Using Tires Instead of The Other Rollers to Make Climber Technical realization

IRSET (Iran Space Elevator Team)

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The purpose of this paper is to present technical report of the climber which had made by IRSET (Iran Space Elevator Team). The mechanical system of the climber has some unique features. The first one is using tires as roller that this provides the possibility to increasing in contacting surface between wheels and tether so friction increases and provides less slip. Secondly, using tire provides more durability compared to the other kinds of metallic wheels. of this view, it is similar to the real climber. The rings and pulleys according to the needs of the climber had designed and made by our team. In the electronic system, we had used transmitters and receivers infrared and ultrasonic sensors to measure the slip and climber speed and the engine RPM.

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1. Introduction

IRSET has three members. Mohammad Aramideh -Mechanical engineering student- is team leader and has designed and built the mechanical system. Masoud Aramideh- Electronics engineering student- designed electronic system and did hardware and software of controlling motors and Data processing. Mojtaba akbarzadeh -Mechanical engineering student- helped in mechanical design. This climber is the first climber which we designed and made. And of course this is the first one in Iran. We have started studying and researching about the space elevator system and the climber, from a year ago. And after followed-up news and research developments and even ts in this field, we saw the news of EuSEC, to be Presence in the research events, we decided to participate in this competition.

The technical report is presented in two mechanical part and electronics part. Available choices for using as wheels and their disadvantages are mentioned. Then tires are proposed as an appropriate choice for this system. In next section the formulas that used to design the climber, are presented and the final model of the climber is explained. In electronics part after presenting the electronics functional block diagram, methods of controlling motors and usage of sensors to make measurements are explained.

2. The development-process of IRSET Climber

2.1. Concept

In space elevator climber system there is some wheels that placed on the two sides of the tether and the tether is kept between the wheels. Motivation force from motor is applied to the wheels via a mechanical system. The generated friction between the tether and the wheels causes to climbing. So wheel physical properties have a significant effect on climber performance. There are different choices to roller implementation:

1. Metallic rollers with smooth surface: by increasing in contacting surface, the friction between rollers and tether increases. As increase in vertical force on the rollers, doesn't increase contacting surface in this kind of rollers, the friction doesn't increase too, and finally there is not suitable quantity of friction to climbing.
2. Metallic rollers with non-smooth surface: a method to increase friction is changing smooth surface to non-smooth surface, but due to being rigid contacting surface doesn't increase and friction doesn't increase too.
3. Covering metallic rollers by rubber: to increase the contacting surface we should search for a method. An available method is using rubber to cover rollers surface. This increases the contacting surface but due to non-homogeneous, rubber will be ruptured and puts a bad influence on climbing action. A real space elevator must be able to travel long distances, so this problem is considered as an issue to the climbers.
4. Using tires: instead of mentioned type of wheels, tires are used in our climber, that solves the mentioned problems and provides following advantages:
    - Damping vibration: as for tubeless tires are flexible act as damper and prevent climber vibration.
    - Generating more friction: as tire is not a rigid object, contacting surface will have a temporary deformation, due to vertical force on the tire, and contacting surface will increases. So the climber could go up better.
    - More durability: using tire provides more durability compared to the other choices. It is recommended to use tubeless tires in real climbers.

Less slip: due to increasing in contacting surface, friction increases and provides less slip. Slip is introduced in following section.

2.2. What Slip Is

Slip is defined as relative movement in the direction of travel at the mutual contact surface of a traction or transport device and the surface which supports it (ASAE 1983). Slip can also be considered as the reduction in actual vehicle travel speed when compared to the theoretical speed that should be attained from the speed of the tire or track surface. Slip is ultimately a measure of the relative motion between the surface of a tire or track and the ground plane where the tire or track is operating.[3]

2.3. How to calculate slip:

$$slip = \frac{actual\ climber\ travel\ speed}{theoretical\ speed\ that\ should\ be\ attained} \quad (1)$$

the traveled distance in each wheel rotation is 220mm. and the traveled distance in each motor rotation is 36.7mm. so:

$$slip = \frac{V}{\omega \times 0.0367} \qquad (2)$$

V: climbing speed (m/s)

