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To cite this article: N V Belov *et al* 2019 *IOP Conf. Ser.: Mater. Sci. Eng.* **489** 012012

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Track vehicles self-extrication mechanism

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Abstract. The analysis of extrication of stuck track vehicles methods available led to the conclusion that in case of light or moderate sticking it is justified to employ the self-extrication method using the drive wheels of the vehicle as winch heads. However, it is seldom resorted to taking into account high labor intensity and complexity of the efforts necessary to accomplish it. To exclude this drawback the authors propose a structure containing a drum with a wire wound on it that is attached to the drive wheel externally. To increase the efficiency rate and to reduce the load on the wire and the head with the wheel a fixed block is used. Essentially, this results in a winch with a tackle system whose ratio is 2. For self-extrication it is necessary to mount the mechanism on the drive wheels of the track vehicle (without removing the tracks), to fasten the blocks on fixed bearing(s), such as a stump, a tree or an anchor log, located at a distance from the vehicle, to pass the wire from the head through the block and to fasten it on the vehicle's towing shackle. The authors use the example of a 14-ton heavy vehicle to determine the main geometrical parameters of the mechanism and provide the fields of equivalent stress distribution calculated using the finite element method.

1. Introduction

It is well-known that the application of track running gear facilitates the vehicle's off road capability and enhances its towing performance when moving across the terrain characterized by weak supporting capacity or in total road impassability.

The off-road capability is one of the key features of combat vehicles; it is mainly determined by the contact pressure, the area of the running gear contact with the supporting face and their adherence. The distribution of the weight of the vehicle across a much larger contact surface than that of the wheel the unit pressure affecting it is significantly lower, whereas the availability of lugs provides for their advanced adherence. However, there may be cases when weak supporting capacity of the terrain (mud, swamp, snow, etc.) or because of insufficient clearance of the vehicle, the latter is stuck. Thus, when accomplishing combat missions, track combat vehicles may fail not only because of breakages received during the operation, but because of getting stuck as well. Its extrication is one of the integral parts of the technical support of the military.

2. Task setting

According to the Guidelines on Armored Vehicle Extrication [1], there exist the following methods of extricating stuck track vehicles: self-extrication, extrication by tractors, extrication by the recovery winch and tackle gear. It is natural that the employment of a particular method is determined by the type of sticking, the technical condition of the vehicle and the extrication means available. If a mobile



vehicle is stuck because of insufficient adherence power between the tracks and the surface, and the towing effort it can potentially develop using its engine power exceeds the motion resistance force, it is preferable to use self-extrication. This method does not require any tractor, which constitutes its main advantage.

Lepeshinsky et al. [2] provide the description of the following self-extrication techniques: using a log attached to the tracks of the stuck vehicle (figure 1); using a wire attached to the tracks of the stuck vehicle (figure 2); attaching a tow wire to the tracks of the stuck vehicle and using the drive wheels of the stuck vehicles as the winch head (figure 3). The techniques based on attaching the wire to the tracks prove to be easier, however, if self-extrication attempts are made without proper preparation, this may lead to more severe sticking. Secondly, the distance that the vehicle may be moved to is estimated as less than a half of the track length as after the points of wire attachment are released from beneath the supporting surface, the means of self-extrication of the vehicle itself may be damaged. Thirdly, practically all the load is concentrated in one or two track links. The technique that consists in using the drive vehicles of the stuck vehicle as winch heads proves the most efficient in the majority of cases as it allows to obtain the highest momentum on the wire, which will enable the extrication of the stuck vehicle. However, this is a labor-intensive and, therefore, time-consuming procedure, which results in its rare employment, regardless of its efficiency.



Figure 1. Self-extrication of a track vehicle using a log

3. Solution

As the main difficulty in using drive wheels of the stuck vehicle as winch heads consists in the need to remove and then put back the tracks (e.g. the weight of each track of IFV 2 is over 600 kilos) that impede the attachment and winding of the wire onto the wheel, it is expedient to fasten the head on the outer part of the drive wheel.



Figure 2. Self-extrication of the vehicle using wire attached to the tracks and to the fixed bearing

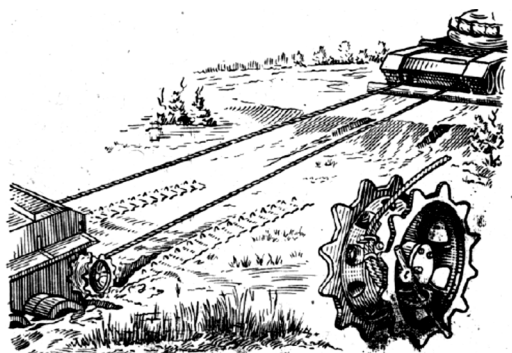


Figure 3. Self-extraction of a track vehicle by winding the wire onto the drive wheels

