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Forklift with small turning radius and its efficiency

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Forklift with small turning radius and its efficiency

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Abstract. A forklift is one of the most widely used vehicles in industry sectors in few decades. Therefore, it is important to create or improve their entire designs. This article proposes a method for determining the required corridor width by calculating the turning radius of standard counterweight Forklift and the new construction of forklift and compares their parameters. The effect of the new type of fork on the efficiency of forklifts and warehouses was studied.

1. Introduction

Nowadays, the technical performance of vehicles plays an important role in the application of certain areas. One of the main parameters is the turning radius of the vehicle during parking and use. Studies of cars have shown that they can reduce the turning radius by 36-70% [1]. However, forklifts which are used commonly in industries and warehouses with rear-wheel steering causes certain delusive driving features. The rear wheels cornering stiffness coefficient at every speed in requirement of vehicle stability is larger than that of the front wheels [2]. It can increase the risk of the overturning of vehicles. Therefore to eliminate the demerits of rear-wheel steering vehicles, some research works [3–9] are held over the period last few decades.

As a result of the growing needs of humanity, many large enterprises and warehouses are being established internationally. This requires enterprises and warehouses to be highly efficient. The width of the aisles for the movement of Forklifts is one of the main indicators in the design of industrial enterprises and warehouses. Therefore, the calculation of the width of the aisles considers the technical characteristics of the existing and manufacturing forklifts, that is, they are designed considering the width of the aisle, which corresponds to the models of the forklift. This allows efficient use of the designated area.

The technical characteristics of the produced forklifts include only the width of the aisles for loads placed on standard pallets. The dimensions of the standard pallets may distinguish in size and weight of the loads to be transported, and pallets of 1200x800 or 1200x1000 mm are mainly selected for the production of forklifts. In this case, the center of gravity of the transported load must be at a distance of 500 or 600 mm from the back surface of the fork [10]. An increase in this distance leads to a decrease in the load-carrying capacity of the forklift, and at the same time can cause difficulties in moving or turning the vehicle along the standard aisle.

2. Exist models and their turning radius

For design industrial enterprises and warehouses considers the rotation of forklifts moving in their aisle at 90° with the load. Three and four-wheel forklifts with counterweights are mainly used in these areas. The scheme of movement of these forklifts with the load at 90° in the load placement is shown in Figure 1.

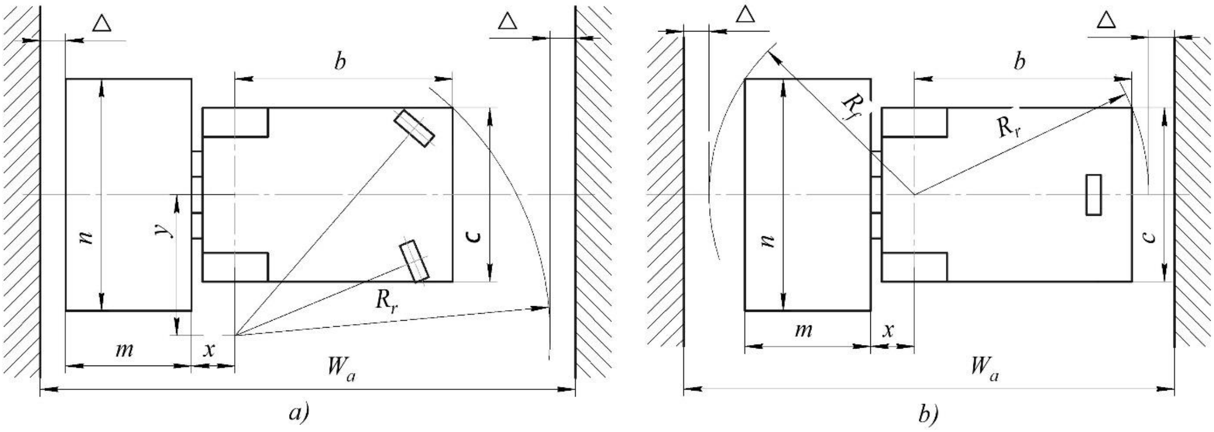

Figure 1. The scheme of turning the existing counterbalanced forklifts with the load at 90° in placing or receiving cargo: a) four-wheel; b) three-wheel.