ω: rotational speed (round/s)

As $V = \frac{\Delta h}{\Delta t}$ and $\omega = \frac{n}{\Delta t}$:

$$slip = \frac{\Delta h}{n \times 36.7} \qquad (3)$$

n: revolutions

Δh: displacement of climber

2.4. Mechanical Design

In this climber system, one pulley placed on the motor shaft and by a timing belt connected to the pulley on the wheel shaft. When the engine is switched, motion and force get transfer to the pulley on the wheel shaft. After that, wheel and climber move on the tether.

In this design, the climber weight and payload have been considered 5 kg and 3 kg. As for the mechanism, we calculate the torque.

We know that the torque formula to calculate a moving with constant acceleration is:

M=(mg+ma).r (4)

In this formula, (r) is equal to the radius of the wheel that we show it by r_w , a is equal to the acceleration, m is total weight and g is gravitational acceleration.

To calculate the torque, we need to know the acceleration quantity. As for the distance (25 meters), our choice for time is 2 seconds. So we have:

X=25 m , t=2 s , $V_0=0$

$X=\frac{1}{2}\, a\, t^2$ (5)

$25=\frac{1}{2}\, a\, (2)^2 \rightarrow$ so $\rightarrow$ a= 12.5 m/s^2 (6)

Now we calculate the torque on the wheel.

r_{wheel}=35 mm
r_{pulley}=49 mm
$r_{motor(pulley\ on\ motor)}$=9 mm

$\rightarrow M_{wheel}$=(78.4+100) . 0.035 $\rightarrow$ M_{wheel}=6.25 N.m

Similarly, the torque on the pulley on the wheel shaft is equal to:

$M_{pulley}=\frac{r_{wheel}}{r_{pulley}}.\, M_{wheel}$ (7)

And at the end we get The final formula for torque on the motor pulley:

$M_{motor}=\frac{r_{motor}}{r_{pully}} \cdot \frac{r_{wheel}}{r_{pulley}}$. (mg+ma).r_{wheel} (8)

$\rightarrow M_{motor=}$ 0.826 N.m

The amount of power required that the climber reach speed of 12 $^{m}/_{s}$ is:

$$P = N.M_{motor}.\frac{2\pi}{60} \quad (9)$$

(N) is the vertical force and it is equal to:

$$N = \frac{60}{2\pi}.V.\frac{r_{pulley}}{r_{wheel}^2} \quad (10)$$

And M_{motor} is:

$$M_{motor} = \frac{r_{motor}}{r_{pulley}^2}.r_{wheel}^2.(mg + ma) \quad (11)$$

By putting the (N) formula and (M) formula in (P) formula we have:

$$P = V.\frac{r_{motor}}{r_{pulley}}.(mg + ma) \quad (12)$$

Now, we put the parameters in the (P) formula:

P= 395w → The amount of power required

The another important parameter for design is revolutions per minute. As for the radius of wheel is 35 mm , we calculate perimeter of wheel, so :

$$p = 2r.\pi \quad \rightarrow \quad p = 2\,(0.035)(3.14) \quad \rightarrow \quad p = 0.22\,m$$

The Perimeter represents the traveled distance in each wheel rotation. So, as for the selected speed, The numbers of rotations to travel 12 meters in one second is equal to:

$\frac{V}{p} = \frac{12}{0.22} =$ 45.5 n (13)