The idea of attaching the head to the drive wheels was long ago developed for cars. For example, Patent № 74622 entitled ‘Self-extraction mechanism for a skidding car’ published on March 31, 1949 describes the mechanism designed as a head attached to the drive wheels of the car ‘onto which the rope is wound that is anchored to the fixed object located in front’. The research in the public domain did not allow to discover the description of the mechanism used to accomplish this method for track vehicles. The only outcomes were two technical improvement proposals developed at Novosibirsk Higher Military Command School. The first one by A.N. Chernenko and A.A. Klepikov is entitled ‘IFV self-extraction mechanisms using the drive wheel’ and the second one by S.A. Boyarinstev, A.N. Chernenko and A.I. Tsarenko is entitled ‘IFV self-extraction mechanisms using the drive wheel without the disconnection of the track’. With the view to reducing the force extending the wire as well as enhancing the efficiency rate of the mechanism, we suggest upgrading the structures described in the technical improvement proposals by additional blocks. This will result in actual winch with a tackle system whose ratio is 2. To conduct self-extraction it is necessary to mount the mechanisms onto the drive wheels of the track vehicle (without removing the tracks), to fasten the blocks on fixed bearing(s) – for example, a tree, a stump, or an anchor log – located at a distance from the vehicle (see figure 2), the wire from the head must be passed through the block and fastened at the towing shackle of the vehicle.

Let us determine the main geometrical parameters of this mechanism. To exemplify our calculations we take a track vehicle with a full weight of 14 tons. In this case the value of the pulling force F with light or medium sticking should not exceed 54 kN on each drive vehicle considering the efficiency rate provided that the force is evenly distributed between the two vehicles. For further calculations we accept the pulling force to equal 61 kN.

We take into account that during self-extraction works, the employment of the wire tends to be rather short-term. Therefore, to facilitate it in field conditions we need to take its assurance factor at 1,7 – 2 [2], which leads us to choosing the wire matching the following characteristics: 12.5-200-B-JI-OGOST 3077-55 with a breaking stress of no less than 101.01 kN.

For design purposes we take the outer diameter of the head at 320 mm, the diameter of the limiting wall that prevents the wire slipping lengthwise at 410 mm, the distance from the rotational axis of the head to fixation holes at 220 mm; the length of the head at 150 mm.

The wall of the drum will be in the condition of combined stress [3], however, the compression strain will be the dominant factor. Let us calculate the approximate value of its thickness on the basis of the values of these compressions:

$$\delta = 0.5 \cdot \left(D - \sqrt{D^2 - \frac{2pD^2}{[\sigma]}} \right),$$

where D is the outer diameter of the head;

$[\sigma]$ is working stress;

$p = \frac{2F}{Dt}$ is the distributed load on the wire;

t is the wire thickness.

Then $p = \frac{2 \cdot 61000}{0.32 \cdot 0.0125} = 30.5 \text{ MPa}$;

$$\delta = 0.5 \cdot \left(D - \sqrt{0.32^2 - \frac{2 \cdot 30.5 \cdot 10^6 \cdot 0.32^2}{350 \cdot 10^6}} \right) = 0.015 \text{ m, if } [\sigma] = 350 \text{ MPa.}$$

As apart from standard compression strains, the wall of the head will experience the strain from the bending moment and tangent stress from the rotative moment, we take $\delta = 16 \text{ mm}$. In this case the compression strain from the distributed load p is calculated as follows:

$$\sigma_c = \frac{2pD^2}{D^2 - (D - 2\delta)^2} = \frac{2 \cdot 30.5 \cdot 10^6 \cdot 0.32^2}{0.32^2 - (0.32 - 2 \cdot 0.016)^2} = 321 \text{ MPa};$$

strain from the bending moment stands at:

$$\sigma_b = \frac{32M_b D}{\pi(D^4 - (D - 2\delta)^4)} = \frac{32 \cdot 61 \cdot 10^3 \cdot 0.15 \cdot 0.32}{3.14 \cdot (0.32^4 - (0.32 - 2 \cdot 0.016)^4)} = 8.3 \text{ MPa.}$$

Tangent stresses caused by the rotative moment are:

$$\tau = \frac{16T_t D}{\pi(D^4 - (D - 2\delta)^4)} = \frac{16 \cdot 61 \cdot 10^3 \cdot 0.22 \cdot 0.32}{3.14 \cdot (0.32^4 - (0.32 - 2 \cdot 0.016)^4)} = 6.1 \text{ MPa.}$$

According to the strength theory of maximum tangent stresses, the maximum equivalent stress equals:

$$\sigma_{eq} = \sqrt{(\sigma_c + \sigma_b)^2 + 3\tau^2} = \sqrt{(321 + 8.3)^2 + 4 \cdot 6.1^2} = 329.5 \text{ MPa.}$$

As the calculation object is represented by rather a complex structure that finds itself in complex strained conditions, the outcomes of the calculations obtained using material strength methods can be considered approximate. Therefore, more defined calculations involving the finite element method will be conducted at the Nastran software. Figure 4 represents the model of the mechanism of self-extrication of a track vehicle with the weight of 14 tons; figure 5 gives the equivalent stress distribution (where figure 5,a gives the picture at the upper surface and figure 5,b the one in the horizontal cross-section). It was predictable that the maximum equivalent stresses in the wall that arose due to the increased edge stiffness of the envelopment slightly increase the values calculated and amount to approximately 385 MPa, rather than 329.5 MPa. These stresses exist at the inner surface. The yield limit for 12XH3A steel, for instance, stands at 700 MPa. Therefore, the assurance factor ratio for yield equals 1.82, which is rather acceptable in our case.

