Design of a Type of Semi-Automation Stretcher-vehicle

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Abstract. The semi-automation stretcher-vehicle is used to rescue people in various situations. The vehicle is designed with certain new features, including power-drive, semi-automation, and the capability to climb stairs and go over obstacles. It is equipped with Servo Motors, triangular wheels with tracks, lifting device and so on. This structure realizes the semi-automation in the rescue process and solves the main problems of traditional stretchers, like their low moving speed, inefficiency, instability and so on. Besides, the stretcher could keep horizontal when it is climbing slopes, so it could keep the patient comfortable and prevent him from injury.

Introduction

The stretcher-Vehicle is used to rescue people in various situations, so it is designed with certain features. The unique structure of this vehicle allows it to climb the stairs and climb over obstacles. Besides, the stretcher could keep horizontal even when it is climbing slopes. Together with damping device which could reduce the vibration of the stretcher, it could keep the patient feel comfortable and prevent him from getting injured. The stretcher-vehicle consists of three parts: the dynamic part, the vehicle body and the lifting device including the stretcher.

The design process

The main structure design. By analyzing the current information [1-4], and comparing many structures, we conclude that the triangular wheels with track could provide a stable structure to climb both the stairs and the slopes. What is more, this kind of wheel could also help the vehicle to move stably on the rugged roads. So, we design a lifting device to control the stretcher to remain horizontal. Finally, we choose the stretchers with the material that is light and durable. The stretcher can be separated from the vehicle, so that it could be stored or used independently when it is separated from the vehicle. The 3D model is shown in Fig. 1.

Fig. 1. The 3D model of the stretcher-vehicle
The power part. We choose the Servo Motor as the power part, which is motivated by electricity and controlled by SCM. According to the weight of the machine, speed, and other parameters, we calculate and choose the motors. And according to the calculation, the motor should meet the parameters in Table 1.

| Rated Voltage [V] | Rated Current [A] | Rated Power [W] | Output Speed [RPM] |
|------------------|------------------|----------------|------------------|
| 24               | 3.25             | 78             | 190              |

The main body. The main body is the platform of the stretcher-vehicle, on which the power part, the wheels and other parts are located and fixed. The size of the main body is related to the stretcher and lifting device above. The wheels and the motors are fixed on the body, and they can be adjusted along the dovetail grooves on the body. The stretcher-vehicle is scalable also because of the dovetail grooves. Certain devices can be placed on the main body, which could store first aid items like medicines and bandage.

The lifting device. The lifting device consists of worm and turbine, pivoted lever, crank-rocker mechanism and slide block. The manipulator could adjust the angle of the stretcher on time to keep it horizontal even if the vehicle is moving on the rugged land.

The lifting device must obtain the following functions: (1) The lifting device could adjust the angle of the stretcher; (2) The lifting device should be adjusted quickly as well as should save human labor; (3) The device must be reliable and safe; (4) The lifting device should be inexpensive and easy to manufacture.

According to the requirement above, we design the lifting device as Fig. 2 shows. The reason of designing worm and turbine mechanism is that it has self-locking mechanism. It makes the lifting device stop at the point when the manipulator stops rotating the handle. Besides, we design the crank-rocker mechanism to amplify the distance of traveling. The slide block is connected with the bar in its middle. This kind of structure could widen the distance to the swing point, so that it could increase torque and make the manipulator easy to adjust the stretcher [5-6].

Substitutive Design. The lifting device is made of steel to make sure it is durable and reliable. There are nine holes on the inside bar and one hole on the outside pipe. The pipe is connected with bar by screw bolts. People could adjust the angle of the stretcher by pulling the bolt out and adjusting the height of the lifting device and then fixing them with the bolts. According to the calculation, the angle of the stretcher could be adjusted from -30° to 30°.

The triangular wheels with tracks. There are four groups of wheels – two groups on each side, as Fig. 3 shows. Every group of triangular wheels consists of three wheels. One is the driving wheel, and the others are the supporting wheel and the driven wheel. All of them are circled by one track, which shapes an inverted triangle so that the wheels could climb stairs as well as climb over obstacles. The
innovation of this type of wheels is the up-side-down triangular design which makes the stretcher vehicle capable to move on the rugged land in the disaster areas, and also makes it able to climb stairs upward and downward.

**Fig. 3.** The triangular wheels with tracks

The data and the calculations. We choose the motors according to the output power and torque of the motors.

The moving speed of the stretcher vehicle is \( v = 1 \) m/s. The kinetic friction coefficient between the wheels and the ground is \( \mu = 0.3 \). The weight of the stretcher is 100 kg. The acceleration of gravity is \( g = 9.8 \) m/s\(^2\). The diameter of the driving wheel is \( D = 100 \) mm. We assume that the stretcher-vehicle move forward in constant speed.

The angular velocity of the wheels:

\[
\omega = \frac{2v}{D} = \frac{1}{0.05} = 20 \text{ rad/s}
\]

Because:

\[
\omega = \frac{\pi n}{30}.
\]

Therefore the output torque of the motor is:

\[
n = \frac{30\omega}{\pi} = \frac{30 \times 20}{3.14} = 191.1 \text{r/min}.
\]

The power of the stretcher-vehicle moving forward:

\[
P = F \cdot v = \mu mg \cdot v = 0.3 \times 9.8 \times 1 = 294W.
\]

The transfer efficiency of the motor:

\[
\eta = 95\%.
\]

The output power of the motor:

\[
P = \frac{P}{\eta} = \frac{295}{0.95} = 310.5W.
\]

The output power of a single motor (there are four motors):

\[
P_0 = \frac{P}{4} = \frac{310.5}{4} = 78W.
\]

The torque of a single motor:

\[
T = 9550 \times \frac{78}{191.1} = 3.898 N \cdot m.
\]

According to \( P_0 = UI \).

\[
I_e = \frac{P_0}{V} = \frac{78}{24} = 3.25A.
\]

According to the calculation, the power of the motors is 78 W, the rated voltage is 24 V, the rated current is 3.25 A, the output rotational speed is 195 RPM.

