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EVALUATION OF SUPPLIERS' QUALITY AND SIGNIFICANCE BY METHODS BASED ON WEIGHTED ORDER

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Abstract: Slovakia has become one of the leading automobile manufacturers in Central Europe, mainly due to the presence of three global automakers - Volkswagen (Bratislava), PSA Peugeot Citroën (Trnava) and Kia Motors (Žilina). There is the automotive industry necessary for the development of the Slovak economy as decisive industry. Many businesses work right for the automotive industry. A substantial part of these companies is engaged in plastic products, such as the production of large-size plastic mouldings such as dashboard, car door trim and the like. These mouldings are produced on large-size injection moulding machines, with massive injection moulds. One of the problems of these companies is the handling of these massive forms, which can weigh tens of tons. The article is devoted to the design of the transport device, which is designed for the transport of this type of moulds, which is able to easily and safely secure moulds of various dimensions and transport them from the press to the mould warehouse, or vice versa from the mould warehouse to the injection press. There is the strength calculation of the structure is solved using FEM in conclusion.

1 Introduction

The inter-operative transport and storage is one of the limiting factors for the further development of assembly processes. The automotive industry is a decisive industry and a driving force for the development of the Slovak economy [1,2]. The development of progressive technical means for realization of inter-operational transport and storage is initiated mainly by the requirements of flexibly automated production [3,4]. A quick and flexible connection of individual assembly workplaces, systems and their functions as a whole by material flow is important.

A task of means for inter-operational transport and handling is to ensure material flow between individual assembly workplaces and systems. It is necessary to ensure the material flow of all kinds of objects, tools, jigs and materials necessary for the implementation of the assembly process. The inter-operative transport is designed as an integral part of the assembly process. It is necessary to ensure system coherence between the types and types of assembly, handling and transport equipment and their technical parameters [5-9].

Transport machines and handling equipment reach through all fields of the national economy by their commitment and activity. Each production process consists of handling, transport and ancillary work because only their joint and mutual interaction produces a product. Material handling is therefore an important part of any industrial process. Evaluated economic studies show the value of each of the sub-operations and work operations that follow and follow each other. They are realized by means of transport and handling equipment. Thus, not only operations and technological, operations are important for the realization of production, but also includes an average handling cost of 10 to 30%. Modern engineering production cannot do without perfectly solved material handling as well as means of transport for transportation [10-12].

For many years, the automotive industry has been the engine of the Slovak economy and directly employs approximately 120,000 people. After counting the money spent by both companies and people involved in the production of passenger cars, the number of dependent jobs will increase to 200,000. Last year, automobile production alone accounted for up to 44 percent of the Slovak industry and exports of passenger cars accounted for 35 percent of domestic exports. For several years Slovakia has been leading the number of cars produced per thousand inhabitants [1].

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This article was created based on the requirement of a company working for the automotive industry. This company produces large-sized plastic mouldings such as dashboard, car door trim and the like. These mouldings are produced on large-size injection moulding machines, with massive injection moulds. One of the problems with this business was the handling of these massive forms, which can weigh tens of tons.

The material handling means can be divided into different aspects. In terms of the path travelled by the material being handled, these means are divided into free-moving material means, material-free moving material means and path-independent means. In terms of temporal continuity, the handling means can be divided into continuous and periodically operating means as well as cyclically operating means. In terms of the forces acting on the handling means, we can divide them into gravity, with mechanical force transfer and with transport in auxiliary medium. From the point of view of manipulated material, the manipulation means can be divided into loose materials, lump material and liquids and gases [13].

Transport trucks are the most used handling means of transport. They are used for a material transport and storage, in between object, inside object, in-process transport and in warehouses.

The article is devoted to this issue of transport equipment design which is designed for the large-size moulds transport. This device must be able to easily and safely secure the injection moulds of different dimensions and transport them from the press to the mould store or from the mould store to the injection moulding machine.

2 Characteristics and requirements given to handling equipment

The task was to design a transport device for transporting a mould from an injection moulding machine to a warehouse and vice versa from a warehouse to a press. It was an injection moulding machine of the type Engel duo 1500, with a clamping force of 1500 tons. This press can work with the largest mould size 1400 x 700 x 3750 mm, which can weigh up to 30 tons. It was therefore necessary to design a transport device, hereinafter referred to as a trolley, with a lifting capacity of 30 tonnes, with an adjustable arresting device for various mould sizes.

The transport truck design was inspired by road vehicles, namely low loaders for the transport of heavy civilian and military equipment, automatically controlled forklift trucks and construction solutions used in trucks.

