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INDUSTRIAL WHEELS FOR INTERNAL TRANSPORT EQUIPMENT IN AUTOMOTIVE INDUSTRY

*Nenad Miloradović [1], Rodoljub Vujanac [2]**

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RESEARCH ARTICLE

ABSTRACT: During many transport manipulative operations within the automotive industry, the supporting structure of the used equipment relies on various industrial wheels. The paper describes the characteristic types of wheels and castors and their constituent components. The role of the wheels with rubber and polyurethane coatings and with hard tread is highlighted. The process of choosing the right wheel for the given working conditions is presented. In addition to numerous applications in automotive and mechanical industries, various types of the wheels are also used on: machinery and equipment for the food industry, packaging and transport containers, constructions, scaffolding and road paving equipment, hospital equipment, environmental installations, entertainment equipment and as components in the textile and furniture industry or the sports equipment. Examples of concrete solutions for transport systems within logistic and manipulative operations are given.

KEY WORDS: *industrial wheels, automotive industry, internal transport*

[1] *Nenad Miloradović, University of Kragujevac, Faculty of Engineering, 6 Sestre Janjić Str., 34000 Kragujevac, Serbia, mnenad@kg.ac.rs , https://orcid.org/0000-0001-6846-6091*
[2] *Rodoljub Vujanac, University of Kragujevac, Faculty of Engineering, 6 Sestre Janjić Str., 34000 Kragujevac, Serbia, vujanac@kg.ac.rs , https://orcid.org/0000-0002-8215-5668 (*Corresponding author)*

INDUSTRIJSKI TOČKOVI ZA SREDSTVA UNUTRAŠNJEG TRANSPORTA U AUTOMOBILSKOJ INDUSTRIJI

REZIME: Tokom mnogih transportno manipulativnih operacija u okviru automobilske industrije, noseća konstrukcija korišćene opreme se oslanja na različite industrijske točkove. U radu su opisani karakteristični tipovi točkova i nosača, kao i njihove sastavne komponente. Istaknuta je uloga točkova sa gumenom i poliuretanskom oblogom, kao i sa tvrdim gazećim slojem. Prikazan je proces izbora pravog točka za zadate radne uslove. Pored brojnih primena u automobilskoj i mašinskoj industriji, razne vrste točkova se takođe koriste u: mašinama i opremi za prehrambenu industriju, ambalaži i transportnim kontejnerima, u građevinarstvu, na skelama i asfaltiranju puteva, bolničkoj opremi, ekološkim instalacijama, opremi za zabavu, kao komponenta u tekstilnoj industriji i industriji nameštaja ili kao element sportske opreme. Navedeni su primeri konkretnih rešenja transportnih sistema u okviru logističkih i manipulativnih operacija.

KLJUČNE REČI: *industrijski točkovi, automobilska industrija, unutrašnji transport*

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INTRODUCTION

Internal transport is an important part of material handling in all types of the production processes. Related methods of internal transport should be cost-effective, low energy consuming, safe, smooth and quiet. They should also help to increase productivity and profitability of the industrial processes. Many operations are part of the internal transport (loading, unloading, reloading and transfer). The scope of internal transport operations includes various mechanical, hydraulic, pneumatic and electrical systems, with autonomous systems as modern additions [1].

Internal transport devices use industrial wheels and brackets during transportation and manipulative processes in various applications. Each application involves specific operating conditions that are defined by technical solutions and international standards. Various types of industrial wheels are in use [2], like the wheels with rubber, polyurethane, monolithic (hard tread) and pneumatic coverings.

The tyred wheels have coverings made of elastomer that originates from natural and/or synthesised rubber and is made by using vulcanization or injection moulding. During the vulcanization process and due to added mineral agents, rubber acquires improved elastic properties over time that provide adequate traction and load capacity. Thus, the wheels with vulcanised rubber coverings can have diverse mechanical characteristics. The most important parameters that define the quality of vulcanized rubber wheels are: hardness, density, impact strength, tensile strength and wear rate. During the injection molding process, the material is injected into the mold through a process of chemical synthesis, whereby the rubber retains its properties after molding.