Then we check the strut stability check for the supporting poles.
First of all, the strut stability constraint condition is that one side is fixed and another side is hinged supported, as Fig. 4 shows. We can know from the manual: $\mu \approx 0.7$.

The material of the supporting poles is Steel 45, the length of the pole is 900 mm, the diameter is $D = 30$ mm, the supporting weight is about 80 kg. Therefore:

$$F_{\text{max}} = \frac{F}{4} = \frac{80 \times 9.8}{4} = 196N.$$  \hspace{1cm} (11)

We know from the Mechanical Design Handbook [4] that the range of the safety factor of Steel 45 is: $n_{st} = 30 - 40$

Then we check it by formulas:

By Euler Formula is:

$$\lambda_i = \sqrt{\frac{3.14^2 \times 210 \times 10^7}{280 \times 10^6}} = 86.$$  \hspace{1cm} (12)

Because the cross section is a round:

$$i = \frac{I}{A} = \frac{\pi d^4}{4},$$  \hspace{1cm} (13)

$$\lambda = \frac{\mu l}{i} = \frac{4 \mu l}{d} = \frac{4 \times 0.7 \times 900}{30} = 84,$$  \hspace{1cm} (14)

$$\lambda < \lambda_i.$$  \hspace{1cm} (15)

Therefore, we cannot use Euler Formula to calculate the critical pressure:

$$\lambda_2 = \frac{a - \sigma_z}{b} = \frac{461 - 350}{2.568} = 43.2,$$  \hspace{1cm} (16)

$$\lambda_2 < \lambda < \lambda_i.$$  \hspace{1cm} (17)

We can find that the compliance of the supporting poles is between $\lambda_1$ and $\lambda_2$. It is the problem of medium compliance strut.

By linear equation, we can find $a$ and $b$ of Steel 45 from the table of material manual: $a = 461$ MPa, $b = 2.568$ MPa.

By linear equation, the critical stress is:

$$\sigma_{cr} = a - b \lambda = 461 - 2.568 \times 62.5 = 301MPa.$$  \hspace{1cm} (18)

The critical pressure is:

$$F_{cr} = \sigma_{cr} \cdot A = \frac{\pi}{4} \times (30 \times 10^{-3})^2 \times 301 \times 10^6 = 212.7KN,$$  \hspace{1cm} (19)

$$n_{st} = 350,$$  \hspace{1cm} (20)

$$n = \frac{F_{cr}}{F_{\text{max}}} = \frac{212.7}{1063} = 0.2 > n_{st}.$$  \hspace{1cm} (21)

Therefore, the pole is safe and reliable.
Then we check the twisting strength for the driving axis. The diameter of the cross section of the driving axis is $\Phi 12$. The material of the axis is Steel 45. The driving axis mainly bears the torque, so the strength condition is:

$$
\tau_r = \frac{T}{W_r} = \frac{9550 \times 10^3 P}{W_r} \leq [\tau_r].
$$

(22)

As to solid round axis:

$$
W_r = \frac{\pi D^3}{16} = \frac{3.14 \times 12^3}{16} = 339.12 \text{ MPa},
$$

(23)

$$
\tau = \frac{9550 \times 10^3 P}{W_r} = \frac{1543.56}{339.12} = 4.6 \text{ MPa}.
$$

(24)

By the Mechanical Design Handbook [4,6]:

$$
[\tau_r] = 30\text{--}40\text{MPa},
$$

(25)

$$
\tau < [\tau_r].
$$

(26)

Finally we check the supporting axis.

The stress analysis of the supporting axis is shown in Fig.5.

![Fig. 5. The stress analysis of the supporting axis](image)

$$
F_1 + F_3 = F_2,
$$

(27)

$$
F_2 = \frac{G}{4} = \frac{980}{4} = 245N,
$$

(28)

$$
F_1 \times 20 + F_2 \times 150 = F_2 \times 62.5,
$$

(29)

Put the data into the formula, the answer is:

$$
F_1 = 165N,
$$

(30)

$$
F_3 = 80N.
$$

(31)

(1) Check the shear stress

$$
\tau_1 = \frac{F_3}{A} = \frac{165}{3.14 \times 15 \times 15} = 23.35\text{MPa},
$$

(32)

By the table:[$\tau$] = 30MPa,

(33)

So: $\tau_1 < [\tau]$. Therefore it is reliable.
Check the bending force

We can know from the moment figure that the maximum moment occurs at the cross section, therefore: \[ M = -165 \times 23 + 245 \times 53 = 9190N \cdot m, \] (35)

For cylinder poles: \[ \sigma_{\text{max}} = \frac{M_{\text{max}}}{bh^2/6} = \frac{9190 \times 6}{14 \times 26^2} = 5.83 \text{MPa} \] (36)

Check the Mechanical Design Handbook[4], we can find:

\[ [\sigma] = 100 \text{MPa}, \] (37)

\[ \sigma_{\text{max}} < [\sigma]. \] (38)

Therefore, it is reliable.

Conclusions

So far, there is no similar production in the market, but the demand is always growing. We design this machine from the needs of the market and practical situations. We meet the requirements of the society and deal with the problems never solved before. The structure of this stretcher-vehicle is simple, but it is very reliable and useful. If this type of machine could be put into massive production, it will be very cheap to purchase. This type of rescue machine has many advantages, so it could be used in disasters and also in the hospitals.

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