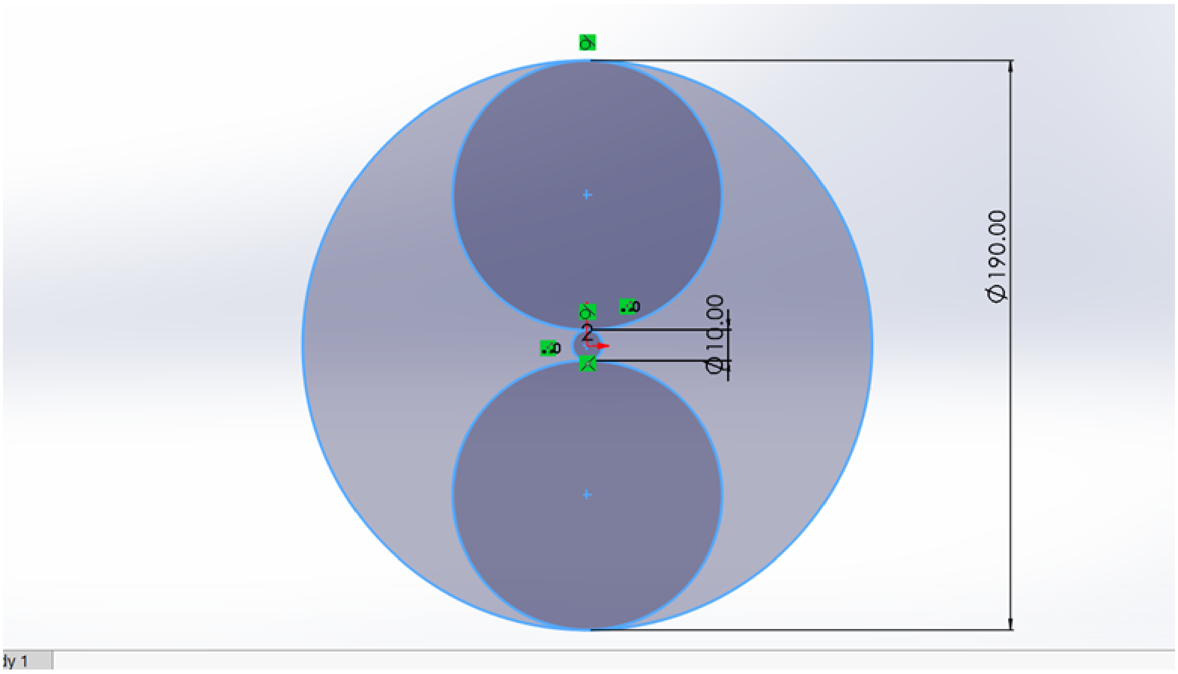

Figure 1: gear system dimensions

0.0.5 3d modeling

Following components were modelled using SolidWorks:

0.0.5.1 Middle Drive Wheels:

For Traction and load-carrying capacity. Which is made of natural rubber has the ability to withstand high load and relatively not so heavy. The wheels for AGVs are designed to meet both lightweight and high durability to allow for continuous operation with various loads.

