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MAXIMUM LOADING HEIGHTS FOR HEAVY VEHICLES USED IN TIMBER TRANSPORTATION

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Abstract: *In the last period the specific trend in timber transportation refers to tonnage increment for specialized forest vehicles. On the other hand, the forest road systems are dimensioned for old concept transportation vehicles, usually presenting reduced mass and net loads by comparison with newer ones. In this context, a possible solution may reside in establishing the maximum loading capacities for vehicles in order to correspond to actual road complex dimensions. In the present paper there tare presented both, descriptions of increased tonnage vehicles as well as loading heights resulted from the calculation.*

Key words: *heavy vehicles, timber transport, net load, loading optimization.*

1. Introduction

Timber harvesting, as an industrial production process, is currently expressed by new perspectives which are coming from sustainable development concept [4].

An important aspect refers to the continuous technology development and labour productivity increment. The solutions in the timber harvesting process must comply with silvo-ecologic and technical-economic requirements [4].

Timber harvesting process presupposes a series of transformations and movements of the extracted timber, in conditions of increased complexity due to the conditions in which it is usually deployed [4].

As a consequence, its structure comprises partial processes characterized by distinct technological objectives and work places [4].

These partial processes refer to: timber harvesting, timber logging-yarding, landing site processing, timber transportation and timber processing in final processing plants.

The timber transportation is particularly important being defined by high volumes to be transported. Its realization presupposes the existence of a transportation structure and of a transportation means. Timber transportation is developed partially in the forest and partially outside it and presents some characteristics which are the result of the forest management process:

- It-presents a collector character, due the fact that the material to be transported is deployed in large areas;
- It-uses the transportation structure at full capacity only in a single direction;
- It presents a periodical character;
- The transported material is degradable, and presents high masses.

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The timber harvesting process is composed of specific operations which are technological and manual actions representing a certain process stage carried out using the same means and work tools by applying the same technology in conditions in which the work object attains a certain transformation or position state [3].

The timber transportation consists of three operations: loading, proper transport and unloading [4]. In actual conditions, timber loading and unloading is realized by applying fully mechanized means (hydraulic cranes installed on vehicles) [2].

These cranes are usually composed of a rotating device, a grapple, a grapple rotation device and a stabilizing device. The crane's performances depend on the lifting height as well as by arm extending distance [2].

A full working cycle comprises the following phases: the vehicle's preparation for loading and loading-unloading phases [4]. In cases in which the unloading specialized means are not provided, this operation is realized by the hydraulic crane mounted on the vehicle [4].

2. Increased Tonnage Vehicles Used in Timber Transportation on Forest Roads

The advances in vehicle construction industry as well as the necessity to assure economically feasible transportations determined the continuous increment of vehicles tonnage [1]. Presently, in our country in forest transportation, along with traditional truck-trains having between 18...20 and 25...30 t, there are used foreign concept truck-trains (IVECO, RENAULT, MAN, SCANIA etc.) [1]. The overloading of the forest roads generated by vehicles heavier than traditional ones for which the roads were designed, corroborated with climatic factors conducted to exploitation safety and bearing capacity reduction [1].

Due the fact that there is a strong correlation between vehicle and road, there have been imposed some legal prescriptions regarding the gauge dimensions as well as vehicle tonnages in case of merchandise transport [1].

3. Calculus and Determination Methodology

There are very important the allowable loads per axles and, for their determination there can be schematically represented the forces which directly load the axles as well as the reactions which appear from the road system.

Three possible calculus variants were considered:

- forest truck-train with a crane mounted in the rear part;
- forest truck-train with a crane mounted on the front part;
- forest truck-train without crane.

The variable factor which influences the truck-train loading refers to loading with stems height (h) of the truck-train. There can be monitored the allowable loads and their over passing.

By considering the technical schema from Figure 1, and load distribution according to three calculus variants, there can be carried out some calculations in order to determine the maximum loading heights which correspond to maximum allowable loads (7.5 kN on simple axle and 15 kN on double axle).

3.1. Variant 1: Forest truck-train having the crane mounted in the rear part

In this variant the input data for calculations refers to: G_1 - vehicle mass; G_2 - load mass.

The load mass (G_2), can be determined at a certain moment by considering the following elements: L - load length; lat - load width; h - load height; c - a coefficient

