POLITECNICO
MILANO 1863

3D PRINTED PLANETARY GEAR

POLITECNICO DI MILANO

DEPARTMENT OF MECHANICAL ENGINEERING

COMPUTER-AIDED DESIGN AND MECHANICAL PROTOTYPING

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1.0. INTRODUCTION

Epicyclic gears, often referred to as planetary gears, were initially created to forecast the motions of the planets in the solar system.

This kind of gearing is easily explained as follows: The planetary gears are made up of two mounted, aligned gears. These gears consist of a sun-like central drive gear and several "planet" gears that revolve around it. The way the different gears work together gave the planetary gearbox its name. The input gear is often the central "sun" gear. The planet and sun gears mesh such that their pitch rings roll without slipping thanks to the rotation of a ring gear (satellite) that surrounds the central and planet gears and connects their respective centers. An example of a planetary gear box is illustrated and can be seen below in figure 1.

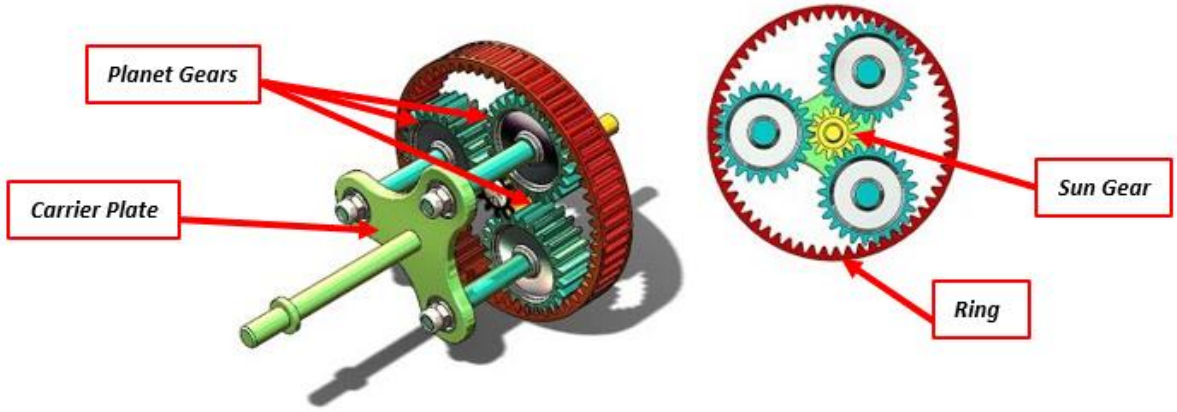

Figure 1: Planetary gearbox.

Planetary gears have grown in popularity in 3D printing for a variety of reasons. An example of a 3D printed planetary gearbox can be seen below in figure 2. A high gear ratio can be offered by planetary gear boxes while maintaining a small, lightweight design.

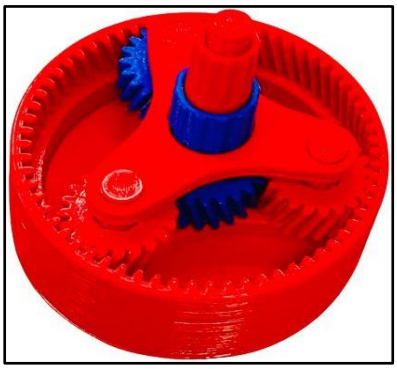

Figure 2: Real 3D printed planetary gearbox.

1.1. The Purposes, Advantages and Areas of Usage of the Planetary Gears

The planetary gears' main function is to transmit the necessary torque. The transmission ratio of the gearbox is unaffected by the number of teeth. Even the number of planets might change. The load distribution and, thus, the torque that may be transmitted increase as the number of planetary gears rises. The rolling force is also decreased when the number of tooth interactions increases. A planetary gear is very effective since just a portion of the entire output needs to be delivered as rolling power. This load distribution is a planetary gear's benefit over a single spur gear. Utilizing planetary gears, high torques can be transmitted with high efficiency using a small design.