The load-bearing structure shall be designed and assembled to withstand, with the appropriate degree of reliability, all the loads and influences which may be incurred during construction and operation during the proposed service life. To meet the appropriate usability requirements specified for the load-bearing structure or load-bearing element. The load-bearing structure shall be dimensioned to have adequate resistance, durability and usability [14-16].

The particular design situations shall be appropriate to the circumstances that may actually occur and where the load-bearing structure is required to perform its function. Design situations must be classified as:

- permanent design situations under which normal use is understood,
- temporary design situations, e.g. during transportation or assembly,
- extraordinary design situations, these are exceptionally the conditions to which the structure is exposed, e.g. earthquake and the like [17].

The design situations selected must be sufficiently rigorous and at the same time diverse to include all circumstances that may actually occur [18].

We know two types of limit states, namely the ultimate limit states and the serviceability limit states.

The ultimate limit state is that which is before the collapse of the structure. The load-bearing structure shall be checked for ultimate limit states where:

- loss of stability of the structure or any part thereof,
- failure of excessive deformation, transformation of the load-bearing structure or some of its parts into a movable mechanism, various types of material failure, loss of stability of the supports of the structure or foundations,
- fatigue or other time-dependent effects.

The serviceability limit state is considered to refer to the function of a given structure or load-bearing elements during normal use [19]. This includes large sags or large cracks. The verification of these limit states should be based on the following considerations:

- deformations that change the appearance of the structure or the serviceability of the structure,
- vibration which limits the fitness of the structure,
- permanent damage that may adversely affect the service life or performance of the structure.

The structure design according to limit states must be based on simulation models of structure and loads for particular limit states. It must be verified that none of the limit states is exceeded [14].

3 Design of transport equipment

3.1 Carrying steel structure

Carrying structures or transport truck frames can be welded or riveted from bent sheets or rolled steel profiles. Steel profiles are most often in the form of I, O, U, Z and the like. Some vehicle frames are made of round, square, rectangular, etc. tubes. with different wall thickness [20].

The frames are most commonly rectangular ribs, consisting of two longitudinal beams on which the crossbars are arranged. Such frames are popularly used in the production of commercial vehicles, semi-trailers,

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trailers, etc. The individual parts of the frames are joined by welding or riveting [21-24].

It often happens that over time it is necessary to modify the device lifting platform, crane, etc. In this case, the vehicle frame needs to be strengthened at specific critical points. As often as possible, different reinforcements (profiles) are welded to the most stressed places of the frame [25].

The supporting steel structure (Figure 1) of the trolley is made by welding UPE 300 steel profiles, 15 mm thick steel plate and smaller 15 mm thick steel plates. To reduce the overall height of the trolley, UPE profiles at both ends are reduced by 185 mm. The individual parts are welded with a corner weld. The bottom plates serve for holding the spring bed. The relief holes are burned in the UPE profiles. The total weight of the beam is 2.1 tons and its dimensions are 4500 x 1800 x 315 mm. The material of UPE profiles and sheets is steel S355.

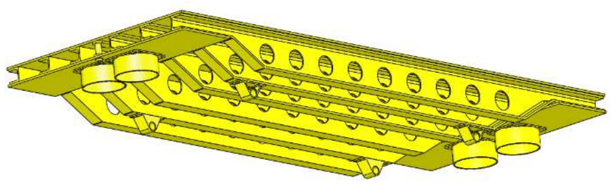

Figure 1 3D model of carrying steel structure

3.2 Front axle of transport truck

Driving the vehicle is used to maintain direction or change the direction of travel of the vehicle, if necessary. When cornering, each wheel describes a circle with a different radius but with the same centre. The correct steering geometry must be adhered to ensure safe steering of the vehicle when cornering. For geometrically correct rolling of the wheels, the extended axes of all wheel's rotation must intersect at a common point. This point is called the theoretical corner of the vehicle and, in the case of two-axle vehicles with steered front wheels, is located on the extended rear axle axis (pole line) [17, 26].

For Ackermann's regulation geometry (1), (2) (Figure 2) is given:

$$cotg\ \beta_1 = \frac{R+\frac{s}{2}}{L} \quad (1)$$

$$cotg\ \beta_2 = \frac{R-\frac{s}{2}}{L} \quad (2)$$

where: R- theoretical turning radius (m),
s – pin axis distance (m),
L – axles distance (m),
β_1, β_2 - outer and inner wheel angles (°).