The polyurethane wheel covering actually represents an elastomer that was created on the basis of the synthesis of the appropriate raw materials. Polyurethanes are chemical compounds obtained by mixing two components in liquid state triggering the polymerization reaction. The resulting mixture is cast into appropriate moulds or directly injected into heated moulds that have plastic or metal bases. In this way, different elastomers with the desired mechanical characteristics are formed. For example, mould-on polyurethane has good elasticity characteristics, while injected polyurethane has inferior elasticity characteristics, but superior hardness compared to mould-on polyurethane.

The centre and the covering of the monolithic (hard tread) wheel are made of the same material. The most frequently used materials for this type of the wheels are cast iron and thermoplastic materials. These materials determine the physical and mechanical characteristics of the wheel.

The pneumatic wheel covering is made of a rubber tyre with ply insert and an inner tube. The tread is usually grooved to increase the wheel-ground grip potential.

The wheels of material handling devices were analysed for different experimental load conditions using numerical analysis in [3]. The maintenance strategy of driving wheels and the influencing parameters on the wear process were analysed in [4].

1. THE BASIC ELEMENTS OF THE INDUSTRIAL WHEELS

The industrial wheel has the following components: the tread, the covering, the core, the hub and the swivel bearing, Figure 1 [5].

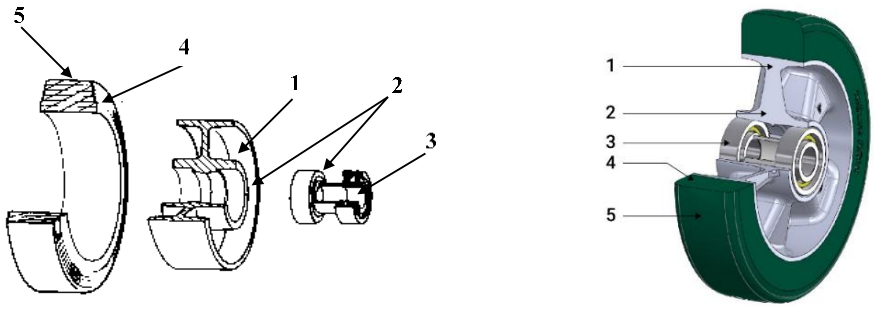


Figure 1. Basic industrial wheel components: core (1), hub (2), swivel bearing (3), covering (4), tread (5) [5]

The wheel tread is probably the most important part of the wheel, because it comes into direct contact with the ground. The tread can be smooth or with patterns that improve the wheel performance in critical areas such as noise, handling, grip and tire wear.

The wheel covering represents an outer ring and it is made of different materials. It is fixed to the wheel core using an adhesive or a mechanical connection.

The wheel core is the wheel element on which the wheel covering is mounted. It is built as a single element or as several elements joined together that connect the wheel covering with the wheel hub. The wheel core shapes can be made of a large number of different materials.

The wheel hub is the central, cylindrical part of the wheel. The wheel axle and the bearing are directly connected to it, so the hub participates in facilitation of the wheel rotation.

Most types of industrial wheels need the bracket to be connected to the equipment. There are two types of wheel brackets: the fixed type and the swivel type. The fixed brackets do not permit the change in direction of the equipment and they must be placed parallel to each other. The swivel bracket rotates about its own vertical axis which is offset with respect to the wheel vertical axis, providing good manoeuvrability of the equipment. There are several forms of the brackets, depending on the type of attachment with the equipment, Figure 2.

a) *b)* *c)* *d)*

Figure 2. The swivel brackets for industrial wheels: a) plate swivel bracket, b) bolt hole swivel bracket, c) smooth stem swivel bracket, d) threaded stem swivel bracket [5]

2. SELECTING THE RIGHT WHEEL

In order to select the most economical solution for the wheels applied on the given internal transport device, it is necessary to define the working conditions and all external influencing factors. The right wheel can be selected as the result of the analysis of the following factors:

- type and condition of the ground surface,
- working environment,
- load parameters,
- equipment speed and traction devices and
- demands on equipment manoeuvrability.

There are three phases in selection of the right wheel according to the working conditions:

- identification of the correct type of the wheel based on the floor type and working environment,
- determination of the wheel diameter by calculating the static load, the dynamic capacity and smoothness required by the specific application,
- identification of the correct bracket and verification of the dynamic capacity of the wheel and bracket set.

