Modernization of the cable skidding system by upgrading the articulated carriage

V Svoikin¹, F Svoikin¹, N Vokhmyanin², S Zotenko² and S Alekseeva²

¹Syktyvkar Forest Institute (branch) of the Federal State Budgetary Educational Institution of Higher Education «Saint-Petersburg State Forest Technical University named after S.M. Kirov», 39 Lenin Street, Syktyvkar 167982, Komi Republic, Russian Federation
²St. Petersburg State Forest Technical University, 5 Institutskiy Lane, St. Petersburg 194021, Russian Federation

*Corresponding email: svoykin_fv@mail.ru

Abstract. The article presents the constraining factors (including climatic) of the use of traditional solutions for skidding round wood (logs) in the winter cutting period of 2019-2020 years in the Northwestern Federal District of the Russian Federation on non-straight forwarding roads, a technical solution is proposed to improve the existing cable skidding systems (CSS) using a new carriage structures - articulated carriage (AC), as well as the improvement of this design by strengthening the structure with stiffeners to increase reliability based on the analysis of the stress-strain state of the AC parts by mathematical modeling in the SolidWorks Simulation environment. The implementation of the model of the proposed solution for the modernization of the AC by printing on the DF-Print 3D printer in the future is given. The use of the new modernized design of the AC contributes to solving the problem of the skidding of round wood in the winter cutting period.

1. Introduction

Unusual climatic conditions that are not comfortable for organizing timber harvesting in the winter cutting period of 2019-2020 in the Northwestern Federal District of the Russian Federation [1] did not allow the region's loggers to fully implement the development of the allowable cut [2]. The existing ways of improving the timber harvesting process [3] cannot be applied due to a number of dynamically changing factors.

Problem. A clear trend for high average air temperatures in the winter cutting period in the Northwestern Federal District of the Russian Federation [1] makes it difficult or impossible to harvest timber in the areas designated for these purposes. This leads to a decrease in the volume of timber harvesting by 20% or more. Which leads to direct losses of logging enterprises in the North-West region.

At the present time, more and more attention is paid to the study of the possibility of active introduction of cable skidding systems (CSS) in various spheres of industry and the national economy [4], and the defense complex [5] both in the Russian Federation [6] and in the CIS countries, especially in the Republic Belarus [7], as well as in foreign countries [8, 9].
2. Methods and Materials
The implementation of the specified modes of the CSS [10] is assumed in the form of a constructive improvement of the CSS with the use of an articulated carriage of a new design [11] for the non-straightness of the rope-railroad. This design of the carriage provides the passage of turns of the carriage with swept assortments on the curved track of the traction rope. It is proposed to use the existing designs of carriages in terms of moving the carriage with swept assortments. By connecting the fastening of the support wheel pairs with a pair of articulated joints, two independent carriages are formed that maneuver along the traction rope on one roller, which easily overcomes the turns of the track. Such a carriage is called articulated carriage (AC) and is planned for implementation in CSS [11]. The proposed design of AS for CSS is shown, figure 1.

![Figure 1. Proposed articulated carriage (AC) for CSS before modernization.](image)

It is worth noting an essential design feature of modern CSS, which significantly limits the scope of such installations. In a situation with a rigidly fixed roller, it is possible to turn the track (rope) in plan at a very limited angle (up to 10°). At the same time, the use of a structure with rollers differentiated from the carriage is not possible, since the axis of the rollers must be fixed on both sides, as a result of which it is impossible for the guy to pass at the turning point.

3. Results and Discussion
A significant advantage of AC for CSS is that its application does not require changes in the design of existing CSS. And also the possibility of completing any existing CSS with an improved carriage of the proposed design.

In this area of work, 3D models are actively used. For the development of models in the field of solving design problems, it is relevant to use the SolidWorks program [12]. Compared to similar programs, SolidWorks software has a simpler interface. This program allows you to simulate rope skidders (including their elements) and the subsequent calculation of the parameters required for operation. For the analysis of the stress-strain state of the AC parts, mathematical modeling of the model was carried out in the SolidWorks Simulation software [13]. In the course of the analysis, the AC element was subjected to a stress similar to that that occurs during the passage of the carriage through the swing support in the plan of the route. Thermal exposure was also applied, allowing static analysis to be taken into account as an alternative to production testing as an initial study.

The calculation of the design features of the proposed design shows that the use of a CSS with a AC will allow organizing skidding routes, without significant wear of the ropes, with turning angles up to 45 degrees.
A general view of the proposed solution for the modernization of the AC (volumetric isometry) is shown, figure 2.

**Figure 2.** General view of the proposed solution for the modernization of AC (volumetric isometry).

The frontal view of the proposed solution is shown, figure 3.

**Figure 3.** General view of the proposed solution for the modernization of the AC (frontal view).

The design elements of the proposed solution are shown in figures 4-10. A general view of the swing shoe is shown, figure 4.
Figure 4. General view of the swing shoe.

The swing shoe bracket is shown, figure 5.

Figure 5. Swing shoe console.

The carrier rope guide is shown, figure 6.

Figure 6. Carrier rope guide.

The moving elements of the AC (hoisting rope roller and support roller) are shown, figure 7.
Figure 7. Carrier rope guide: (a) – the roller of the hoisting rope, (b) – support roller.

The connecting link is shown, figure 8.

Figure 8. Connecting link.

The initial design of the AC body elements [6, 11] did not provide for the presence of stiffeners is figure 9.

Figure 9. AC body without stiffeners.

In the course of the analysis, the AC element was subjected to a stress similar to that that occurs during the passage of the carriage through the swing support in the plan of the route. Thermal exposure was also applied, allowing static analysis to be taken into account as an alternative to production testing as an initial study. As a result of the operation, after checking the strength
characteristics of the structure for a static load using the SolidWorks 2020 Simulation software (SolidWorks 2020 subroutine), the structure was reinforced with stiffeners to increase reliability is shown, figure 10.

![Figure 10. AC body with stiffening ribs.](image)

It should be noted that this model is supposed to be printed on the DF-Print 3D printer and to be tested with a 4 mm thick steel rope (a topical topic for further research).

Based on the analysis of the stress-strain state of the AC parts by mathematical modeling in the SolidWorks Simulation environment, it is proposed to reinforce the AC body with stiffeners. As a result of the design and development activities, the following elements of the CSS were developed: a swing shoe console, a swing shoe, a carrier rope guide, a hoisting rope roller, a carrier roller, a connecting link, an improved body design with stiffening ribs.

The refined design of the AC with a body reinforced with stiffeners is presented. Taking into account the previously proposed technical solutions [10, 11], it is possible to clarify the operating modes of the CSS. The use of the CSS with the AC of the new modernized reinforced proposed design will allow organizing skidding routes, without significant wear of the ropes, with turning angles up to 45°.

The use of the new modernized design of the SSC contributes to solving the problem of the primary haulage of wood in conditions of high air temperatures and non-straight skid lines with a turning angle of up to 45° in the winter harvesting period in the North-West Federal District of the Russian Federation by means of variability and non-straightness of the skid lines.

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