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Experimental Assessment Of The Breaking Strength Of Tross Used In The Management Systems Of Reduced Vehicles.

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Annotation. This article analyzes the reliability of modernized vehicles for people with disabilities and the cables used in them. Steel cables used in mechanical control devices for people with disabilities were investigated. During the research, international and national standards were analyzed, and a methodology for determining the compliance of cables used in manual control systems with established requirements was developed. New technological approaches to testing cables for elongation and tear during the conversion of vehicle foot pedals to manual control are also being considered. The article's results are aimed at testing the ability of people with disabilities to withstand the loads that arise when using vehicles, as well as developing a justification for prohibiting or prohibiting their use and offering solutions.

Keywords: Modified cars, pedals, manual control equipment, disabled drivers, controls, cables, safety.

Introduction

Re-equipped vehicles are used today in many areas, especially to improve the quality of life for people with disabilities. Re-equipped vehicles are primarily intended for drivers with disabilities who should not experience discomfort while operating such vehicles. Today, when transitioning vehicles intended for people with disabilities to manual operation, rigid metal tubular transmissions are used. Since these transmissions ensure uninterrupted movement transfer and do not have elasticity, they are effective when converting leg control elements into manual control, but to install these transmissions, it is necessary to allocate a large space in front of the driver.

To address this issue, cable drives were developed to transmit manual control systems using a cable, allowing disabled people to operate vehicles safely and efficiently. [1]


(a) (b)

Figure 1. Hard metal tubular elements used in vehicles converted to handle people with disabilities.
a-element equipped with a special controlled lever, b-lever designed for pedal adaptation.

Traditional foot-operated manual pedal control systems are equipped with hand-operated handles, including gas, brake, and clutch pedals. These changes will not only provide good comfort for drivers with disabilities but will also serve to increase their social activity and mobility. These control levers serve to manually move the pedals driven by the feet. [2;3]

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This research is aimed at analyzing the cables used as transmissions in manual control systems, ensuring their reliability, and determining them from a safety perspective. The research is also aimed at ensuring that these cables comply with international and national rules and safety standards when transmitting traffic. [4]
Testing of cables used as transmissions and transmission elements made from other materials using a special laboratory stand serves to predict future emergencies and determine the stability of transmissions to such situations, as well as to develop special recommendations.

Methodology

In this study, combined methods combining technical analysis, experimental testing, and laboratory conditions are used to test the tension and safety of cables used in manual control systems of re-equipped vehicles. The methodology consists of three main components: *literature review*, *experimental verification* of compliance, and laboratory research.
To study the theoretical foundations of breaking and tensile testing of cables used as gears in manual control systems, existing research, standards, and regulations were comprehensively examined.

Literature review:

In the article "Mechanical design and motion control of a hand exoskeleton for rehabilitation" by Andreas Vege, Konstantin Kondak, and Gunter Hommel, detailed studies of situations arising in the process of managing manual control systems for people with musculoskeletal defects were conducted. [1].
International standards: ISO 6892-1:2019 - Metal materials - The tensile testing standard contains instructions for conducting tests[2].

Experimental tests of cables used as gears in manual control systems:

Tests of cables used as transmissions in manual control systems were conducted by the person driving the vehicle, based on forces and events arising in emergency situations and during the free operation of these systems under operating conditions.
During the tests, various parameters were tested using an electronic cable traction machine that connects manual controls with leg controls. Three samples of cables used as transmissions in convertible vehicles were tested for tensile strength: The first sample is based on parameters arising from the driver's free use of the vehicle during operation (Table 1), the second sample is based on parameters arising under moderate conditions (Table 2), and the third sample is based on parameters arising from the driver's application of force in emergencies (Table 3).
The test processes were carried out based on the parameters in the following tables:

Table 1

Parameter name	Value	Note
Pulling speed	5 mm/min	Driver's free use status
Speed	0.0100 kN/h	Strength is given gradually.
Pressure velocity	0.1000 MPa/s	The pressure is increasing slowly.
High strength	800 N	Maximum recommended performance
Holding time	2 sec	Maintaining strength at each stage

Table 2.