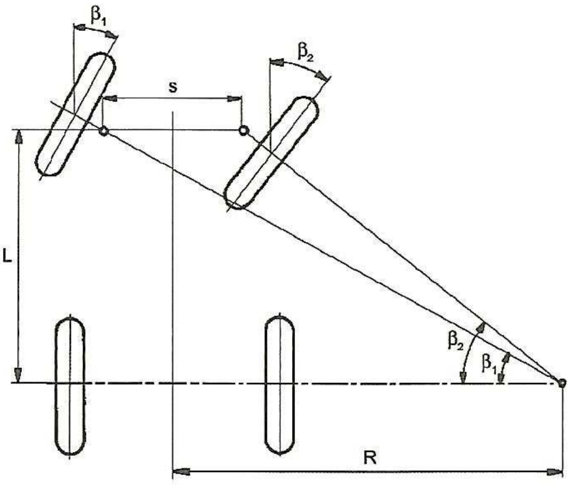

Figure 2 Theoretical car steering geometry [7]

The front axle (Figure 3) was designed as a suspended fixed axle with steered wheels and functional kinematics. The steering is provided by a trolley which is powered by the towing vehicle. The angle between the wheels at full turning is approximately 4 °, and the wheel turning radius is approximately 4.5 m (Figure 4).

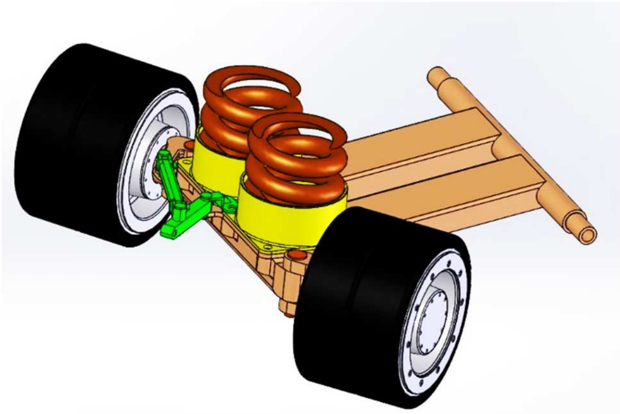

Figure 3 Front axle

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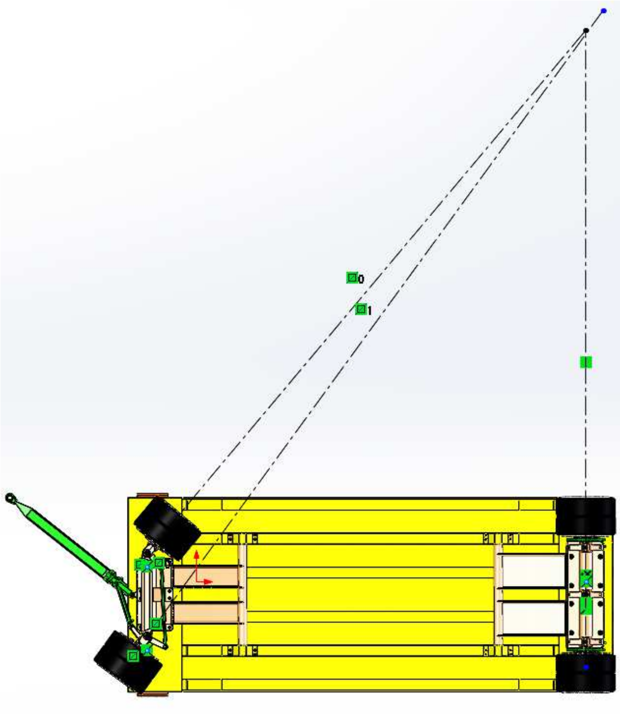

Figure 4 Axle kinematics

3.3 Rear axle of transport truck

The rear axle (Figure 5) was designed fixed with the wheels rotating. On the axle there is a directly mounted spring bed. The rear axle wheels are braked by separate track brakes.