The type and condition of the floor and the existing obstacles must be considered while selecting the wheel appropriate for given application. These factors also influence the performance of the moving equipment and the efficiency and the life span of the wheels and brackets. In the case the wheels are moving over uneven floors or over some obstacles, the magnitude of the generated resistance forces depends on the elasticity of the wheel covering material. The wheel with the elastic covering absorbs the greater amount of energy than the wheel with the rigid covering. Given the same load capacity, the greater diameter should be chosen for the wheels surpassing the obstacles than for the wheels going over uneven floors.

For each type of the industrial wheel, the standard working conditions are prescribed. Thus, in order to select the right wheel, it is imperative to determine whether the materials used to make the wheel covering, the wheel core, the wheel bearing and the bracket meet the specific requirements of working conditions (chemical conditions, temperature, humidity, inductive phenomena). Special attention must be given to operating conditions with aggressive agents. If there are oils, fats and hydrocarbons in the operating environment of the wheels, a polyurethane wheels should be selected, while in humid environments, the stainless steel brackets should be used.

Load parameters have a great effect on wheel load capacity. The general formula for calculation of the wheel load capacity is:

$$Q = \frac{P_u + P_c}{n} \tag{1}$$

where: Q is the load capacity of each wheel, P_u is the weight that should be transported, P_c is the trolley weight and n is the number of wheels in contact with the floor.

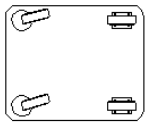
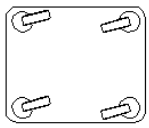
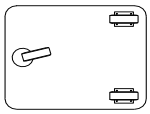
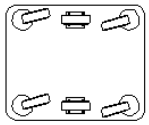
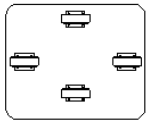
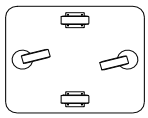
Since the industrial wheels are exposed to fatigue due to a high number of stress cycles, the wheel with appropriate dynamic load capacity can be chosen from manufacturer's catalogues.

The speed of the equipment must be taken as the factor in selecting the right wheel. If the equipment is used mainly in static conditions (speed equals zero), then the load capacity of each wheel should be compared with catalogue values of the wheel manufacturers. If the speed has non-zero values, than the used traction devices should be considered (manual or mechanical). Manual traction implies that the traction force comes from one or more persons, while mechanical traction means that there is a mechanical device (on-board drive or towing device) which exerts the traction force.

Manoeuvrability is the ability of the equipment to easily move around the limited spaces and on the difficult routes. Good manoeuvrability features of the equipment make the operator tasks easier.

The most common wheel layouts are shown in Table 1 [5].

Table 1. The most common wheel layouts [5]

DIAGRAM	CASTOR LAYOUT	OPERATING CONDITIONS	APPLICATION EXAMPLES
	*Stable trolley*: two wheels with swivel castor and two wheels with fixed castor	Long and straight routes Few direction changes	Mechanical workshops, semi-automated warehouses, metallurgical workshops.
	*Stable trolley*: four wheels with swivel castor	Short routes Frequent direction changes Approach to machines or shelves	Supermarkets, wood machining companies, small distribution centres.
	*Stable trolley*: one wheel with swivel castor and two wheels with fixed castor	Long and straight routes Few direction changes	Small trolleys Tool/object carriers Light loads
	*Tipping trolley*: two wheels with fixed castor and four wheels with swivel castor	Long routes with mechanical towing Few direction changes	Moving in railway, postal, airport areas. Heavy loads
	*Tipping trolley*: four wheels with fixed castor	Long and straight routes without direction changes	Assembly or machining lines with round trip and head transfer device
	*Tipping trolley*: two wheels with fixed castor and two wheels with swivel castor	Long routes with manual or mechanical towing Few direction changes	Mechanical and metallurgical workshops, semi-automated warehouses

Based on required load capacity and working speed and on the adopted wheel materials, the working diameter of the wheel is defined.

Potential choice of the wheel materials is listed in Figure 3.