Parameter name	Value	Note
Pulling speed	10 mm/min	In non-extreme operating conditions
Speed	0.0200 kN/s	Average increase in force
Pressure velocity	0.2000 MPa/s	Corresponding pressure velocity
High strength	700 N	Driver's application of increased force

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Holding time	2 sec	Force retention

Table 3.

Parameter name	Value	Note
Pulling speed	20 mm/min	High-speed mode
Speed	0.0400 kN/s	Strength increases faster, but within the limits permitted by the methodology
Pressure velocity	0.4000 MPa/s	Approximate to dynamic motion
High strength	1100 N	Near recommended maximum
Holding time	1 sec	For faster cycles

Three samples with a length of 200 mm and a diameter of Ø2 mm were taken from the cables used as transmissions in the manual elements of the convertible vehicles.

Figure 2. Examples of cables used as transmissions in manual control elements.

To determine the cross-sectional area of the sample, calculations were performed using the following formula.

(1)

Here: π=3.14, d=sample diameter

The testing process was initially secured to the clamps of the ChengYu-WDW 100kN device and carried out sequentially based on the parameters given in the tables above.

Results.

The stretching test of the cable used as a transmission connecting the handheld control levers and pedals driven by the foot in convertible vehicles provided important information about the fact that the handheld control parts of the vehicle meet operational requirements in real conditions. Using the research, the cable used as a transmission when connecting the handheld control levers to pedals driven by the foot was tested based on three parameters: forces arising when the driver uses it freely while driving the vehicle, forces arising in moderate conditions, and forces arising when the driver uses sharp force in emergencies.

Testing based on forces arising from the driver's free use of the vehicle during operation.

During the test, the tension speed was 5 mm/min, the force was applied gradually at a rate of 0.0100 kN/s and maintained for 2 seconds at each stage. The load was increased to a maximum of 800 N, which is equivalent to the maximum operating load that can occur in real cable operation conditions.

The results showed that the cable material gradually deforms, as shown in the stress-strain graph. At the initial stage, in the stretching range from 0 to 1.5%, the material was in an elastic state, and the stress was recorded within 100 MPa. At this stage, it was observed that when the applied force is removed from the cable, it returns to its original state. (*Table 4*)

Table *4*

No	Stretching (%)	Voltage (MPa)
1.	0.5	25.
2.	1.0.	60.
3.	1.5.	110.
4.	2.0	160.
5.	2.5.	210.
6.	3.0.	240.
7.	3.5.	260.
8.	4.0.	270.

In the next stage, i.e., in the stretching range from 1.5% to 2.5%, the transition from the elastic phase to the plastic phase occurred. During this time, the voltage increased significantly and reached 180 MPa to 230 MPa. After exceeding the tensile strength by more than 2.5%, irreversible deformation was clearly manifested in the cable. The maximum stress at a tensile strength of 4% was recorded at approximately 270 MPa.

