TRENDS OF TECHNICAL CHARACTERISTICS OF WHEELED SKIDDING MACHINERY

Jurii Belenkii[1], Aleksandr Andronov[1], Boris Martynov[1], Anna Khakhina[2]
[1]Saint Petersburg State Forest Technical University, Russia;
[2]Peter the Great Saint-Petersburg Polytechnic University, Russia
andronovalexander@gmail.com, bm@mail.ru, hahin@mail.ru

Abstract. The paper is devoted to trends analysis of technical characteristics of wheeled skidding machinery in the last decade. Material for the study consists of information provided by machinery manufacturers in 2007 and 2019, total 118 samples in 2007 and 107 samples in 2019. Comparative analysis finds that by 2019 the average mass of the cable skidder exceeds 19 tons, which is significantly higher than an analogous indicator by 2009, the difference is up to 90 %. The engine power averages 170 kW, which is up to 70 % higher than in 2009. The average value of the wheelbase is increased by 23 % and amounts to 3.85 m, gauge increased by 31 % and amounts to 2.85 m. By 2019, the average mass of grapple skidders has increased by 46 %, compared to the same indicator by 2009, and exceeds 18 tons. Their average engine power increases by up to 50 % and amounts to 180 kW. The average value of the wheelbase increases by 25 % and amounts to 2.43 m. The average value of the opening area of the grapple increases by 76 %, the figure was 1.74 m^2. By 2019, the average weight of forwarders exceeds 17 tons, which is up to 30 % higher than the figure received by 2009. The average engine power increases by 40 % and exceeds 155 kW. The average cargo capacity of forwarders by 2019 reaches 14 tons, which is higher than the figure received by 2009, by 20 %. The track of modern forwarders averages 2.82 m, which is 36 % higher than in 2009. The average value of the lifting moment of the manipulator increases by 70 %, amounting to 120 kN·m, the manipulator's reach increases by 12 % to 8.6 m. The results show that almost all the parameters of cable skidders, grapple skidders and forwarders relate to the machines' mass. The results establish that almost all forestry machines, about 87 %, presented on the market by 2019, belong to the heavy class, while there is a decrease in the share of samples belonging to small and medium classes of energy saturation with an increase in the share of machines in large and extra-large classes.

Keywords: energy saturation, technical characteristics, forwarder, grapple skidder, cable skidder.

Introduction

Companies that manufacture skidding equipment compete in market conditions. In order to attract consumers, they strive to produce large-sized machines with higher travel load, engine power, weight. Studying morphological characteristics and correlations between forestry vehicle parameters is an important task of forest engineering, allowing development of models for sustainable forestry management [1-3]. One can insist that there has been a persistent tendency to release a larger number of samples of machinery belonging to the class of heavy machines [4-6], but the tendency has not been described numerically. At the same time, scientists have already noted that such an approach does not always lead to increase in the technological indicators of the skidding process. For example, consumers, focusing on the information of manufacturers of equipment, are faced with the inability to operate equipment in their natural conditions due to the loss of its passability [7-9].

The aim of this study is to analyze the trends in increasing of the main technical characteristics of wheeled machinery over the past decade.

Materials and methods

The research methods include statistical data analysis, in particular the least-squares method (LSM). The material for the study consists of information provided by the manufacturers of skidding equipment for 2007 and 2019. In 2007, the monograph [4] was published, which collected and analyzed characteristics of wheeled forestry machines (cable and grapple skidders, forwarders), mass-produced at that time by the companies John Deere, Ponsse, Rottne, Caterpillar and Valmet, total 118 samples. We will rely on this information in the course of further analysis. For comparison, we use information from the websites [10-13], which provide one with information about forestry machines (cable and grapple skidders, forwarders) produced by John Deere, Ponsse, Rottne and Komatsu companies, total 107 samples. These data apply to the vehicles offered in 2019.

