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The Chassis Design of the Swerveomni Directional Wheel

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Abstract: *For the design of the FRC race chassis, this project uses the official motor and parts as materials and Autodesk Inventor for modeling to design and produce a four-wheel drive, independently controlled motor chassis structure. The power system of the chassis structure contains two motors, one of which is the Falcon 500 as the drive motor of the power system, and the other is the 775 pro chosen as the drive motor of the steering system. The drive system consists of a gear train containing spur gears and bevel gears. The control system uses a classical PID algorithm to achieve accurate overall robot motion by outputting a specific amount of motor rotation. In the project, a single Swerve drive module was designed and built, and its performance was tested on a mobile platform equipped with multiple Omni-directional wheels.*

Keywords: *Swerve, FRC, Omni-directional wheel, gear drive*

1. Introduction

1.1. Origin of the subject

The FRC Competition, that is, the FIRST Robotics Competition for Secondary School Students in grades 9-12, is an international robotics competition sponsored by the FIRST (For Inspiration and Recognition of Science and Technology) group with a worldwide impact. Inventor Dean Kamen founded the FIRST organization to inspire young people to become interested in science and technology.

As a robotics event open to high school students worldwide, FRC has a high level of enthusiasm among the student community who love science and technology. For FRC, it encourages high school students to design, build, program, and compete independently. In this event, students are required to build their own machine that can accomplish the goal. This machine is generally required to have a chassis to participate in the competition.

In the FRC event, there is a very strong team with team number 254, which is an extremely difficult team to beat. However, one team developed its own Swerve chassis in a competition and beat 254 in the event. As a result, a wave of enthusiasm about Swerve was started in the FRC competition. As a team member, the intention of this article is to design a Swerve chassis to strengthen the team and thus increase the chances of winning.

1.2. Research background

The Swerve drive is a specially designed drivetrain, which enables the robot to rotate as it travels along any path over the terrain. With each wheel rotating on a vertical axis, the drive's maneuverability is unstoppable. The steering drive mounts can be rotated and panned independently; they can even be rotated while cruising in a straight line. The 3D model drawing of the Swerve chassis is shown in the figure.

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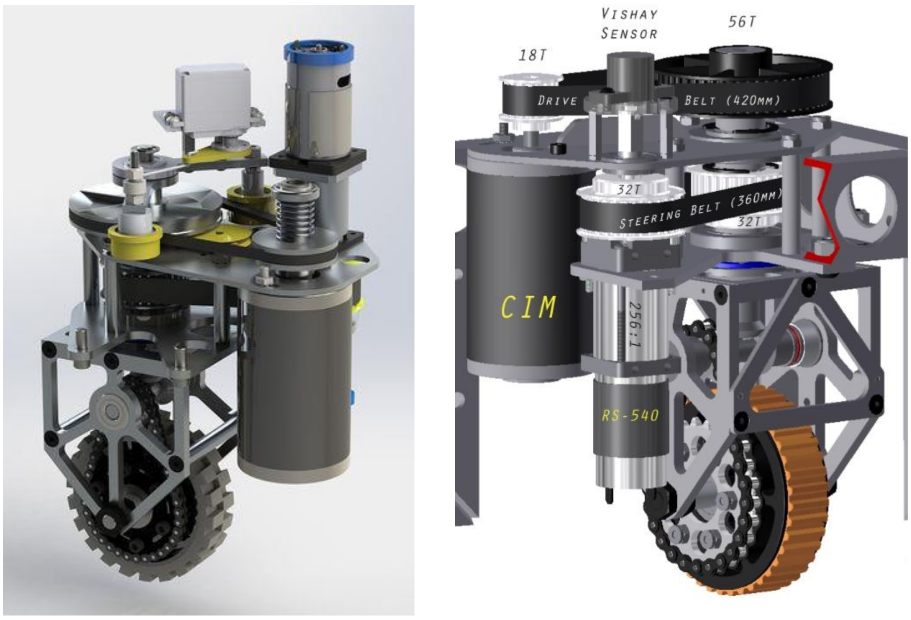

Figure 1: 3D model drawing of Swerve module

Swerve chassis includes the following advantages:

Agility: equipped with a true two-dimensional drivetrain whose drive direction may be separated from the chassis direction.

Traction: Compared to other complete drive systems, high traction can be used to pull the wheels without negative consequences; in addition, the drive can be vectorized in any desired direction.