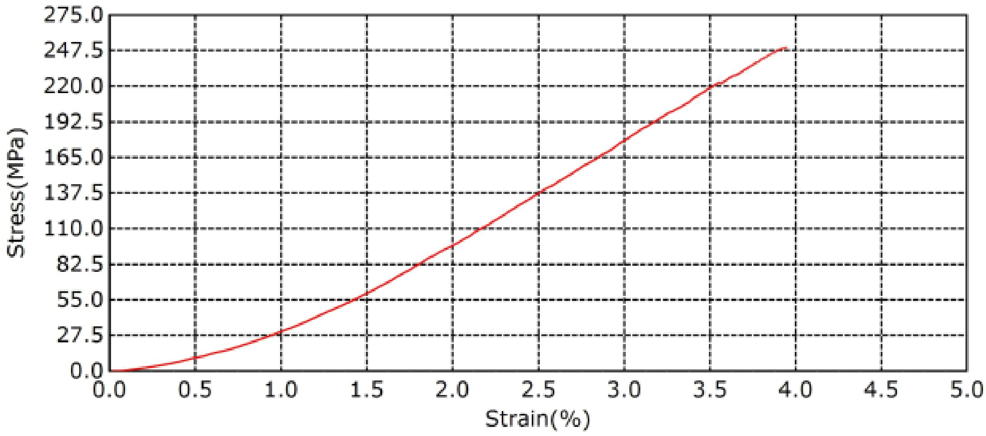

Figure 3. Stress-strain test graph based on forces arising from the driver's free use of the vehicle during its operation

Test based on forces arising in moderate conditions.

The test was conducted based on a static load, where the pulling speed was 10 mm/min, and the force gradually increased at a rate of 0.0100 kN/s, reaching a maximum of 800 N. At each stage of the load, a 2-second holding interval was used.

According to the graphical analysis results, the degree of tension of the cable material gradually changed in the range from 0.5% to 4.5%, and the stress accordingly increased from 20 MPa to 250 MPa. The obtained data are summarized in Table 5 below:

in Table 5

No.	Stretching (%)	Voltage (MPa)
1.	0.5.	20.
2.	1.0.	55.
3.	1.5.	105.
4.	2.0	150.
5.	2.5.	185.
6.	3.0.	215.

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7.	3.5.	235.
8.	4.0.	245.
9.	4.5.	250.

The results show that the cable material has sufficient elasticity and durability under medium operating conditions - i.e., within the range of forces applied by the driver during natural motion. Even in the stretching stages up to 3.0-4.5%, the cable continued to withstand the stress while maintaining its structure.

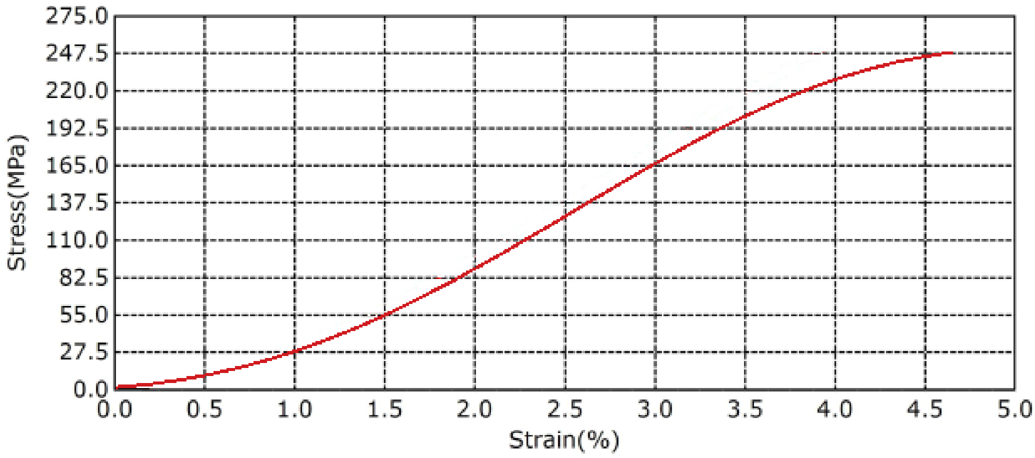

Figure 4. Stress-strain test based on forces arising in medium conditions

Test based on forces arising from the application of force by the vehicle driver in emergency situations

During the test, the force was applied quickly, the tension speed was 20 mm/min, the force was applied gradually at a rate of 0.0400 kN/s, and it was maintained for 2 seconds at each stage. The load was increased to a maximum of 1100 N, and repeated, sharp increases and decreases in the load were observed. The experimental results table and the stress-strain graph fully reflect this process.