Results and discussion

Basing on the reference data processing for both 2007 and 2019, we can conclude that almost all of the indicators of cable skidders, grapple skidders and forwarders are related to the mass of the machine. Analysis with LSM leads to the following equations:

- for cable skidders

$$N = 7.2581m + 27.559 \quad (1)$$

$$B = 0.0769m + 2.3384 \quad (2)$$

$$R = 0.0787m + 1.3753 \quad (3)$$

- for grapple skidders

$$N = 9.2693m - 2.423 \quad (4)$$

$$B = 0.1266m + 1.7299 \quad (5)$$

$$R = 0.0511m + 1.5074 \quad (6)$$

$$GA = 0.1025m - 0.268 \quad (7)$$

- for forwarders

$$N = 9.0587m - 6.7349 \quad (8)$$

$$L = 0.801m + 0.3902 \quad (9)$$

$$B = 0.1091m + 3.4019 \quad (10)$$

$$R = 0.0834m + 1.1554 \quad (11)$$

$$LM = 8.6171m - 37.485 \quad (12)$$

$$MR = 0.0675m + 7.0722 \quad (13)$$

where m – machine mass, t;
N – engine power, kW;
B – wheelbase, m;
R – gauge, m;
GA – grapple opening area, m^2;
L – load capacity, t;
LM – manipulator lifting moment, kN m;
MR – maximum reach of the manipulator, m.

The links are illustrated with graphs in Figures 1-3 (round markers refer to 2007, square ones refer to 2019). Tables 1 – 3 present the results of the comparison.

Basing on the analysis results, we can conclude that by 2019 the average weight of cable skidders reaches 19.52 tons, which is a significantly higher value than the similar indicator by 2007, the difference is 90 %. The engine power averages 171.56 kW, which is 71 % higher than in the same period by 2007.

The average value of the wheelbase increases by 23 % and amounts to 3.85 m, the track gauge increases by 31 % and amounts to 2.85 m.

By 2019, the average weight of grapple skidders increases, compared to the same indicator by 2007, by 46 % and amounts to 18.81 tons. The average engine power increases by 54 % and amounts to 177.23 kW. The average value of the wheelbase increases by 25 % and amounts to 2.43 m. The average value of the grapple opening square increases by 76 %, the figure was 1.74 m^2.