Considering the turning radius of a four-wheel forklift, the width of the aisle can be determined using the following expression:

$$W_a = \sqrt{\left(y + \frac{c}{2}\right)^2 + b^2} + x + m + 2\Delta \tag{1}$$

For three-wheel forklift:

$$W_a = \sqrt{\left(\frac{c}{2}\right)^2 + b^2} + \sqrt{(x + m)^2 + \left(\frac{n}{2}\right)^2} + 2\Delta \tag{2}$$

Where,
y - the distance from the symmetrical axis of the forklift to the center of rotation;
c and *b* - constructive dimensions of the forklift;
n and *m* - pallets dimensions;
x - the distance from the front axle to the rear surface of the fork;
Δ - the permissible distance between the aisle wall or the shelf and the forklift, in practice this distance is taken in the range of 100 – 150 mm;
R_r - rear turning radius;
R_f - front turning radius.

3. Proposed model and its improvement.

The proposed model is shown in Figure 2 consists of several important elements: movable fork 1 along the horizontal axis of the vehicle and its drive unit 2, special platform 3 and a load-lifting mechanism 4 which can move along the axis of the model on the platform 3 with drive unit 5. At the rear of the platform is installed a cab 6, and next to it is mounted drive unit 7, which moves the forklift.

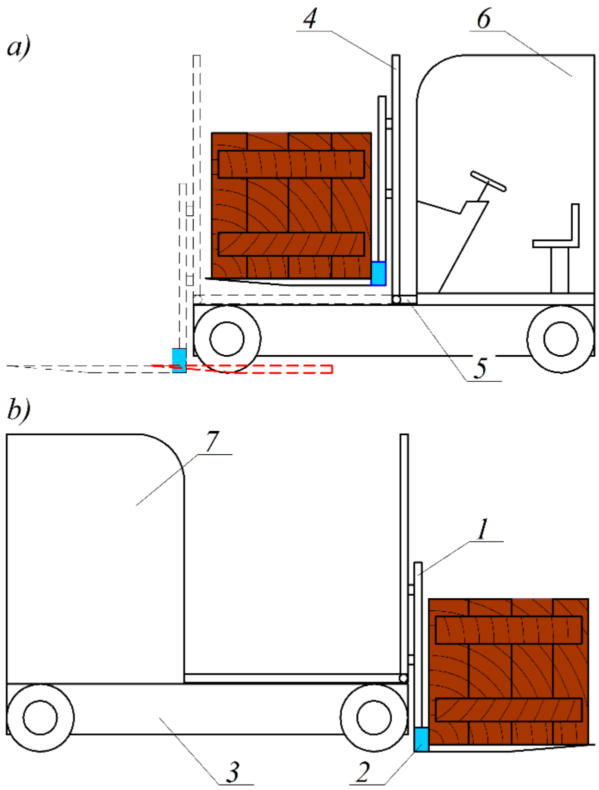

Figure 2. Schematic views of the proposed forklift at loaded position: a) view from the left side with high balanced performance; b) right side view with a lower position of the fork.

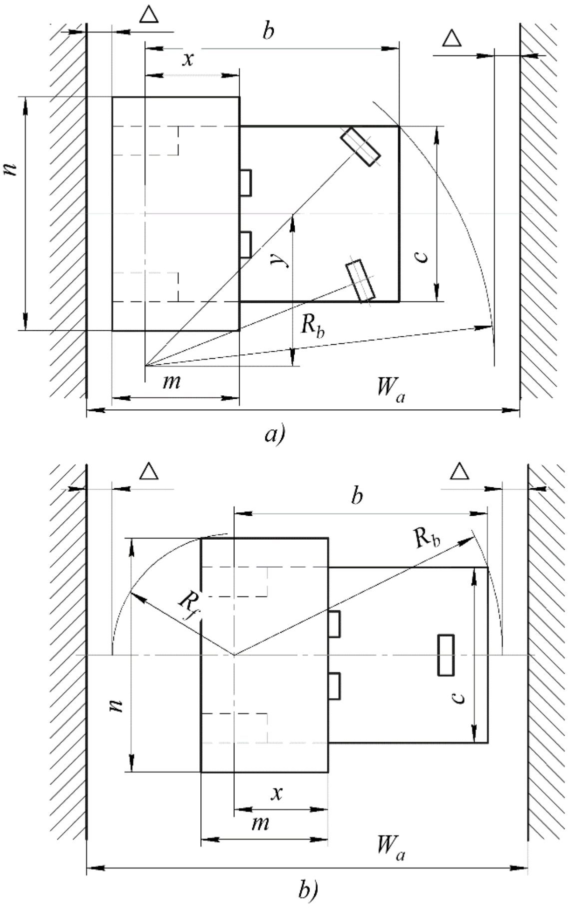

Figure 3. The scheme of turning the proposed forklift with the load at 90 ° in placing or receiving cargo: a) four-wheel; b) three-wheel.