Table 6.

No.	Stretching (%)	Voltage (MPa)
1.	2.5.	90.
2.	4.2.	160.
3.	6.0	245.
4.	7.8.	185.
5.	9.5.	125.
6.	12.0	170.
7.	14.5.	75.
8.	17.2.	95.
9.	19.5	45.
10.	21.0	30.

The graph shows:

Initially, the cable was subjected to a sharp load several times within 5-10% of the tension. The stress value in each interval was within 150-245 MPa, indicating that the cable material can withstand high pressure under short-term extreme loads.

During the test, the voltage sharply increased and decreased several times, which is a simulation of the driver's actions in a real emergency situation.

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By the 6th-7th cycle, the stress value drops below 100 MPa, indicating the beginning of material fatigue.

Although the tensile strength at the final stage was higher than 20%, the stress remained within 50-60 MPa.

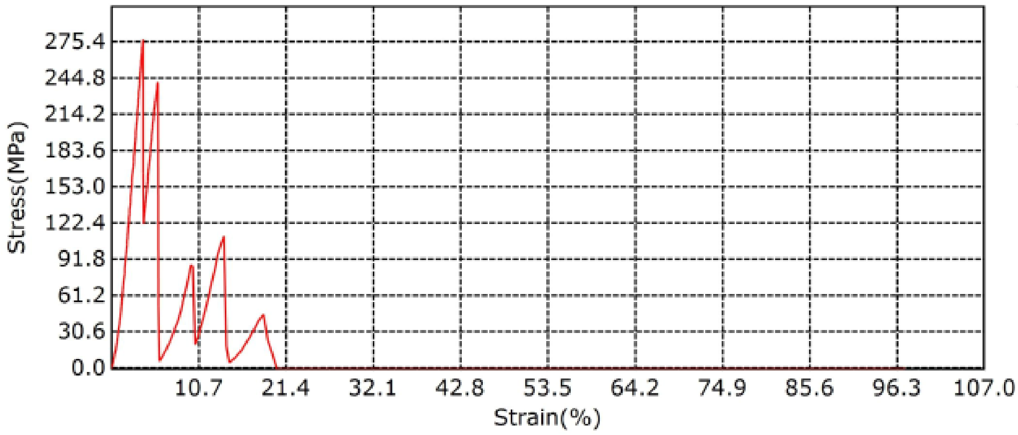

Figure 5. Stress-strain test graph based on forces arising from the use of a sharp force by the vehicle driver in emergency situations

Based on the obtained experimental results, it can be said that the tested cable can ensure reliable operation of the driver in manual control devices. These results meet previously established safety and durability requirements.

Conclusion

As a result of the conducted tests, the mechanical stability, elasticity, and strength of the cable element under various operating conditions - normal, medium, and emergency - were determined. The tests were conducted based on static and cyclic loads and analyzed using a stress-strain graph.

Under normal operating conditions, it was observed that the cable material stretches to 4.0-4.5% and withstands a maximum stress of 270 MPa. This ensures reliable cable operation within the normal force (60-120 N) applied by the driver.

Even under medium conditions, the cable demonstrated sufficient elasticity against deformations, consistently transmitting the force. Stresses up to 250 MPa are balanced with a 4.5% elongation, confirming the material's practical strength.

During emergency tests, i.e., under conditions where the driver applied a sharp force for a short period of time, the cable material gradually lost its ability to withstand the force, despite being subjected to a stress of more than 240 MPa several times. Despite the fact that the voltage exceeded 20%, the voltage remained at 50-60 MPa. This indicates the occurrence of internal fatigue and plastic deformation.

In general, the cable element:

Has the property of stable operation in simple and medium conditions;

In emergency situations, it can withstand short-term loads, but prolonged fatigue loads reduce the material's strength.

These results serve as an important scientific and technical conclusion for justifying the use of cable material in manual vehicle control systems adapted for disabled people.

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