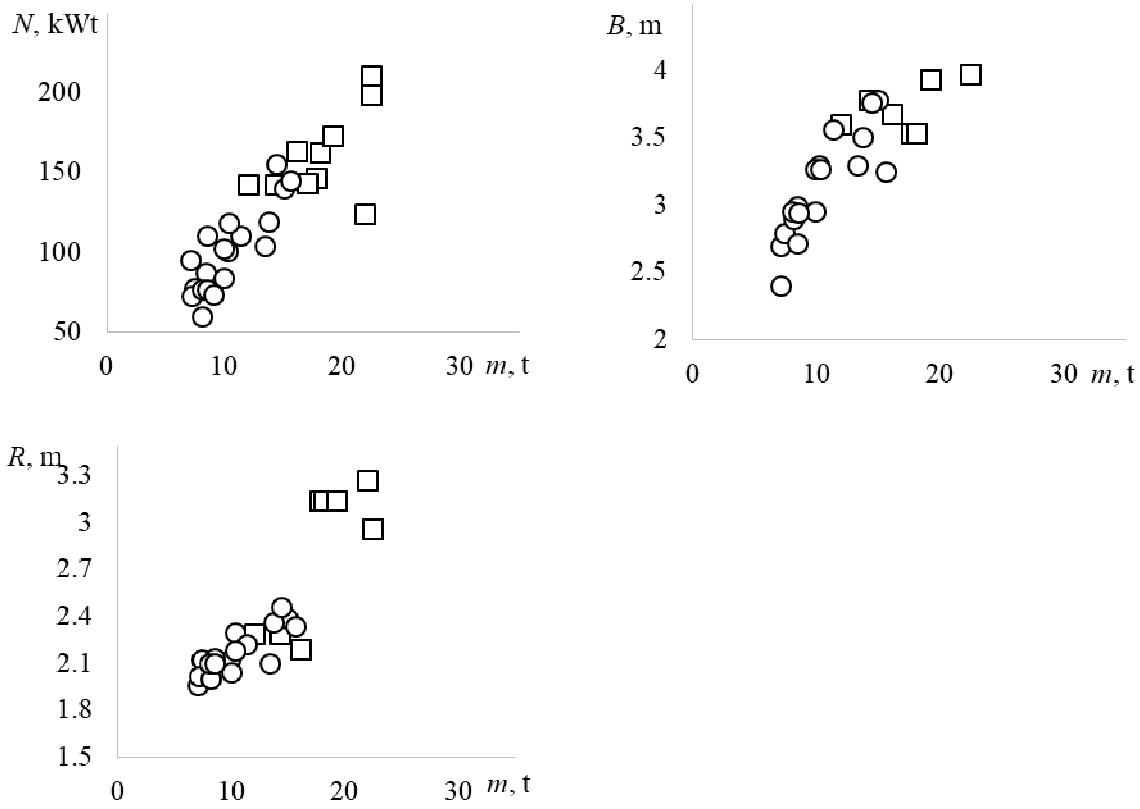

Fig. 1. **Technical characteristics of cable skidders related to mass**

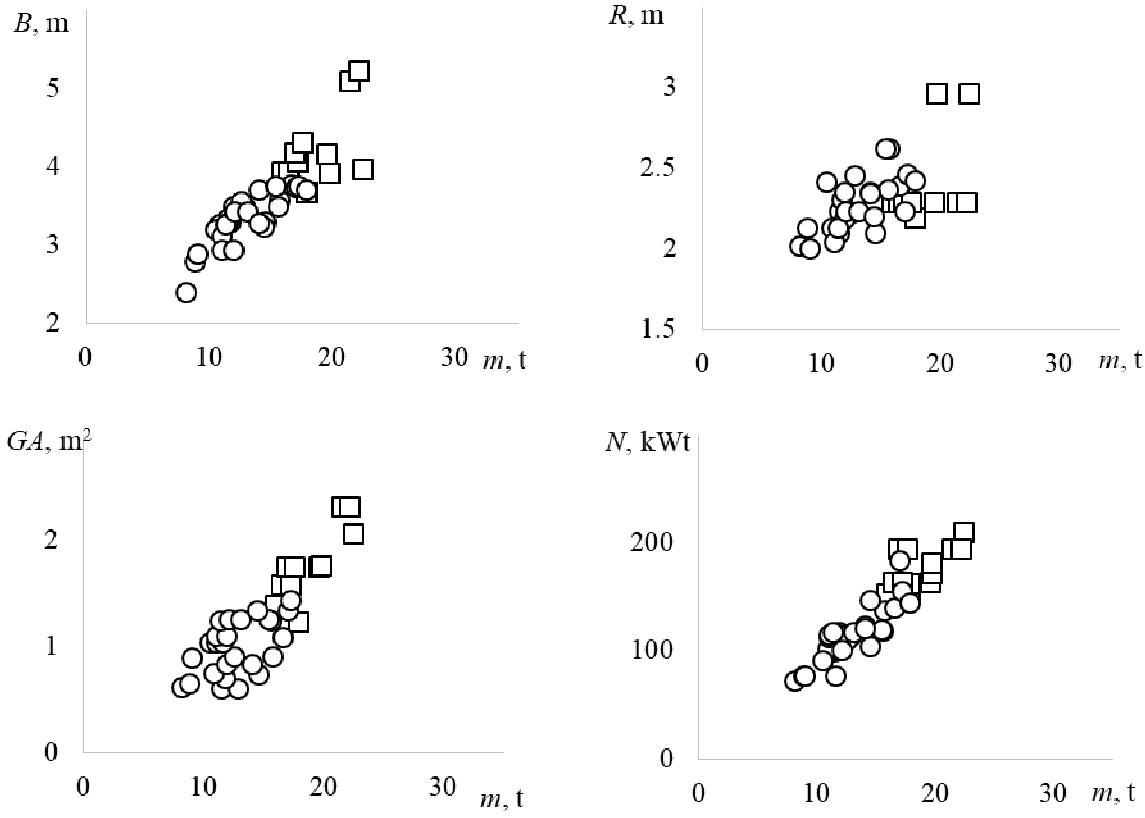

Fig. 2. **Technical characteristics of grapple skidders related to mass**

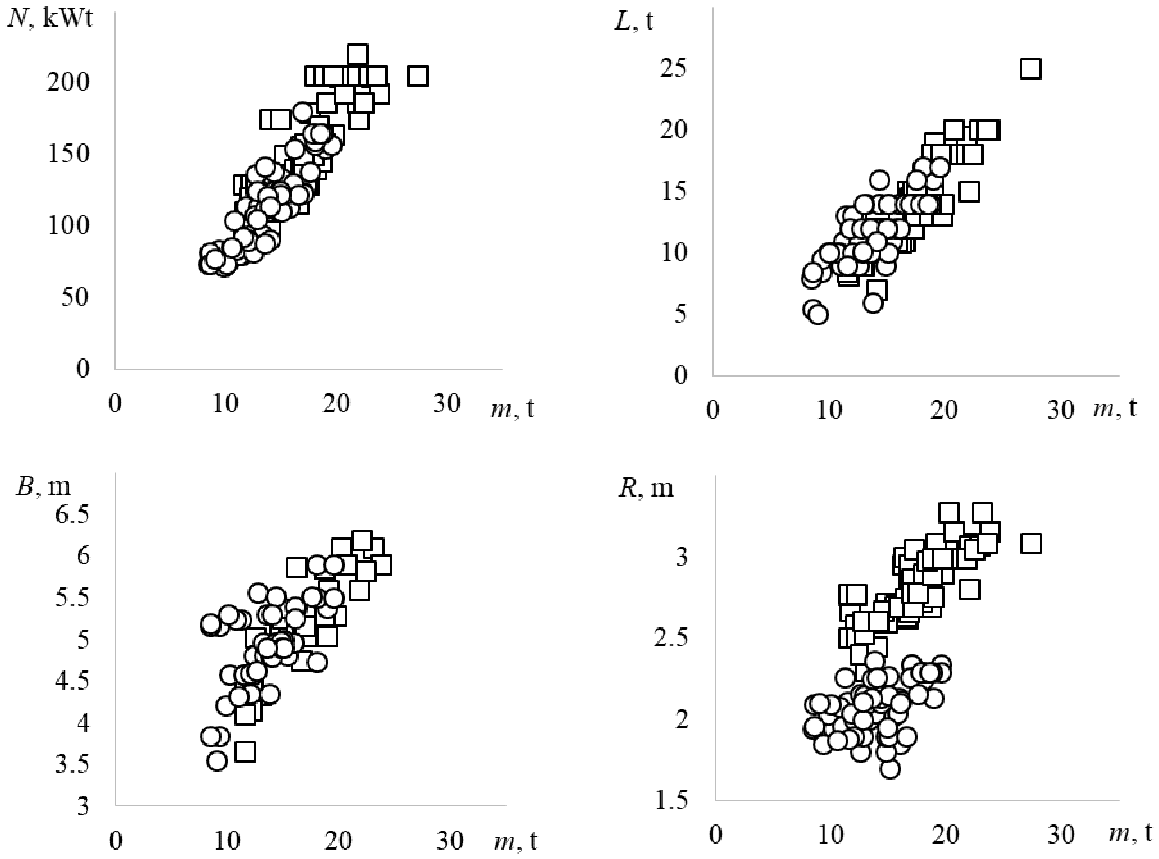

Fig. 3. **Technical characteristics of forwarders related to mass**

Table 1

Analysis of technical characteristics of cable skidders

Year	Stat. indicator	Characteristics			
		Machine mass, t	Engine power, kW	Wheelbase, m	Gauge, m
2019	Number of the models analyzed	16	16	14	14
	Sample mean	19.52	171.56	3.85	2.85
	Standard deviation	5.7612	41.503	0.4303	0.413
2007	Number of the models analyzed	19	19	18	17
	Sample mean	10.3	100.39	3.13	2.17
	Standard deviation	2.7856	26.492	0.3774	0.1483
Calculated *t*-criterion when comparing two samples		5.8513	5.9186	4.9522	5.8569

