MECHANICAL WINCH CHARACTERISTICS CALCULATION

Andre Oltean Ioan
Marcel S. Popa
Simon Vasile
Technical University of Cluj-Napoca,
Department of Manufacturing Technology
Bld. Muncii 101-103, Cluj Napoca, Romania
e-mail: andrei.oltean@tcm.utcluj.ro
e-mail: marcel.popa@tcm.utcluj.ro
e-mail: vasile.simon@tcm.utcluj.ro

Abstract
The winch represents a special appliance which is fitted on the forest tractors. This appliance allows executing operations of rolling up and cutting out the wood from the forest. Recently in the countries with advanced forest technology is used different hydraulic solution for this kind of operations. The winch which is used on the forest tractor it is composed of one carcass where it is fitted worm gear and the crankshaft which is training two cylinders. Operation of these appliances is the next one: from block terminal by coupling the drive gear the torque it is transferred to the worm shaft. In this article I will present the calculation of mechanical characteristics of this winch and which are the differences between the mechanical and hydraulic winch. I do this to see which is the best solution for Romanian forest.

Key words: winch, gear, torque, forest, mechanical

INTRODUCTION
Nowadays, in the world, but also in Romania, there are several forest tractors provided with winches that are mechanically or hydraulically operated. In Romania, the forest tractor is representative equipment used in proportion of 90% of the cases of wood exploitation.[1] This forest tractor is equipped by a winch with two mechanically operated drums.

The main move that makes the traction force is provided by the tractor transmission following this track: Diesel motor – clutch – gearbox – drive shaft – distribution box – winch entailment cardan, worm-driving gear – clutch for coupling and decoupling the drums for the cable, the strip breaks allowing the blockage of cable drums and of the charge in order to move it until the testing platform. In order to operate and order the clutches and the breaks, it is used the compressed air of the tractor installation.
CALCULATION OF THE MOVING SPEED

The speed of the cable may be expressed according to the motor rotation, the transmission reports \(i_{sk}, i_{cd}, i_m\) and the drum radius for the cable:

\[
\nu = \omega r_{c} = \frac{\omega}{2 \pi} \times \frac{1}{i_{sk} i_{cd} i_m} \times r_{c} \quad (1) \text{ or,}
\nu = 0.10472 \times \frac{r_{c}}{i_{sk} i_{cd} i_m} \quad (2)
\]

where, \(n\) is the motor rotation[rpm]

The speed calculation according to the motor rotation in the MATHCAD software[2]

\[
i_{sk1} = 5.762; i_{sk3} = 2.729; i_{sk3} = 1.624;
i_{cd} = 0.85; i_{m} = 14; r_c = 0.133
\]

\[
V1(n) = 0.10472 \times \frac{1}{i_{sk1} i_{cd} i_m} \quad (3)
\]

\[
V2(n) = 0.10472 \times \frac{1}{i_{sk3} i_{cd} i_m} \quad (4)
\]

\[
V3(n) = 0.10472 \times \frac{1}{i_{sk3} i_{cd} i_m} \quad (5)
\]

\[
V4(n) = 0.10472 \times \frac{1}{i_{sk3} i_{cd} i_m} \quad (6)
\]

\[
V5(n) = 0.10472 \times \frac{1}{i_{sk3} i_{cd} i_m} \quad (7)
\]

\[
n = [2300]; n = [2200]; n = [2100]; n = [2000]; n = [1800]; n = [1700]; n = [1600]; n = [1500]; n = [1400]; n = [1300]; n = [1200]; n = [1100]
\]

Fig.2 Efficient speed values for every gear

CALCULATION OF THE TRACTION CHARACTERISTIC

The traction force \(F_{tk}\), when coupled to the gear \(k\) of the gearshift, is generated by the motor moment \(M_e\), its size depending on the charge and the motor rotation:

\[
F_{tk} = \frac{M_e}{r_c} \cdot \frac{i_{sk} i_{cd} i_m}{r_c} \quad (14)
\]

For a certain gear of the gearshift \((i_{sk})\) \(F_{tk}\) is proportional with \(M_e\), its variation curve being similar with the motor torque.

For all the gears of the gear shift, we obtain a curves family.