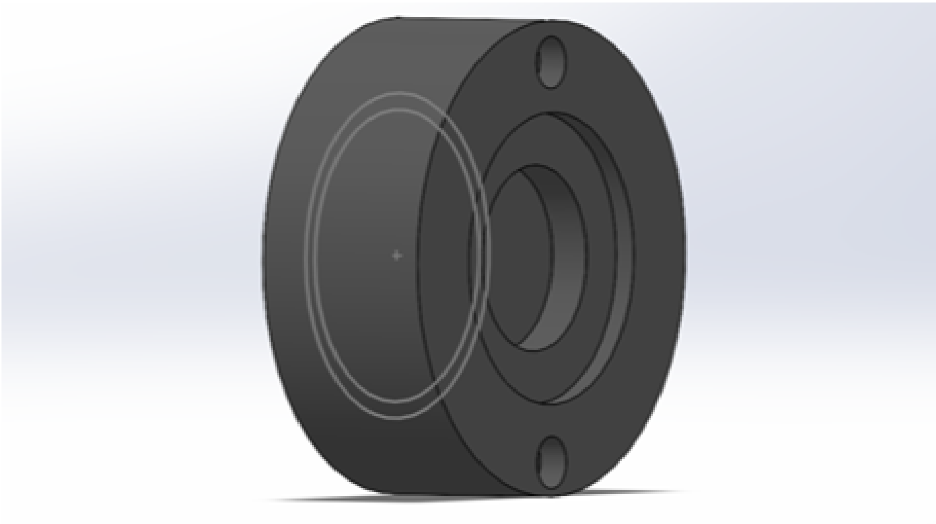

Figure 2: Middle drive wheels made of natural rubber

0.0.5.2 Gearbox:

Compact design with spur gears for efficient transmission. Studies shows spur gears are the most used due to their simplicity, high load capacity, and ease of manufacturing. Their study also discussed the trade-off between gear ratios and torque output, noting that planetary gear systems provide higher torque.

0.0.5.3 Shafts and Bearings:

For smooth rotation and distribution of loads. I made use of both skf bearing 108tn92 and skf bearing 1210ektn9202 while for the wheel holder it was made with hard steel for firmness and durability.

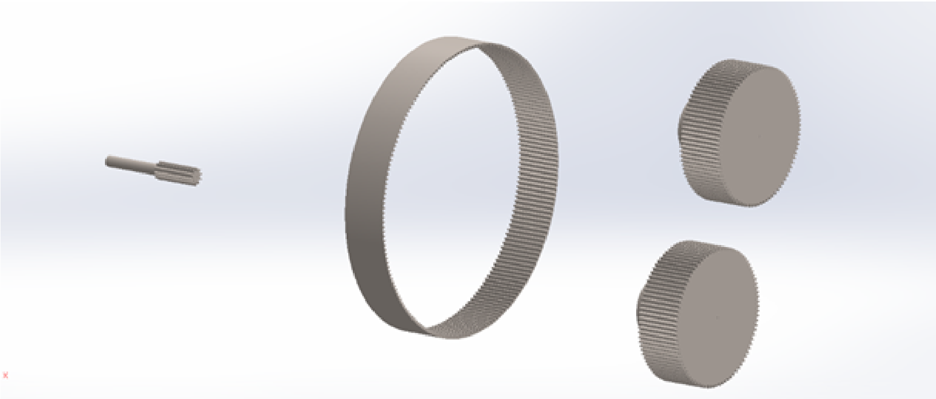

Figure 3: Compact gearbox design

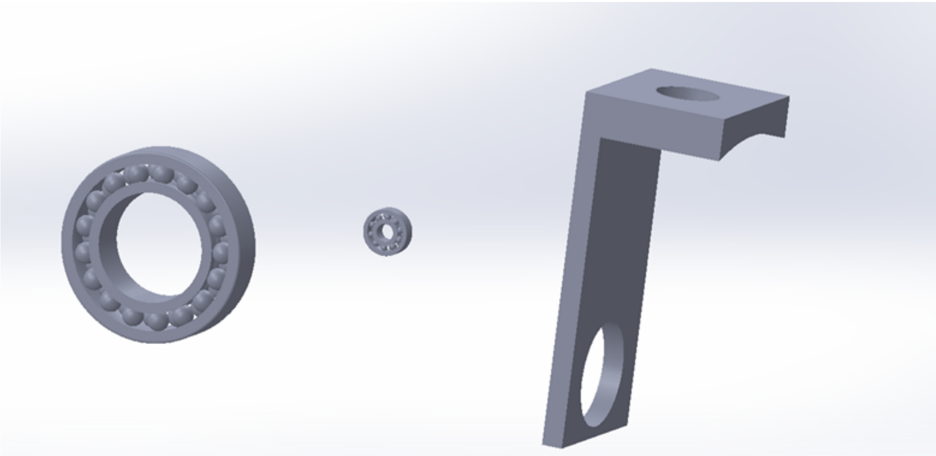

Figure 4: Shafts and bearings assembly

0.0.5.4 Housing:

Enclosed system for protection against dust and debris. Which lightweight aluminum were used to reduce the weight of the gear box.