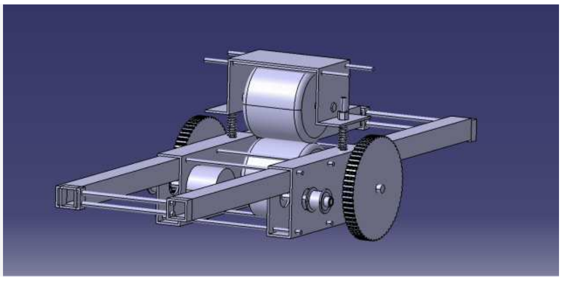
So, in this design, revolutions per minute (RPM) is equal to:

$$\frac{45.5}{1\,s} = \frac{n}{60\,s} \quad (14)$$

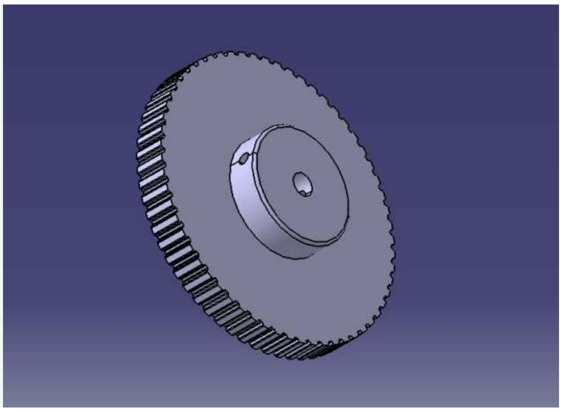
$$\rightarrow \quad n = 2730\,rpm$$

2.5. Modeling

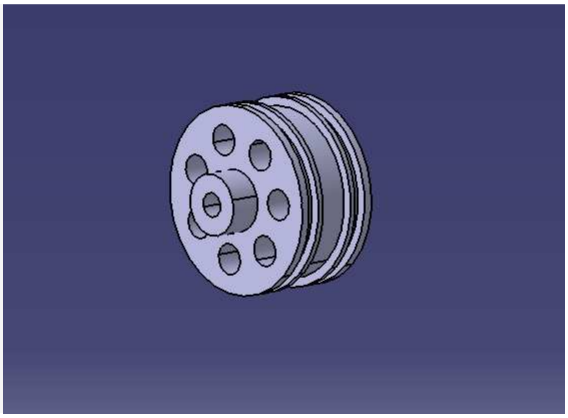
In design Parts and components and modeling this climber, to decrease the cost, we tried to use tools and components which were available in Ahvaz (our city). One of the features of the climber design and modeling is using standard parameters.



The main body made of aluminum.



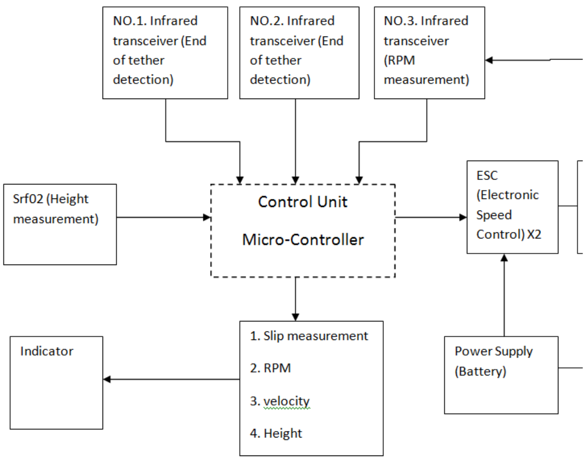
We used CATIA software to design wheel rings and pulleys.



After that, by lathing and milling, we made them .the pulleys and rings material is aluminum. We tried to reduce weight of components by drilling. Control car tires are used as the climber tires.

2.6. Electronics Design

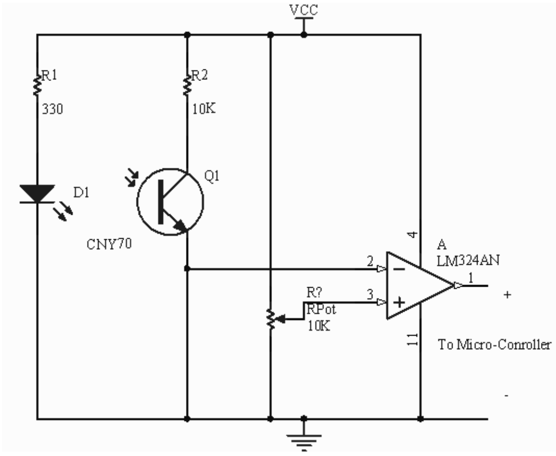
The climber electronic system is divided into two main parts: motor control part and data measurement part. In motor control part, the micro controller applies PWM wave to ESC (Electronic Speed Control) for running the brushless motors. Infrared transceivers (N.O. 1&2) detect the mark on the tether showing the end of line and the climber comes down.