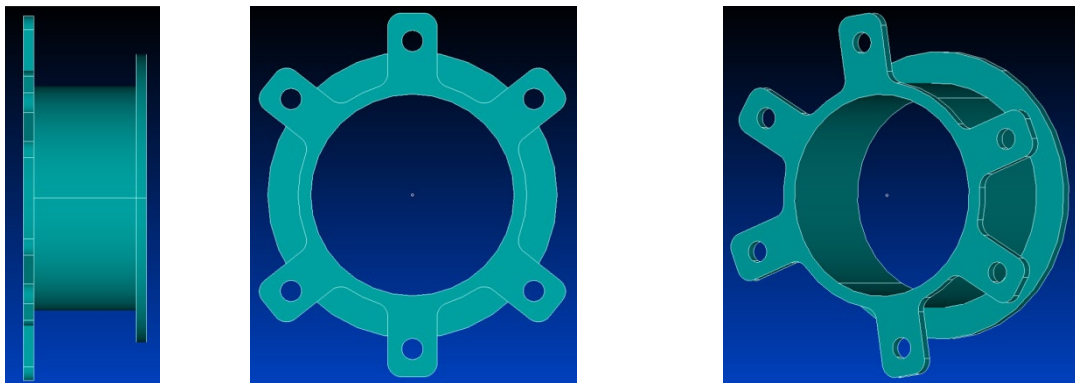


Figure 4. Self-extrication mechanism for track vehicles

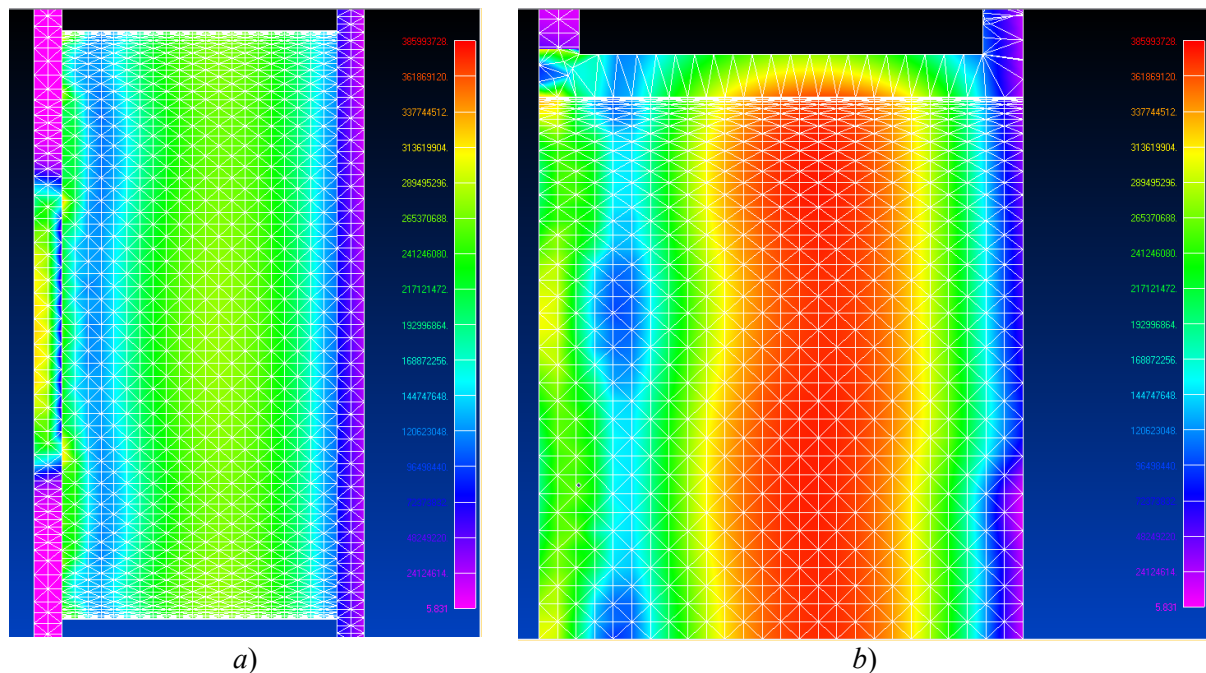


Figure 5. Equivalent stress distribution

Conclusions

Thus the research has determined the main geometrical parameters of the mechanism for self-extrication of track vehicles with the weight of 14 tons (obviously, for extricating a particular vehicle specific calculations are required). The weight of this device is 30.2 *kilos*, however, with 30-meter long metal wire and the shackle it will increase to 60 *kilos*, which is a drawback as it will impede manual fastening on the drive wheel. Therefore, the next stage of the research will consist in searching for designing solutions to facilitate the mounting of the mechanism.

References

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The authors express their gratitude to Ekaterina N. Luchinina, head of the Foreign Languages Department of Moscow Higher All-Arms Command School for the translation of this article