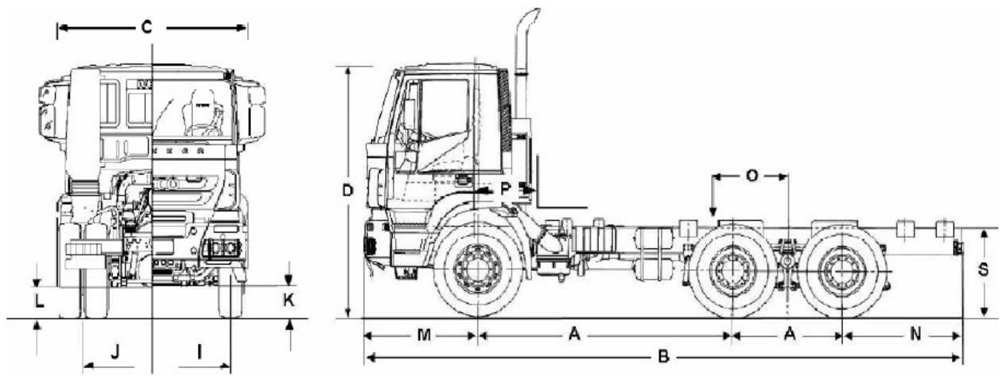

Fig. 1. *Technical schema for a truck-train having a simple axle in the front part and a double axle in the rear part*

which refers to load occupied space; *dens* - stems density which depends on species. Specific relation to the load mass calculation (relation 1) has the following composition:

$$G_2 = L\ lat\ h\ c\ dens, \quad (1)$$

G_3 - crane mass; F_{1lim} and F_{2lim} - maximum allowable masses.

Output data refer to loads per axles (F_1 and F_2), presented as a table corresponding to different loading heights. Calculations refer to F_1 and F_2 determination from moments equilibrium relations for fixed points in F_1 and F_2, as follows:

• for F_2:

$$F_1 l - G_1 l_1 - G_2 l_2 + G_3 l_3 = 0; \quad (2)$$

• for F_1:

$$F_2 l_1 - G_1 l_1 - G_2(l - l_2) - G_3(1 + l_3) = 0. \quad (3)$$

There results that:

$$F_1 = (G_1 l_1 - G_2 l_2 + G_3 l_3) / l, \quad (4)$$

$$F_2 = [G_1 l_1 - G_2(l - l_2) - G_3(l + l_3)] / l. \quad (5)$$

In the above presented relations, l, l_1, l_2 and l_3 represent the forces arms in case of forces which act on the axles (lengths which can be deduced from technical schema of the vehicle).

3.2. Variant 2: Forest truck-train having the crane mounted on the front part

In this variant the input data for calculations refer to: G_1 - vehicle mass; G_2 - load mass.

The load mass (G_2), can be determined at a certain moment by considering the following elements: L - load length; *lat* - load width; h - load height; c - a coefficient which refers to load occupied space; *dens* - stems density which depends on species. Specific relation to the load mass calculation (relation 1) has the following composition:

$$G_2 = L\ lat\ h\ c\ dens, \quad (6)$$

G_3 - crane mass; F_{1lim} and F_{2lim} - maximum allowable masses.

Output data refer to loads per axles (F_1 and F_2), presented as a table corresponding to different loading heights. Calculations refer to F_1 and F_2 determination from moments equilibrium relations for fixed points in F_1 and F_2, as follows:

• for F_2:

$$F_1 l - G_1 l_1 + G_2 l_2 + G_3 l_3 = 0; \quad (7)$$

• for F_1:

$$F_2 l_1 - G_1 l_1 + G_2(l + l_2) - G_3(l - l_3) = 0. \quad (8)$$

There results that:

$$F_1 = (G_1 l_1 - G_2 l_2 + G_3 l_3) / l, \quad (9)$$

$$F_2 = [G_1 l_1 - G_2(l + l_2) - G_3(l - l_3)] / l. \quad (10)$$

In the above presented relations, l, l_1, l_2 and l_3 represent the forces arms in case of forces which act on the axles (lengths which can be deduced from technical schema of the vehicle).

3.3. Variant 3: Forest truck-train without crane

In this variant the input data for calculations refers to: G_1 - vehicle mass; G_2 - load mass.

The load mass (G_2), can be determined at a certain moment by considering the following elements: L - load length; *lat* - load width; h - load height; c - a coefficient which refers to load occupied space; *dens* - stems density which depends by species. Specific relation to the load mass calculation (relation 1) has the following composition:

$$G_2 = L\ lat\ h\ c\ dens, \quad (11)$$

G_3 - crane mass; F_{1lim} and F_{2lim} - maximum allowable masses.

Output data refer to loads per axles (F_1 and F_2), presented as a table corresponding to different loading heights. Calculations refer to F_1 and F_2 determination from moments equilibrium relations for fixed points in F_1 and F_2, as follows:

• for F_2:

$$F_1 l - G_1 l_1 - G_2 l_2 = 0; \quad (12)$$

• for F_1:

$$F_2 l_1 - G_1 l_1 - G_2(l - l_2) = 0. \quad (13)$$

There results that:

$$F_1 = (G_1 l_1 - G_2 l_2) / l, \quad (14)$$

$$F_2 = [G_1 l_1 - G_2(l - l_2)] / l. \quad (15)$$

In the above presented relations, l, l_1, l_2 and l_3 represent the forces arms in case of forces which act on the axles (lengths which can be deduced from technical schema of the vehicle).

4. Results and Discussion

In order to determine the maximum allowable loading heights, several simulations were made by considering gradual increments for all the considered variables.