Different ratios can be achieved by altering the number of teeth on the sun gear and the number of teeth on the planetary gears, provided that the ring gear has a consistent size. The ratio increases as the sun gear gets smaller. Technically, the planetary gears and the sun gear are quite small above and below these ratios, so a meaningful ratio range for a planetary stage is roughly 3:1 to 10:1. However, in our situation, the gear ratio is slightly larger than 1 because the 3D printed parts are utilized to define how the systems work. By connecting many planetary stages in series within the same ring gear, higher ratios can be achieved. We are referring to multi-stage gearboxes in this instance.

Planetary gearboxes are employed because of their robustness, efficiency, and capacity to manage high torque loads. They can be used in conjunction with internal combustion engines, electric motors, or hydraulic motors. They are utilized to transfer the greatest torque in the form that is the densest, or torque density.

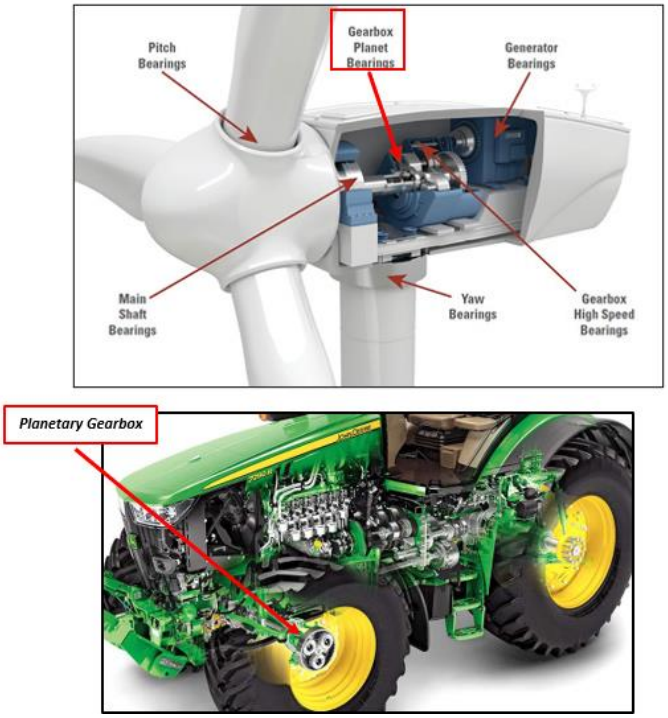

Figure 3: Applications of planetary gearboxes.

Since they are often smaller than other types of gearboxes, planetary gears are employed in applications where space is at a premium. They also serve as the foundation for the hydraulic planetary automatic transmission, the most prevalent type of automatic transmission. In the automotive industry, planetary gears are used in most current automatic transmissions. Planetary gearboxes are frequently utilized in the following transmission applications: In a printing press to slow down the roller speed for precise positioning, in a robot to boost torque, in a packaging machine for repeatable products.

Planetary gears are also utilized in augers, wind turbines, and in-vehicle drive systems for helicopter and airplane engines, among other pieces of machinery. Planetary gear sets are also widely used in industrial machinery like guided robots and laser cutters.

The advantages of the planetary gears can be listed as follows:

- Coaxial arrangement of input shaft and output shaft
- Load distribution to several planetary gears
- High efficiency due to low rolling power
- Almost unlimited transmission ratio options due to combination of several planet stages
- Suitable as planetary switching gear due to fixing this or that part of the gearbox
- Possibility of use as overriding gearbox
- Favourable volume output
- Suitability for a wide range of applications

2. AIM OF THE REPORT

Instead of spur gears in planetary gearbox, we have used helical gears. By using the KISSsoft software which helped us to improve the efficiency, maximum power density (torque) as well as total contact ratio. Moreover, we aim to show the audience the prototype of the gearbox in a certain application which in our case is a wind turbine.

3. DESIGN PROCEDURE

Since we have had access to the gear design software, namely KISSsoft, design parameters and model have taken directly from there and modified in other design software such as Autodesk 3ds Max, Inventor.

Considering the planetary gearbox, the main parts are one carrier plate, one guide carrier, one sun gear, one satellite carrier, seven clips, three rings and three planet gears as it can be seen in the figure 6 below.