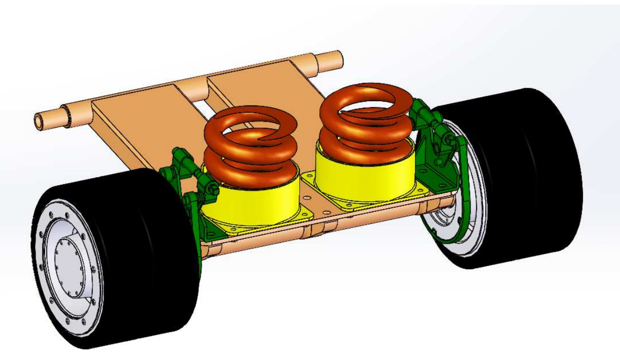

Figure 5 Rear axle

The wheel is designed as a hub on which a pair of wheeled tires is pressed. Wheel rings are designed as steel rings on which is vulcanized rubber. Each wheel is able to carry 6.4 tons, so a pair of hubs can carry 12.8 tons. The manufacturer guarantees the strength of wheels up to 6 km / h. Two sets of cylindrical roller bearings are used, the first is a pair of NJ220EDM bearings capable of absorbing radial and axial force, arranged in the "X", the second set is a pair of NU218EDM bearings that absorb only radial forces. Four bearings per wheel were used to distribute the load evenly to the pivot. The inner set of bearings is secured by KM nut and MB washer, as it is not stressed by axial force is secured by retaining rings. As a lubricant we considered a grease.

3.4 Locking fixtures

The rear locking device (Figure 6) works on the principle of a solid wall with sliding clamping lugs that slide in horizontal guides and are secured by simply tightening the screws. The jig and the jigs are welded. The rear arresting fixture is firmly screwed to the main beam.

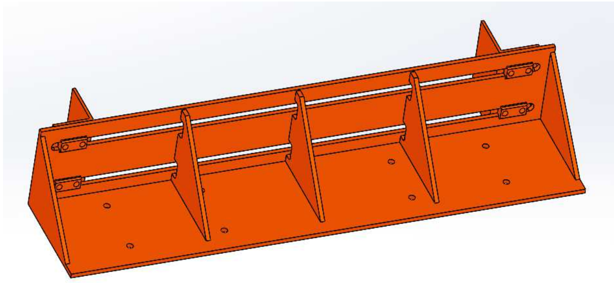

Figure 6 Rear locking device

The front locking device (Figure 7) works on the principle of a sliding wall with sliding clamps similar to the rear detent. The front jig is similar in a construction to the rear jig as it is also welded from 15mm sheets, the difference is that the front jig can be moved along the beam to transport moulds of other sizes. The front locking fixture has recesses on the lower plate to reduce sliding resistance and has a sliding guide with a lock on the sides.

Procedure for securing the mould:

1. The mould is placed on the trolley so that it touches the wall on the rear detent and so that it is approximately at the centre of the vehicle's width.
2. The side jigs of the rear jig are pushed to the mould and secured by tightening the screws.
3. The front locking fixture is pushed to the mould and its sliding lock is secured by tightening on both sides.
4. The side jigs of the front jig are pushed to the mould and secured by tightening the screws.

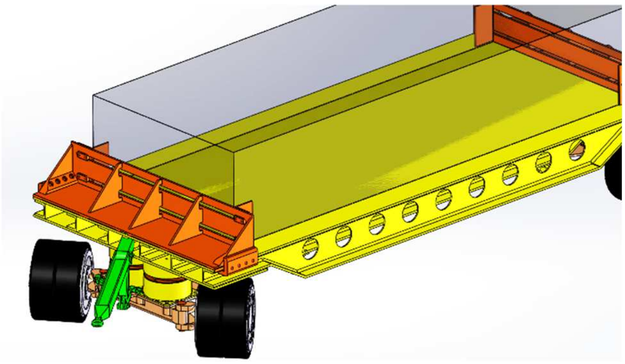

Figure 7 Front locking device

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4 Strength and design calculations of transport equipment

The main beam is loaded with a continuous load which also represents the mould. For the sake of safety, a weight of 60 tons was taken into the account into the calculations, representing a fall from zero height, which could cause a double overload.

FEM analysis has shown the beam complies with the strength. The beam material is S355 steel with a yield point Re = 355 MPa, as shown in Figure 8, at a simulated load of 60 tons, the maximum local stress levels on the beam are about 160 MPa. The peak stress of 316 MPa does not actually arise, it is given by a constraint that does not allow rotation.