The resistant torque of operation according to the motor torque and the transmission efficiency:

\[
F_{tk1} = \frac{M_e}{r_c} \cdot \frac{i_{sk1} i_{cd} i_m}{r_c} \quad (8)
\]

\[
F_{tk2} = \frac{M_e}{r_c} \cdot \frac{i_{sk2} i_{cd} i_m}{r_c} \quad (9)
\]

\[
F_{tk3} = \frac{M_e}{r_c} \cdot \frac{i_{sk3} i_{cd} i_m}{r_c} \quad (10)
\]

\[
F_{tk4} = \frac{M_e}{r_c} \cdot \frac{i_{sk4} i_{cd} i_m}{r_c} \quad (11)
\]

\[
F_{tk5} = \frac{M_e}{r_c} \cdot \frac{i_{sk1} i_{cd} i_m}{r_c} \quad (12)
\]

\[
M_1 = [290]; M_2 = [303];
M_3 = [328]; M_4 = [355];
M_5 = [367]; M_6 = [377];
M_7 = [387]; M_8 = [392];
M_9 = [390]; M_{10} = [366]; M_{11} = [376];
M_{12} = [390]; M_{13} = [366]; M_14 = [376];
\]

Fig.4: The traction force of the cable

TRANSMISSION EFFICIENCY

For the calculation of the total efficiency, it is determined its value for every component of
the transmission branch that participates at the winch operation

![Scheme of movement transmission from the Diesel motor to the forest winch TAF 2010 M](image)

Fig.6 Scheme of movement transmission from the Diesel motor to the forest winch TAF 2010 M

\[
\eta_T = \eta_{CV} \times \eta_{TL} \times \eta_{CD} \times \eta_{TR}, \text{ where: } (15)
\]

- \(\eta_T\), total efficiency of the transmission;
- \(\eta_{CV}\), the gear efficiency of the gearbox;
- \(\eta_{TL}\), the gear efficiency for the winch operation of the distribution box;
- \(\eta_{TR}\), the efficiency of the worm drive;

\[
\eta_T = 0.98 \times 0.95 \times 0.98 \times 0.71 = 0.65 \quad (16)
\]

**CONCLUSIONS**

From the mechanical point of view, the following results should be observed:

1. Maximum speed of cable movement: \(V_{\text{max}} = 3.501 \text{ m/sec.}\), it is obtained in the 5th gear of the gearbox, at the rotation: \(n = 1400 \text{ rpm}\), to which it corresponds a traction force, \(F_t = 1297 \text{ daN}\);

2. Maximum traction force: \(F_{t,\text{max}} = 13140 \text{ daN}\) is obtained in the 1st gear of the gearbox, at the rotation: \(n = 2300 \text{ rpm}\), to which it corresponds a traction force \(V = 0.284 \text{ m/sec.}\).

3. Cable length is only influenced by the winch construction.

4. The efficiency is influenced only by the component of the cinematic chain of the movement transmission.

If we analyse the first two characteristics: the movement speed of the cable and the traction force, we observe that they are antagonistic: to a maximum traction force corresponds a reduced movement speed and vice versa. The operator has the possibility of choosing an optimal regime of exploitation within the two variation fields:

- Traction force \((1297 \div 13140) \text{ daN}\);
- Speed between : \(0.284 \div 3.501 \) m/sec.;

According to the first results obtained, we can observe an advantage for the winches hydraulically operated:

- The control items of the hydraulic transmissions require to the operators reduced forces or torques for operation and can be placed in convenient places, conferring special ergonomic qualities to the working machines.

- The torque developed by the rotating volume hydraulic motors is proportional with the difference of pressure between the energetic connections, being limited only by the admissible efforts of the materials used.

- The heat generated by the internal loses, which limits the performances of any equipment, is taken by the circulated liquid and liberated in the surrounding environment by a heat exchanger placed in a convenient way; thus, the volume equipments have frequently specific powers of more than 1kW/kg.

In order to compare all the parameters that characterize the two types of winches, I am going to finish the calculations for the hydraulic winch and to make the diagrams. Following the resulted diagrams and comparing them, we shall find out what is the most advantageous solution.

**References**