4.1. Forest truck-train with a crane mounted on the rear part (V1)

• Input data:
- G_1 = 11 kN;
- G_3 = 4 kN.

• Elements for load weight calculus (G_2):
- L = 5 m;
- *lat* = 2 m;
- c = 0.64;
- *dens* = 1 t/m^3;
- variation step for load height = 0.1 m;
- maximum calculus height = 2.0 m;
- minimum calculus height = 1.0 m.

• Vehicle dimensions:
- A = 4495 mm;
- A' =1370 mm;
- P = 730 mm;
- crane width = 1070 mm;
- B = 10 205 mm;
- M = 1488 mm;
- maximum load per simple axle = 7.5 kN;
- maximum load per double axle = 15 kN.

Simulation results for variant 1 Table 1

h [m]	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0
F_1 [kN]	4.4	4.5	4.7	4.8	4.9	5.0	5.1	5.3	5.4	5.5	5.6
F_2 [kN]	17	17.5	18.0	18.5	19.1	19.6	20.1	20.6	21.1	21.7	22.2
G_2 [kN]	6.4	7.0	7.7	8.3	9.0	9.6	10.2	10.9	11.5	12.2	12.8
l [m]	5.18	5.18	5.18	5.18	5.18	5.18	5.18	5.18	5.18	5.18	5.18
l_1 [m]	2.59	2.59	2.59	2.59	2.59	2.59	2.59	2.59	2.59	2.59	2.59
l_2 [m]	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99
l_3 [m]	3	3	3	3	3	3	3	3	3	3	3

4.2. Forest truck-train with a crane mounted on the front part (V2)

• Input data:
- G_1 = 11 kN;
- G_3 = 4 kN.

• Elements for load weight calculus (G_2):
- L = 5 m;
- lat = 2 m;
- c = 0.64;
- $dens$ = 1 t/m^3;
- variation step for load height = 0.1 m;
- maximum calculus height = 2.0 m;
- minimum calculus height = 1.0 m.

• Vehicle dimensions:
- A = 4495 mm;
- A' = 1370 mm;
- P = 730 mm;
- crane width = 1290 mm;
- maximum load per simple axle = 7.5 kN;
- maximum load per double axle = 15 kN.

Simulation results for variant 2 Table 2

h [m]	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0
F_1 [kN]	9.3	9.3	9.4	9.5	9.6	9.7	9.7	9.8	9.9	10.0	10.0
F_2 [kN]	12.1	12.7	13.3	13.8	14.4	14.9	15.5	16.1	16.6	17.2	17.3
G_2 [kN]	6.4	7.0	7.7	8.3	9.0	9.6	10.2	10.9	11.5	12.2	12.8
l [m]	5.18	5.18	5.18	5.18	5.18	5.18	5.18	5.18	5.18	5.18	5.18
l_1 [m]	2.59	2.59	2.59	2.59	2.59	2.59	2.59	2.59	2.59	2.59	2.59
l_2 [m]	-0.66	-0.66	-0.66	-0.66	-0.66	-0.66	-0.66	-0.66	-0.66	-0.66	-0.66
l_3 [m]	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8

4.3. Forest truck-train without crane (V3)

• Input data:
- G_1 = 11 kN.

• Elements for load weight calculus (G_2):
- L = 5 m;
- lat = 2 m;
- c = 0.64;
- $dens$ = 1 t/m^3;
- variation step for load height = 0.1 m;
- maximum calculus height = 2.0 m;
- minimum calculus height = 1.0 m.

• Vehicle dimensions:
- A = 4495 mm;
- A' = 1370 mm;
- P = 730 mm;
- maximum load per simple axle = 7.5 kN;
- maximum load per double axle = 15 kN.

Simulation results for variant 3 Table 3

h [m]	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0
F_1 [kN]	7.9	8.2	8.4	8.6	8.9	9.1	9.4	9.6	9.8	10.1	10.3
F_2 [kN]	9.5	9.9	10.3	10.7	11.1	11.5	11.9	12.3	12.7	13.1	13.5
G_2 [kN]	6.4	7.0	7.7	8.3	9.0	9.6	10.2	10.9	11.5	12.2	12.8
l [m]	5.18	5.18	5.18	5.18	5.18	5.18	5.18	5.18	5.18	5.18	5.18
l_1 [m]	2.59	2.59	2.59	2.59	2.59	2.59	2.59	2.59	2.59	2.59	2.59
l_2 [m]	1.95	1.95	1.95	1.95	1.95	1.95	1.95	1.95	1.95	1.95	1.95

5. Conclusions

As seen in Tables 1-3, the maximum load height for average conditions regarding the tree species (1 t/m^3) varies in rapport with the main characteristics of the loading-unloading equipment, as well as the maximum allowable loads per axles. There can be concluded that in the same conditions regarding the maximum loads per axle and double-axle:

- In the first variant the maximum loads are observed only for simple axles regardless the load height;
- In the second variant the maximum loads are observed only for double axles for load heights up to 1.5 m;
- In the third variant the maximum loads are observed only for double axles regardless the load height.

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