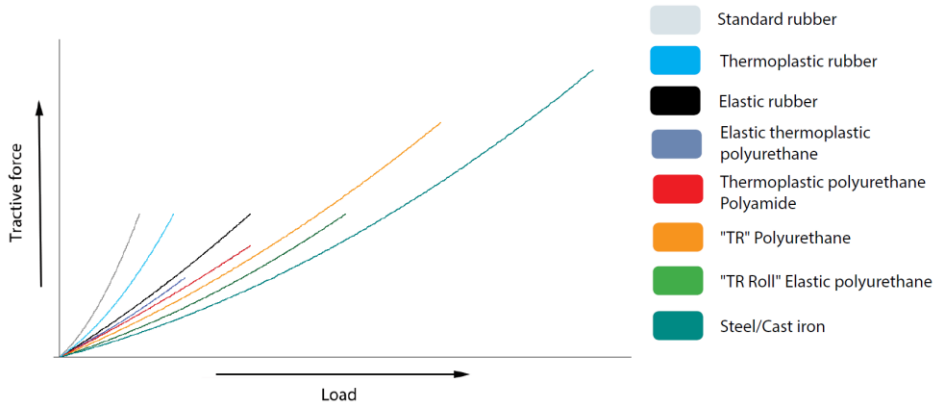


Figure 3. Comparison chart of the rolling resistance between the different wheel materials

3. THE USE OF INDUSTRIAL WHEELS AND BRACKETS IN LOGISTICS AND IN HANDLING OPERATIONS

A vast variety of material handling devices are used during production and transport processes in automotive industry. During the process of lifting and transporting the materials, different types of industrial wheels and brackets are used, as shown in Figures 4 to 6. Figure 6 also indicates the use of full automation using roller or chain conveyor.

Figure 4. Polyurethane wheels with aluminium core

Figure 5. Polyurethane wheels with cast iron core

Figure 6. Polyurethane wheels with aluminium core

Equipment for car repair shops is shown in Figure 7, while characteristic types of corresponding industrial wheels are given in Figures 8 and 9.

Figure 7. Equipment for car repair shops

Figure 8. Polyurethane wheels with aluminium core

Figure 9. Solid polyamide wheels

An integral part of automotive warehouses is a variety of equipment for moving pallets, ranging from manual devices to computer-controlled devices. The most often used devices are: wheeled forklifts, hand pallet trucks, motorized pallet trucks, conveyors and automated guided vehicles (AVGs).

The forklift trucks are devices that are used very often due to their ability to actively pick up and dispose the pallets, but also to stack the load by height, Figure 10. Their mobility is limited by the aisle widths in which they are used. Optimal aisle width should allow the forklift truck to be positioned at the right angle to the aisle. Wider aisles offer more flexibility in picking pallets and immediate loading to the trailers, which implies greater travel speeds and lower cost of operation of wide aisle trucks. However, using narrow aisles

brings greater overall storage density [6]. This means that there should be balance between wheeled truck speed of operation, proper choice of their wheels, storage density and costs.

The wheels of forklift trucks often have polyurethane tyres. These tyres act better on slippery floors and can lift up to 15% heavier loads than rubber tyres. They offer smoother ride and do not leave permanent marks on the floor. The wheels of electric pallet trucks also have polyurethane tyres that enable high speed handling [7].

Some of the wheels and rollers for pallet trucks, stackers and other forklift trucks are shown in Figure 11 to Figure 13.

Figure 10. Forklift trucks

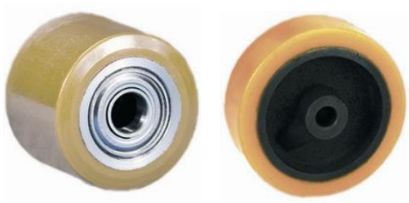


Figure 11. Polyurethane transpallet rollers with steel core

Figure 12. Polyurethane drive wheel

Figure 13. Customised solutions

The heavy duty industrial wheels are made of different materials [5]:

- polyurethane (great resistance to wear and deformations),
- elastic polyurethane (polyurethane with the ability to overcome obstacles, avoid noise, suppress vibrations),
- "Vulkollan" elastomer,
- PA6 (polyamide 6), or
- cast iron.

The wheels made of the above mentioned materials can be also used on the trolleys for the automotive industry.