The proposed forklift's lifting and transporting method differ from other vehicles and it consists of that: the vehicle is driven to the load which has to transport along the corridor to another place, the lifting mechanism moves to the front part of the platform and the fork is lowered to the load position, the movable horizontal part of the fork is operated back and the vehicle is turned 90 ° to the side of the load, the horizontal part of the fork is moved forward to hang the load to the fork, and the load is lifted onto the platform, then the vehicle is turned 90 ° and moved along the corridor. The scheme of rotation of the proposed forklift to 90 ° with load is shown in Figure 3.

The width of the aisle for the four-wheeled type of this new model is determined by the following expression:

$$W_a = \sqrt{\left(y+\frac{c}{2}\right)^2 + b^2} + m - x + 2\Delta \tag{3}$$

For three-wheel forklift:

$$W_a = \sqrt{\left(\frac{c}{2}\right)^2 + b^2} + \sqrt{(m-x)^2 + \left(\frac{n}{2}\right)^2} + 2\Delta \tag{4}$$

4. Discussion

One of the main working elements of forklifts is its fork, and all lifting and hauling works are done with this fork. All forklifts used in industries and warehouses have a fork of constant fixed length. If we pay attention to the technical characteristics of forklifts with small and medium lifting capacity, the length of the forks in them is on average 30% of the total length of the vehicle. This can be seen in the examples of the forklifts of the four companies listed in Table 1.

Table 1. Forklifts fork in four different companies and compare them to the total length of the vehicle.

Manufacturer	Model	Total length (mm)	Length of the fork (mm)	Length of the fork /Total length, (%)
Toyota	8FG/8FD10	3310	1070	32,33
	8FG/8FD15	3355	1070	31,89
	8FG/8FD18	3380	1070	31,66
Doosan	B16X/B18X	2993	900	30,07
	D15S-5/G15S-5	3070	900	29,32
	D20S-5/G20S-5	3150	900	28,57
Heli	CPQ20	3402	920	27,04
	CPQ25	3622	1070	29,54
	CPQ30	3745	1070	28,57
Hangcha	CPD10H-C3E	2895	900	31,09
	CPD20H-C3E	3365	1070	31,80
	CPD30H-C3E	3550	1070	30,14
Average				30,17

The proposed model envisages reducing the turning radius of the forklift by diminishing this amount by 30%, as well as increasing the efficiency of warehouses which has been using standard forklifts with counterweight. That is, due to the small turning radius, the width of the aisle between the shelves in warehouses is also significantly reduced and it can be seen in Figure 4.

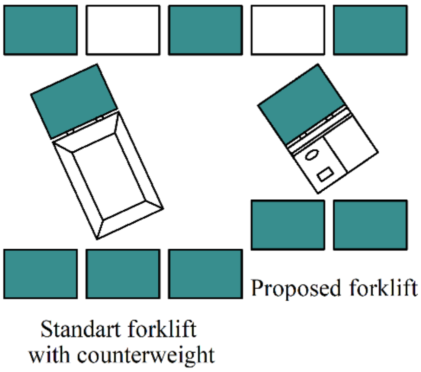

Figure 4. Required aisle width for a standard forklift with counterweight and proposed forklift

In addition, the field of application of the vehicle will be significantly expanded. By lifting the load onto the platform of the proposed forklift, the overall center of gravity of the system shifts toward the rear axle of the vehicle and the forklift achieves a high balanced position. The reserve balancing weight required for forces acting through accidental braking, slipping, or unevenness inroads during movement is significantly reduced.

5. Conclusion

The fixed-length fork of the standard forklift with counterweight causes several drawbacks to the vehicle. That is, the length of the fork is almost 1/3 of the total length of the vehicle, which reduces the field of application of the forklift. The movable horizontal part of the fork and the loading method of the machine is presented as a solution to the above-mentioned shortcomings.

Acknowledgment
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