Invisibility: no need to redirect through chassis to communicate intent

Flexibility: Each wheel's drive direction and power can be controlled independently through software, allowing for a variety of drive modes, including game-specific drive modes.

Dynamic steering: for most FRC drivelines, the driver lever input diagram with driveline motor command is 1:1; The steering direction of each wheel needs to reflect not only the driver's joystick input but also the current "t" state at the time the "t+δt" motor command is determined; from a practical point of view, this can be used as an agility force multiplier.

Minimal steering hysteresis: it requires virtually no overcoming of static friction during steering

Suitability: it has an independent modular wheel drive system design; 1640 can change the pivot module in less than 5 minutes (easily done)

Swerve chassis includes the following disadvantages:

Complexity/difficulty: This is not an easy drivetrain to implement; it is more difficult to implement for both mechanical and procedural aspects

Mass: 1640 reduces the mass of the 4 pivot modules to 31.6 lbs. This is still a lot for a driveline.

Production time: it is not only the CNC machining that takes time but also the assembly of complex mechanisms

Cost: the financial cost of the steering module is a significant part of the build budget (but fortunately, prices are dropping)

Difficulty driving in a straight line: unsurprisingly, the ultra-sensitive drivetrain has difficulty driving in a straight line; the driver compensates for this in remote operation, but this is a particular problem for Autonomy (solved in 2018)

High utilization of cRIO resources

Many of the Swerve chassis designed by the teams themselves are displayed on the GrabCAD website, and there are many innovative points worthy of reference. In the Swerve chassis design of most teams nowadays, I have observed that the powertrain drive is a gear drive, while some teams use a pulley drive.

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The belt drive has many advantages, such as simple structure, smooth transmission, cushioning vibration absorption, the ability to transfer power between large shaft spacing and multiple shafts, low cost, no lubrication, and easy maintenance. However, belt drive also has disadvantages such as inaccurate transmission ratio, low belt life, high load on the shaft, large external dimensions of the drive, and low efficiency. Therefore, under normal circumstances, belt drive is suitable for large center distance, small to medium power, belt speed v = 5 to 25m/s, and $i \leqslant 7$.

Given the wide range of gear ratios, the gear drive can be used for speed reduction or speed increase. The transmission efficiency is high. With a pair of high-precision involute cylindrical gears, the efficiency can be over 99%. However, the gear drive also has some disadvantages, with no overload protection. The noise, vibration, and impact during transmission are relatively large for gears with low precision; the manufacturing cost is high. Some gears with special tooth profiles or high precision need special or high-precision machine tools, cutting tools, and measuring instruments. Therefore, the manufacturing process is complicated, and the cost is high.

The experience in the field shows that the timing belt can not withstand the high pressure running on the playing field and wear out and break. Therefore, gear drive is the main drive method of this design. The author considers using 3D modeling software to design gears and create them by 3D printing technology.

As for the motor, Falcon 500 is chosen as the power motor mainly for its great torque. It can provide a high power of up to 400W at 40A. The Falcon 500 is powered by Tyrone FX and was developed through a partnership between VEX Robotics and Cross the Road Electronics. This is exactly the kind of partnership that led the cutting-edge Tyrone SRX and Victor SPX to participate in the first®Robotics Competition. The Falcon 500 aims to provide teams with unheard of power and efficiency, which in turn reduces the size, weight, and common failure points of other motors on the market.

The competition is allowing machines to punch each other. Therefore, the 775PRO was chosen as the steering motor because of its compact size. The 775pro motor was designed in collaboration with West Coast Products and included dual bearings. This open box motor is more efficient than similar motors on the market. The power of the CIM motor is packaged by the 775PRO is a small, lightweight package. The motor is air-cooled and is designed to run at high speeds; this makes it suitable for applications that will not stall for long periods of time (such as air intakes, conveyors, and throwing wheels).

2. Program design

2.1. Hardware design

Swerve chassis typically consist of four wheels, each driven by a single motor. There are two variants of the steering wheel system. In a rotary drive, the system connects all-wheel pods together by chains and sprockets or gears, the pods all rotate in the same direction to allow 2 planes of motion, and they can be rotated by means of a sliding tank. Each wheelhouse (or pair of wheelhouses) of the Crab Drive system is controlled by a motor that allows movement in two planes of motion, and they can turn in the tank skid method, conventional steering, and quad steering (four-wheel steering).