The wheels of electric pallet trucks, Figures 14 and 15, also have polyurethane tyres that enable high speed handling [8]. Other used types of the wheels include: solid polyamide wheels, Figures 16 to 18, and elastic rubber wheels with aluminium core, Figure 19.

Figure 14. Hand pallet truck

Figure 15. Power pallet truck

Figure 16. Solid polyamide wheels

Figure 17. Complete solid polyamide wheels

Figure 18. Polyamide transpallet rollers

Figure 19. Elastic rubber wheels with aluminium core

Mechanical tugger train compositions are often used in automotive industry. They consist of a train truck and a number of train elements, trailers and trolleys, Figure 20. The train capacity depends on the number of coupled elements [1]. The trolleys have four swivel wheels, Figure 21. Different types of trolleys can contain different designs and dimensions of wheels, Figures 22 and 23.

The trolley and roll container systems (Figures 24 to 26) facilitate the transport of goods and are applicable in many industries and at airports, railway stations and bus stands. They are suitable for medium loads, for indoor-outdoor use and they do not leave marks on the floor.

Figure 20. Tugger trains composition

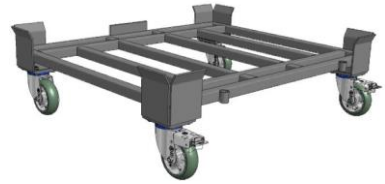


Figure 21. Trolley of mechanical tugger train

Figure 22. Injection polyurethane transpallet rollers with polyamide centre

Figure 23. Polyurethane wheels with aluminium centre

Special trolleys can contain extra heavy duty welded brackets. Characteristic wheel solutions for these systems are shown in Figures 27-32.

Figure 24. Platform trolley

Figure 25. Tool trolley

Figure 26. Roll container

Figure 27. Standard rubber wheel with pressed steel disc

Figure 28. Thermoplastic rubber wheel with polypropylene centre

Figure 29. Solid polyamide wheel

Figure 30. Polyurethane wheel with aluminium centre

Figure 31. Sigma elastic rubber wheel with polyamide centre

Figure 32. Solid red polyamide wheel

Storage and retrieval machines are a special type of cranes for working in warehouses. The main difference compared to forklift trucks is that they are not freely rotating machines, but are attached to rails on the floor or on the ceiling. They move in a straight line through the corridors between the racks, Figure 33. The wheel of these machines are mostly heavy duty industrial polyurethane wheels with cast iron core, Figure 34. Sometimes they use customized solutions for driving wheels in order to meet the required carrying capacity of the transport system, Figure 35.

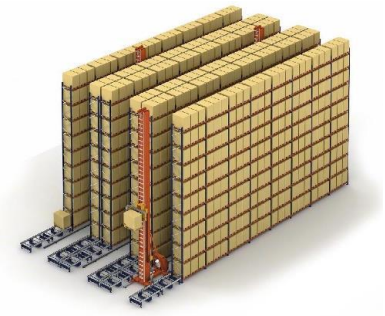


Figure 33. Storage and retrieval machines

Figure 34. High performance polyurethane drive wheels

Figure 35. Customized solutions

In order to fulfil the investor's basic request to obtain the largest possible storage capacity in the available space, i.e. to store the largest possible amount of material, storage designers must know all the possibilities of transport and handling equipment [8]. In this sense, attention must be paid to:

- type and form of the chosen transport device,
- method of control (manual or electric),
- inertial forces due to acceleration and braking (if the steering is electric),
- additional dynamic effects due to braking, accelerating or turning (if a person controls the vehicle),
- wheel diameters,
- wheel material (steel, rubber, polyurethane) and
- distribution of the load on the wheels.

4. CONCLUSIONS

Different internal transport and handling devices in automotive industry utilize a number of different types of industrial wheels. In general, the optimal choice of the wheels for internal transport devices should be based on the following criteria:

- effective use of space,
- low levels of floor damage,
- high speed of throughput,
- minimum overall system cost and
- personnel safety.

The selection of the appropriate type of wheels also depends on: type and condition of the floor, existence of obstacles, operating conditions, load parameters and equipment operating speed.

The wheels for material handling equipment should be made of high-quality materials that provide low-noise operation, very low rolling resistance, high dynamic load capacity, good floor preservation and high abrasion resistance.

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