In data measurement part, the tires slip is measured using N.O.3 infrared transceiver and the ultrasonic sensor, SRF02. N.O.3 infrared transceiver measures the motor RPM using a mark on the motor and forms a simple encoder. Using height difference in a determined time, velocity will be measured and the indicator displays the data.

- Implementation
    - o Detecting end of tether

In order to detecting end of tether we have used a cny70 sensor typical circuit, that is shown below:



As seen on this figure suitable output for detecting end of tether will be generated by the reflected light from the tether surface to the base lead of transistor Q1. The LM324 output is connected to external interrupts of an atmega32 micro controller. In N.O.1 interrupt routine service the climber will come down and in the other external interrupt routine service the climber will be stopped.

o Motor RPM measurement

A simple encoder and ability of the circuit shown on figure… to detection of black and white colors, are used to the motor RPM measurement. By putting a white mark on the motor and after running it, some pulses will be generated. We applied these pulses to Timer/counter1 clock source and measured the motor RPM using it.

o Height and velocity measurement using The SRF02

The SRF02 is a single transducer ultrasonic rangefinder . It features both I2C and a Serial interfaces[4].In order to distance measurement we used I2C interface. The proposed methode to velocity measurement is calculating the difference between two height in determined periods of time provided using timer/counter2 overflow interrupt. So we have:

$$\bar{V} = \frac{h_2 - h_1}{t_2 - t_1} \quad (15)$$

$\bar{V}$ is the average of speed in the determined period $t = t_2 - t_1$. by increasing sampling rate $\bar{V}$ is an approach of moment velocity. The mentioned data will be measured until 6 meters height. This limitation is because of using the SRF02. The method of speed measurement is correct in far distances in case of using another more power full range finder.

o Slip measurement

Slip quantity is measured using the SRF02 , N.O.3 Infrared transceiver, and formula:

$$slip = \frac{\Delta h}{n \times 36.7} \quad (3)$$

- Software

The software is divided into three main parts: 1.initialize, startup and PWM control 2.external interrupts to detect the end the tether 3.the timer overflow and updating measurements

Peripheral unit	**Usage**
Timer/counter0	PWM generation
Timer/counter1	RPM counter
Timer/counter2	Overflow interrupt to make measurements
INT0&INT1	Detecting end of tether

o initialize, startup and PWM control

A PWM wave with determined Duty cycle is needed to drive the brushless motors. In this part of software timer0 is initialized to generate the PWM wave. Some delays is generated to run the motors, and timer2 overflow interrupt is enabled to generate the determined periods of time.

o External interrupts

As said before, the output of the circuit shown on figure… is applied to the external interrupts pins. When end of tether detected, in interrupt routine service the climber comes down if the upper mark is detected and the motors is stopped if the bottom mark is detected.

o the timer overflow and updating measurements

The data sampling is done in timer overflow routine service to make measurements. In every interrupt routine service the quantity of the pulses applied to timer1 clock source and finally rotational speed of motor is calculated. Then the SRF02 data will be updated and height, climbing speed, rotational speed, and slip will calculated using mentioned methods and equations.

3. Conclusions

The presented climber in this paper, due to innovation to use tires instead of the other kind of rollers, is more realistic. Also using tires decrease slip that provides better climbing and damping vibrations causes to more safety for the cabin. The electronics system is capable to measure the parameters slip, climbing speed and motor RPM that provides to study of how the parameters like quantity of pay load, vertical force on tires and etc, influence slip.

4. Reference

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4. The SRF02 technical datasheet.