The Swerve chassis is designed to allow free movement of the machine, followed by size, ease of disassembly of the module, and finally weight and volume, as well as price and durability. The basis of the entire Swerve module is the two motors.

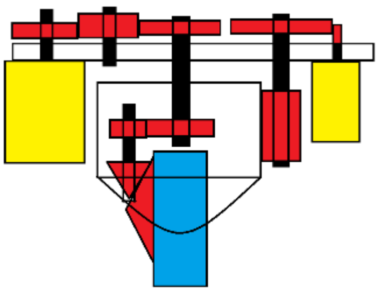

Figure 2: Swerve module schematic

(Red is the gear, black is the shaft, yellow is the motor, blue is the tire)

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2.1.1 775 pro motor

The 775 pro motor is one of the motors commonly used before the introduction of the Falcon 500. The signals can be translated and controlled via the official Talon SRX encoder. The operating voltage is 12 volts and can be connected to an official voltage distributor (PDP).

The 775 pro's small size and torque allow the tire to rotate while carrying a certain amount of weight, which qualifies it as a steering motor but has the disadvantage of lacking an encoder, requiring space in the module to be freed up for an encoder to operate. Considering the price and the space allocation above and below the upper support plate (if the Falcon 500 is used, there is no need to install Talon on the support plate, but there is no space under the aluminum plate for the Falcon 500), the 775 was chosen as the steering motor.

Figure 3: 775 pro physical diagram

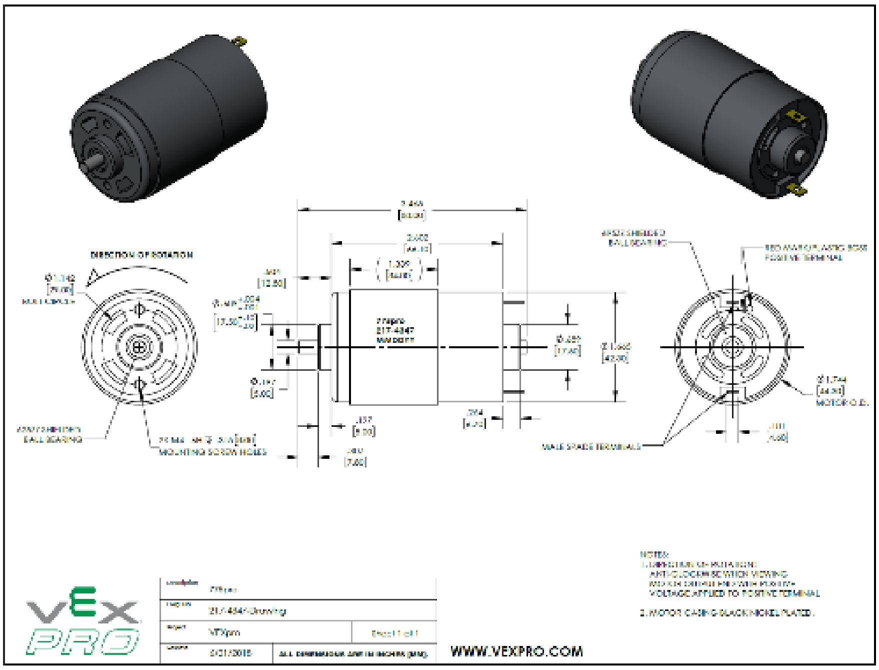

Figure 4: 775 pro engineering drawing

2.1.2 Falcon 500

The Falcon 500 is a relatively advanced brushless motor that can deliver 400 W at 40 A. The FRC is a fixed power environment and can only use one battery. The only way to get more power out of your motors is to increase their efficiency. Higher efficiency means that more of the energy stored in the battery is converted to mechanical energy without being lost to heat. The Falcon 500 has an efficiency of over 80% over most of the FRC's operating range (7-40A).

In addition, the Falcon 500 has a longer lifespan than other motors and more torque than brushed motors. At the same time, it comes with its own encoder, thus saving space inside the robot, and as a counter game to the FRC, ramming is inevitable. Therefore, as a power motor, the torque must be high. The Falcon 500 has a high blocking torque of 4.69 Nm, so using the Falcon 500 as a power motor guarantees the strength of the machine in confrontation.

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Figure 5: Falcon 500 physical drawing

2.2. Production process

First, 3D modeling was performed using Autodesk Inventor, and the design was done mainly with reference to a completed Swerve module. At the same time, this paper made some changes to the design of this Swerve, changing the power system of the pulley drive to a gear drive and using helical gear to increase the engagement area to improve transmission efficiency and reduce noise.