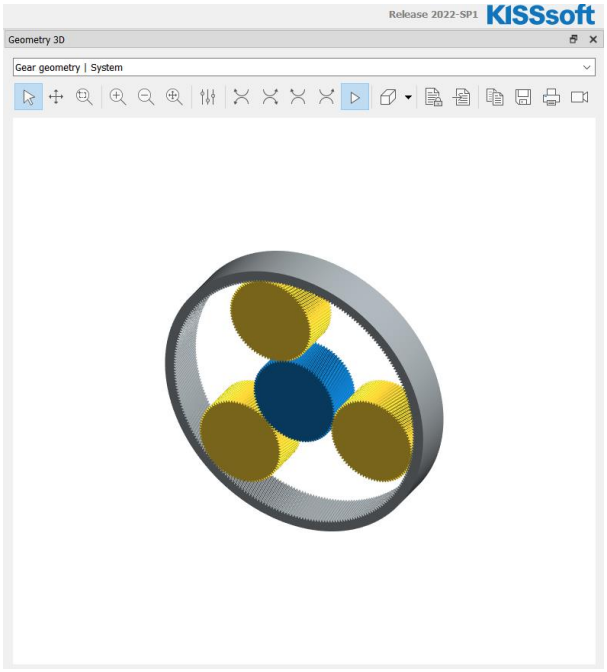

Figure 4: Planetary gearbox in KISSsoft

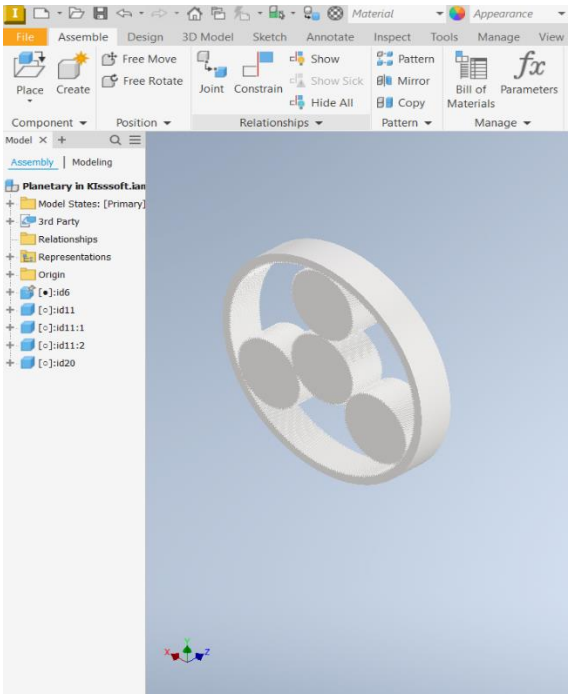

Figure 5: Planetary gearbox model in Autodesk Inventor Professional

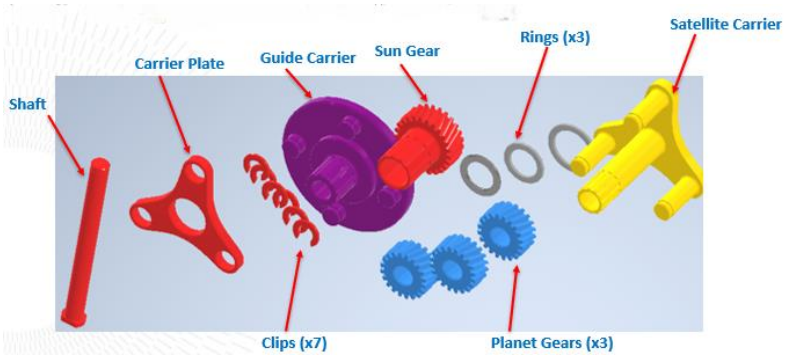

Figure 6: Explode view of designed planetary gearbox in Autodesk 3ds Max

4. 3D PRINTING

After the design part, the parts have gone through some modifications such as scale changes based on the printing procedure by using Sharebot Continuum software in OpenLab at Politecnico di Milano. Finally, the parts have been printed sucessfully in Sharebot 1 printing machine. For the filament material that we used to print our parts is PLA. The filament is basically a plastic wire wrapped around a spool that a 3D printer melts and pushes through a small nozzle (Figure 7).