By 2019, the average mass of forwarders reaches 17.52 tons, which is 27 % higher than the same indicator obtained by 2007. The average engine power increases by 37 % and amounts to 155.77 kW. The average load capacity of forwarders by 2019 amounts to 14.09 t, which is 19 % higher than the figure obtained by 2007. The gauge of modern forwarders averages 2.82 m, which is 36 % more than in 2007. The average value of the lifting moment of the manipulator increases by 73 %, amounting to 122.77 kNm, the reach of the manipulator increases by 12 % – to 8.6 m.

Note that almost all forest machines, about 87 % of the models by 2019, belong to the heavy class (lightweight class includes machines with a mass up to 10 tons, medium-weight class – 10-14 tons, heavy machines have a mass of more than 14 tons), see Figure 4.

Table 2

Analysis of technical characteristics of grapple skidders

Year	Stat. indicator	Characteristics				
		Machine mass, t	Engine power, kW	Wheel-base, m	Gauge, m	Grapple opening area, m^2
2019	Number of the models analyzed	13	13	13	13	13
	Sample mean	18.81	177.23	4.16	2.43	1,74
	Standard deviation	2.1762	18.176	0.4811	0.3071	0,3486
2007	Number of the models analyzed	28	28	28	27	26
	Sample mean	12.92	114.85	3.34	2.27	0,99
	Standard deviation	2.6182	25.261	0.3313	0.1673	0,2584
Calculated *t*-criterion when comparing two samples		7.547	8.9848	5.5632	1.7572	6.8708

Table 3

Analysis of technical characteristics of forwarders

Year	Stat. indicator	Characteristics						
		Machine's mass, t	Engine power, kW	Load capacity, t	Wheelbase, m	Gauge, m	Manipulator's lifting moment, kN m	Maximum reach of the manipulator, m
2019	Number of the models analyzed	78	75	78	52	77	71	74
	Sample mean	17.52	155.77	14.09	5.2	2.82	122.7	8,6
	Standard deviation	10.942	1059.3	12.254	0.280	0.049	754.3	1,407
2007	Number of the models analyzed	71	70	69	48	66	64	71
	Sample mean	13.82	113.81	11.86	4.95	2.07	71	7,65
	Standard deviation	8.2477	777.26	7.1351	0.254	0.026	554.5	0,978
Calculated *t*-criterion when comparing two samples		12.854	45.995	7.713	1.738	10.28	59.59	5.488