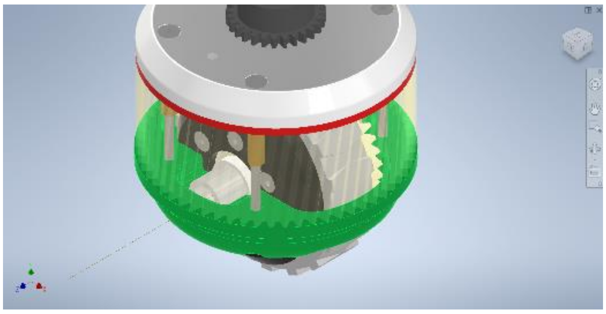

Figure 6: Fixed structure of the shaft (the upper part is made transparent)

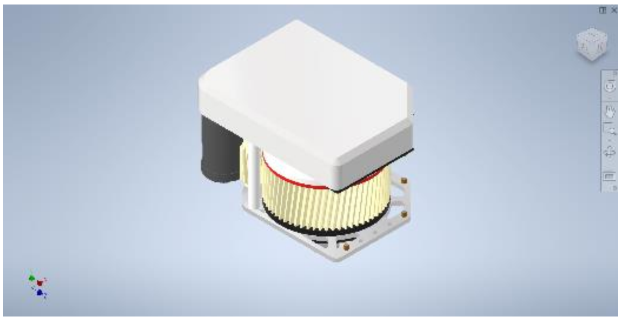

Figure 7: Dust cover and Swerve module

During the building process, the project converted Swerve's aluminum plate structure to wood plates and eliminated the dust cover to reduce costs, because as a pilot version, the Swerve module would not move too drastically and would not be used for a long time. Of course, the most troublesome part is the assembly of the helical gear combination. Unlike spur gears, helical gears cannot be inserted from the top end and engage smoothly because the helical gears are limited in their engagement. In addition to this, during the assembly, I forgot to include tolerances in the design. It caused some structures to be overfilled and difficult to assemble, so I had to use sandpaper to grind them away. Certainly, except for these problems, the whole assembly process went smoothly.

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2.3. Finished product display

Figure 8: Structure below the upper support plate

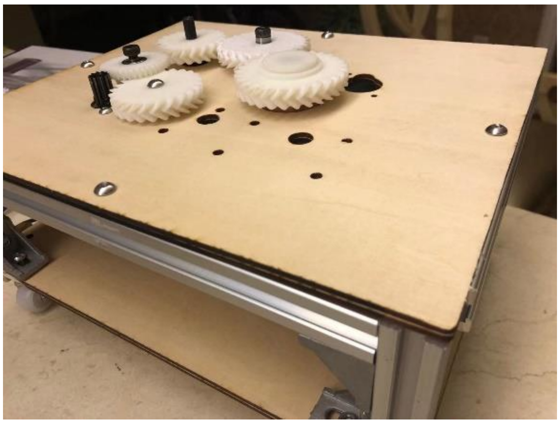

Figure 9: Structure above the upper support plate

3. Conclusion

A Swerve module that can move freely was completed. In actual operation, the Swerve chassis designed and made by the author independently can move freely in two directions with good motion performance, achieving all the expected design goals.

At the same time, the structure on the support plate is very flat due to the presence of the dust cover and does not affect the layout of the modules performing scoring tasks on the upper level. The parts do not conflict with each other and can work properly for further expansion of functions and modules at a later stage.

4. Creative expression

(1) Compared with the pulley drive structure, the gear drive is more stable, and the ratio is more fixed, making the loss of motor rotation to wheel rotation smaller.

(2) Compared with the belt drive, the gear drive will not be repaired too often on the field, can withstand the high-pressure operation on the competition field, and is easy to maintain.

(3) Fixing the wheel axle instead of using the wheel fork enhances the stability of the wheel and avoids unnecessary damage.

(4) The use of helical gears instead of spur gears extends gear life and reduces module operating noise.

(5) The dust cover is independently designed to increase the space occupied by the upper scoring module while preventing dust from entering the drive structure, and the expansion space is reserved.

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5. Shortcomings in design and outlook

(1) No calculated tolerances, reducing the life of the drive structure

(2) Some structures are assembled in a fixed order, which makes assembly difficult and wastes time for assembly and later maintenance.

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