Considering the selection of filament material, there are some characteristics considered: first, lower melting temperature & less warping. When compared to a material such as ABS, PLA has a lower melting temperature. For a comparison, PLA printing temperatures are usually around 205 degrees Celsius (401 F) while ABS is about 230 degrees Celsius (446 F). Not a massive jump, but still a very recognizable difference. The problem with this in 3D printing is if a print cools too much while being printed, it can lead to warping, potentially causing lots of problems. 3D printers are quite precise machines, moving within microns along all directions to do the work they need to do. Secondly, PLA is Safer to Use. Adding to the simplicity of PLA filament, is the fact that it is much safer to use indoors vs. ABS. As explained in further detail in the next section, PLA is basically made from plants and is used in a variety of other ‘green’ applications.

Figure 7: 3D printing filament.

5. ASSEMBLY AND SIMULATION

After completion of printing work, time to assemble what we printed. It has been observed that using helical teeth improved the contact ratio drastically and as a result, we obtained a smoother transmission in our gearbox system.

Then, we mounted our planetary gearbox into a wind turbine model prototype to observed the transmission of the power from DC motor through the planetary gearbox to the turbine blades. The final assembly can be seen below in the figure 8.

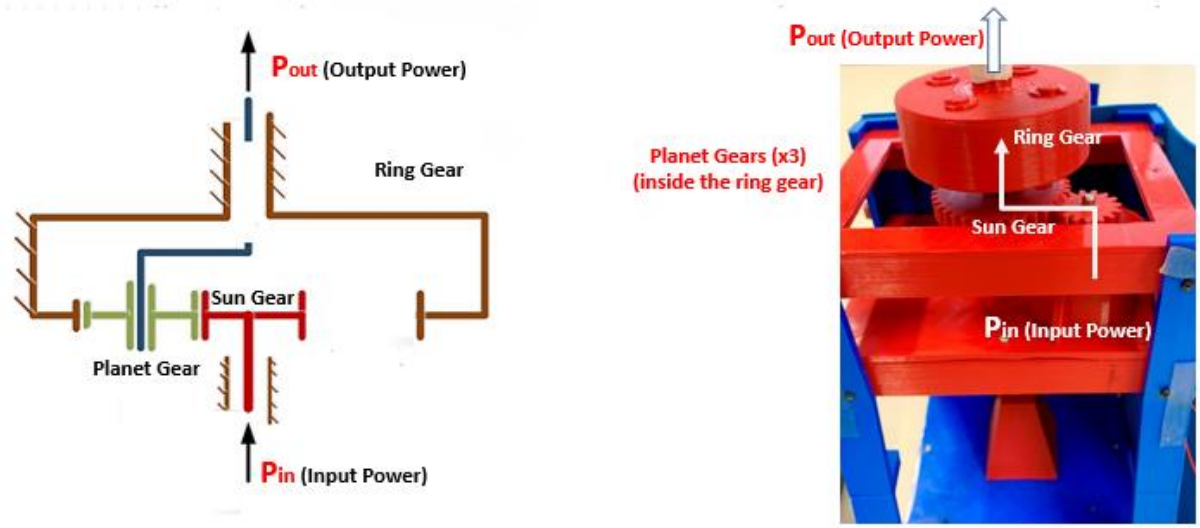

Figure 8: Power transmission schema on the left and the assembly on the right.

As for the whole system. we used the following power source and the motor speed controller.