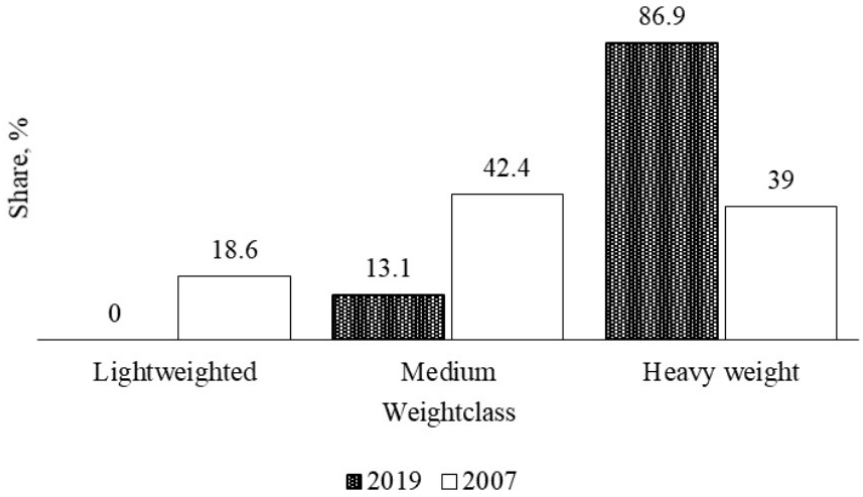

Fig. 4. **Distribution of forest machine models by weight class**

Additionally, we note a tendency to increase energy saturation of the machines: the share of equipment samples belonging to the light and medium energy saturation classes decreases, while the share of machines models in the high and extra high class increases (Figure 5) (the small energy class up to 6 kW·t^{-1}, medium – 6-8 kW·t^{-1}, high – 8-10 kW·t^{-1}, extra high – over 10 kW·t^{-1}).

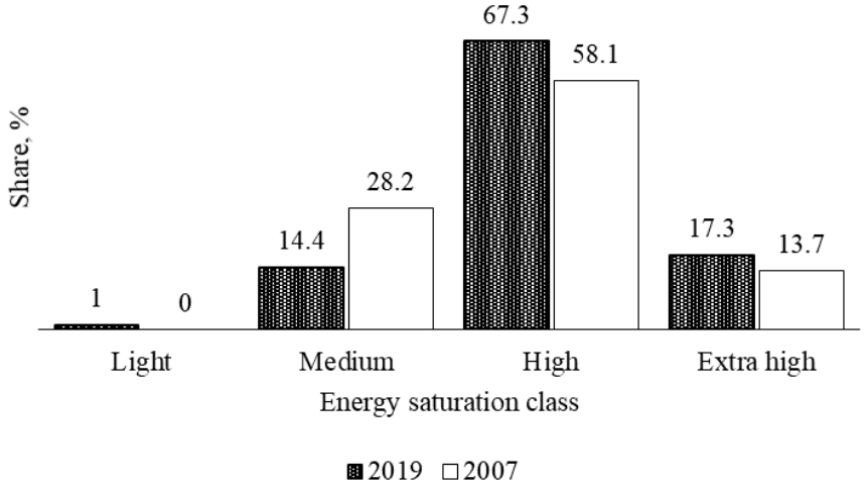

Fig. 5. **Distribution of forest machine models by classes of energy saturation**

Conclusions

Comparative analysis finds that:

1. The results show that almost all the parameters of cable skidders, grapple skidders and forwarders relate to the machine mass.
2. By 2019, the average mass of cable skidder exceeds 19 tons, which is significantly higher than an analogous indicator by 2009, the difference is up to 90 %. The engine power averages 170 kW, which is up to 70 % higher than in 2009. The average value of the wheelbase increased by 23 % and amounts to 3.85 m, the gauge increased by 31 % and amounts to 2.85 m.
3. By 2019, the average mass of grapple skidders has increased by 46 %, compared to the same indicator by 2009, and exceeds 18 tons. Their average engine power increases by up to 50 % and amounts 180 kW. The average value of the wheelbase increases by 25 % and amounts to 2.43 m. The average value of the opening area of the grapple increases by 76 %, the figure was 1.74 m^2.
4. By 2019, the average weight of forwarders exceeds 17 tons, which is up to 30 % higher than the figure received by 2009. The average engine power increases by 40 % and exceeds 155 kW. The average cargo capacity of forwarders by 2019 reaches 14 tons, which is higher than the figure received by 2009, by 20 %. The track of modern forwarders averages 2.82 m, which is 36 % higher than in 2009. The average value of the lifting moment of the manipulator increases by 70 %, amounting to 120 kN·m, the manipulator's reach increases by 12 % to 8.6 m.
5. The results establish that almost all forestry machines, about 87 %, presented on the market by 2019, belong to the heavy class, while there is a decrease in the share of samples belonging to the small and medium class of energy saturation with an increase in the share of machines in the large and extra-large class.

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