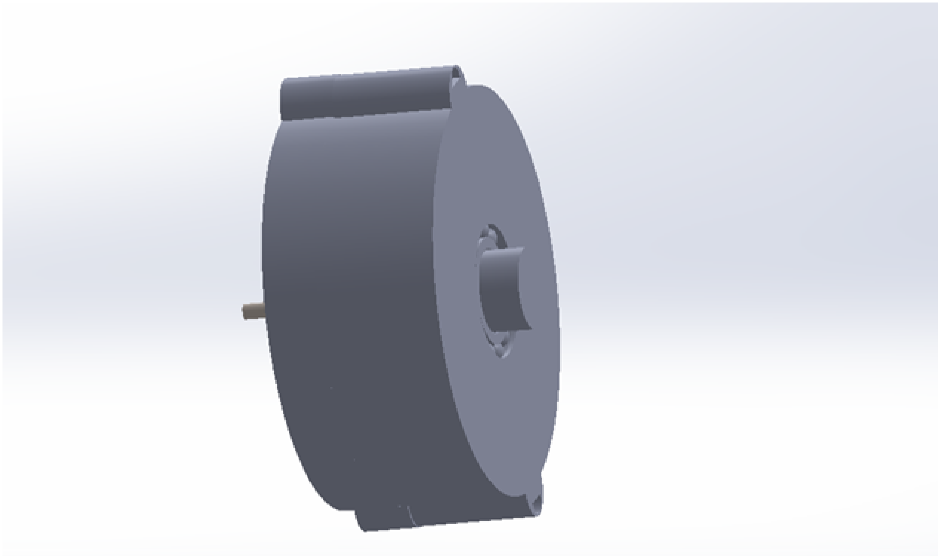

Figure 5: Enclosed housing made of lightweight aluminum for protection against dust and debris.

0.0.5.5 Assembly

The parts were then assembled in SolidWorks for a check on appropriateness and compatibility.

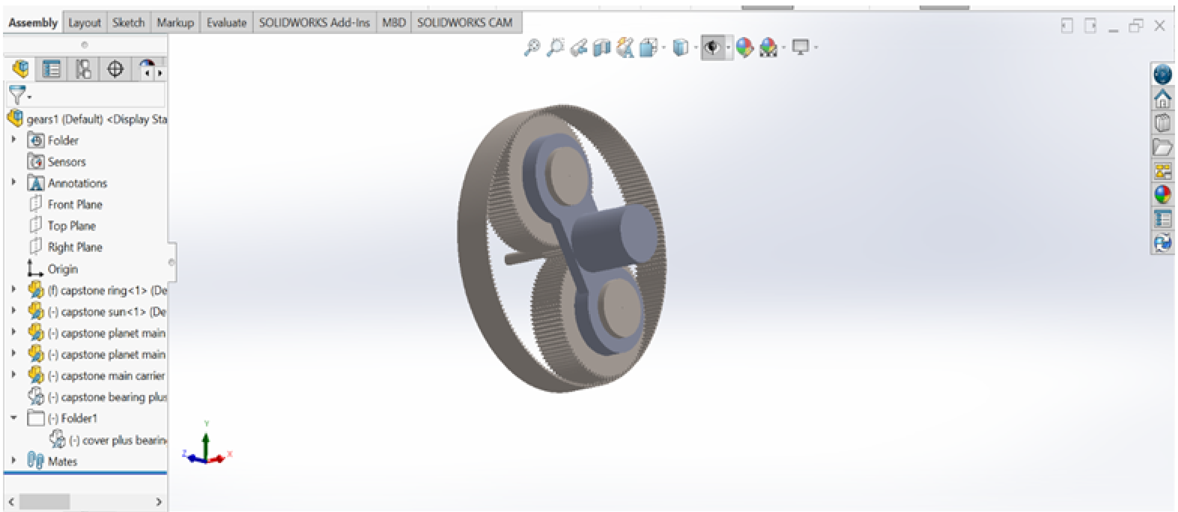

Figure 6

0.0.6 Calculation and analysis

Simulations done in SolidWorks to test performances of the design:

0.0.6.1 GEARBOX CALCULATION

- ring gear $\rightarrow$ 190 Teeth [120 mm ϕ] [Tr]
- PLAMET Gear $\rightarrow$ 90 Teeth [Tp]
- Sun gear $\rightarrow$ 10 Teeth [Ts]