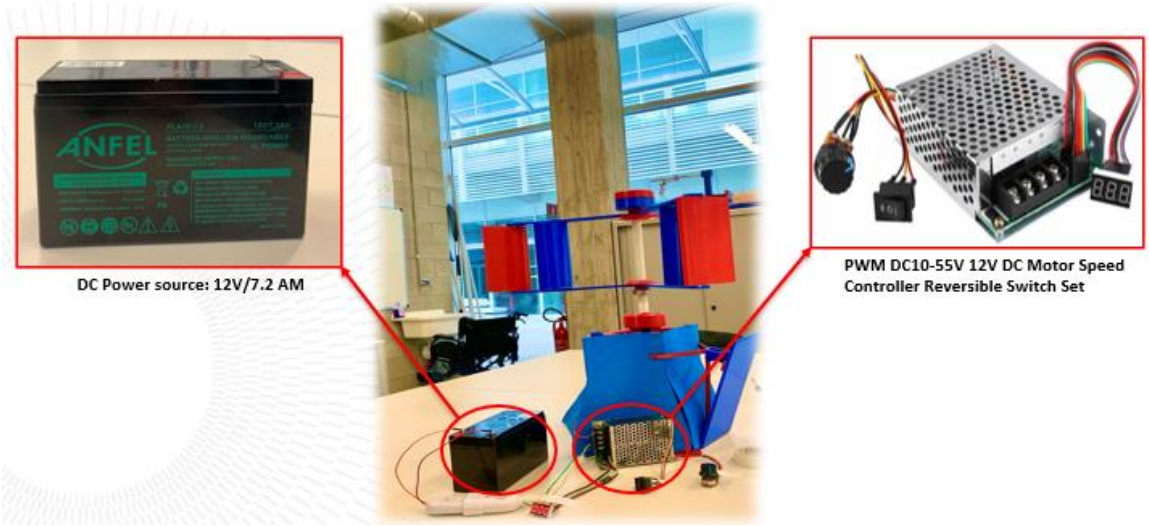

Figure 9: Power source on the left and the speed controller on the right.

7. UNITY SOFTWARE

In our project, we used the UNITY software due to these robust features, Unity 3D has become a popular option to build exceptional, easy, and affordable 2D and 3D visualizations. We can enhance the way we design, manufacture, sales and service our products with Unity. There are also some other advantages using Unity in our project:

- User Friendliness. We found out Unity is more convenient to use as compared to other technologies
- It is compatible with several platforms such as 3ds Max from which we exported .fbx file
- Availability of the Rich Asset Store

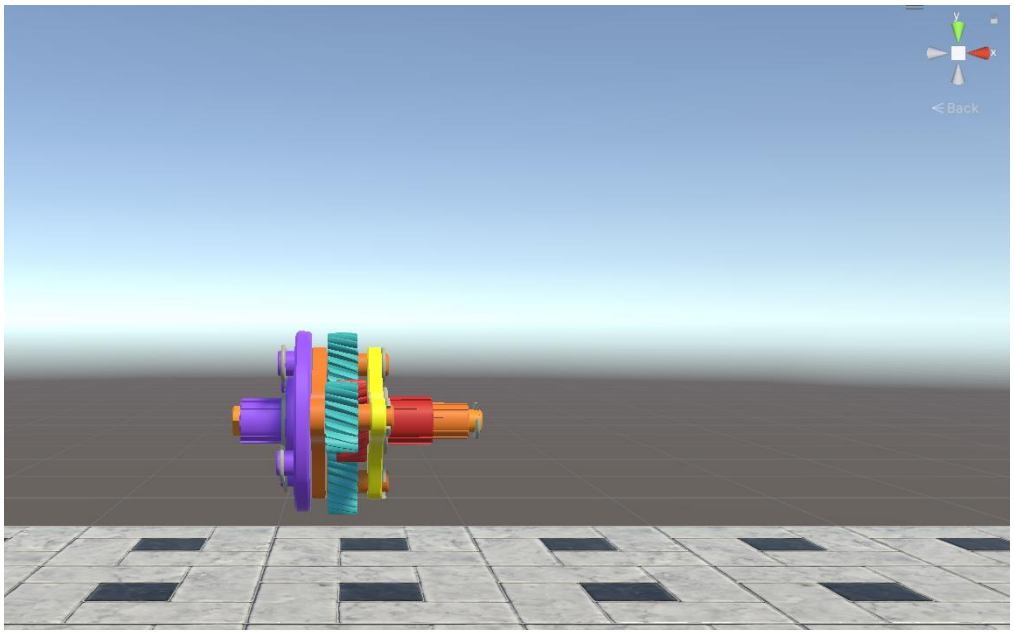

Figure 10: Planetary Gearbox in Unity environment

8. CONCLUSION

We came to the conclusion that by using the planetary gearbox with helix angle in the wind turbine provide us the below-mentioned advantages:

• 30 to 50% more torque capacity than equivalent spur-type planetary gearing

• Better load sharing, which increases life.

• Smoother and quieter operation

• Backlash reduced by as much as 2 minutes of arc