GEAR RATIO : NOTE I want a high ratio of 20 : 1

$$20 = 1 + \frac{T_r}{T_s}$$
$$\frac{T_r}{T_s} = 19$$
$$T_r = 19T_s$$

The planet does not affect the ratio but determines the spacing of the sun and ring gears. Rearanging:

$$\frac{T_r}{T_s} = 19$$
$$IF\ T_s = 10$$
$$T_r = 19 \times 10 = 190$$

from $T_r - T_s = 2T_p \rightarrow$ Spacing in the ring

$$190 - 10 = 2T_p$$
$$T_p = 90$$
$$\rightarrow 1 + \frac{T_r}{T_s} \Rightarrow 1 + \frac{190}{10} = 20$$
$$\rightarrow 20 : 1$$

$\rightarrow$ 1500 input speed $\div 20(gear\ ratio) \Rightarrow 75rmp$ output speed

Considering

Nema 23 stepper motor

Nominal power $\rightarrow$ 240 Watts

Nominal voltage $\rightarrow$ 484

Nominal current $\rightarrow$ 5 A

Maminal rotation $\rightarrow 1500rpm$

$$T_{\text{in}} = \frac{P \times 60}{2\pi \times N} = \frac{240 \times 60}{2\pi \times 1500} \Rightarrow T_{\text{in}} = 1.53Nm$$

- This calalation is assumed 100% efficiency, Real - Idorly will be slightly lower due to losses [heat, friction]

$$\begin{aligned} T_{\text{out}} &= T_{\text{in}} \times R_{\text{atio}} \times \eta \\ &= 1.53 \times 20 \times 0.94 \\ &= 28.2Nm \end{aligned}$$

$$\eta\,[\text{ efficiency }] = \frac{\text{Out put power}}{\text{Input poise}} \times 100\% = \frac{75 \times 28.2}{1500 \ \times 1.53}$$

$$= \frac{2,115}{2,280} = 0.927 = 92\%$$

0.0.7 Motion analysis:

Wheels' rotation and torque transfer in the gearbox simulated.
Result: Smooth motion with efficiency in power transmission.

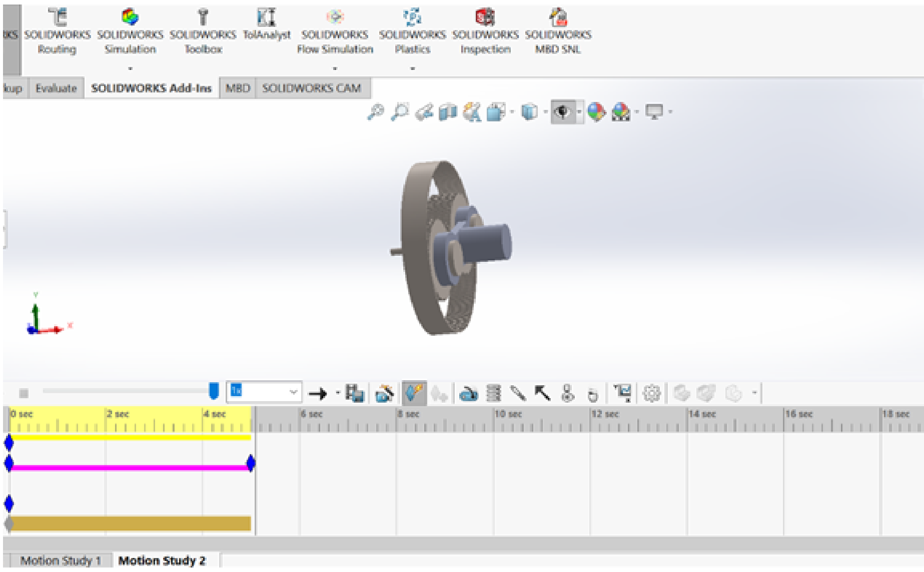

Figure 7

Material Selection
Wheels: Natural rubber, corrosion resistant and high load capacity.
Gears: Hardened Steel for increased strength and wear resistance
Shafts: Steel for durability
Housing: aluminum protection