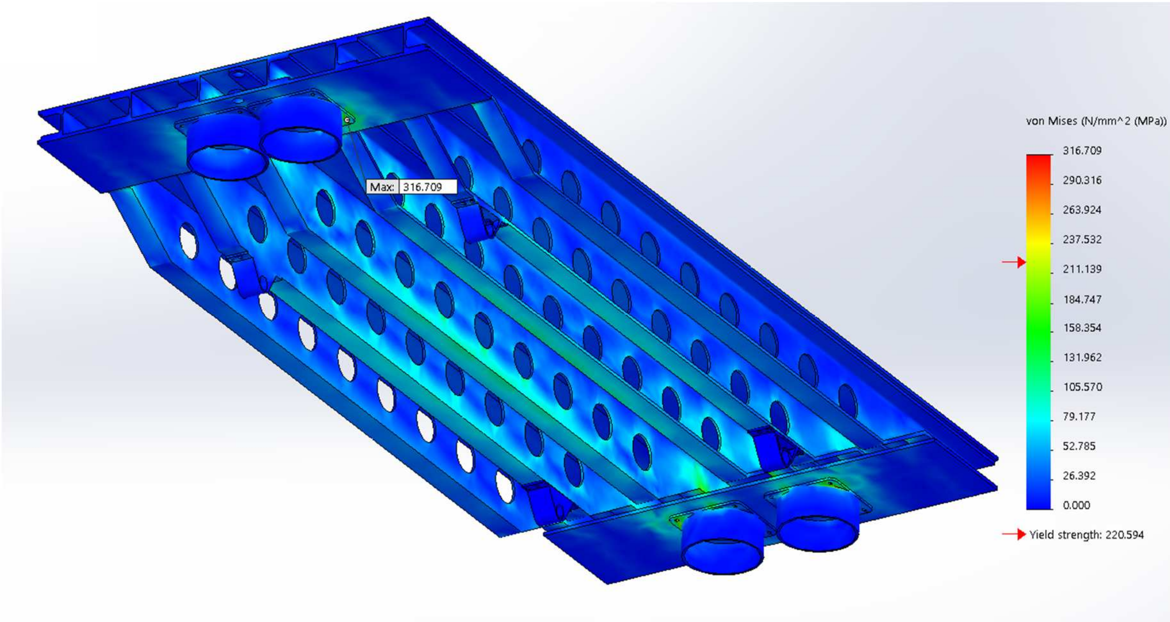

Figure 8 Results of FEM beam simulation

The simulation of the rear axle (Figure 9) represents an embedded beam, which is subjected to a force from below, it was considered an extreme case. Load per wheel of 18 tons, which incorporates double the weight of the mould and the weight of the trolley. The rear axle material is steel with a yield point Re = 850MPa.

Axle shaft complies with strength. In the extreme case, the average stress levels are about 400 MPa, the maximum 693 MPa does not actually occur, is given by the coupling. In normal operation, the values are halved.

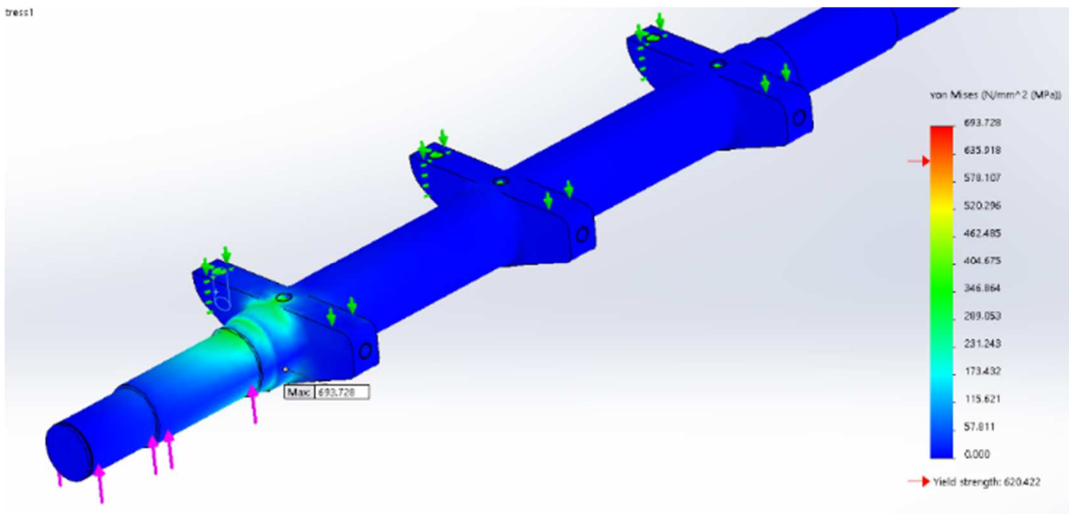

Figure 9 Rear axle beam simulation

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When simulating the front axle (Figure 10), the load is the same as the gripping method, the difference being that it consists of several parts, and the pivot pin is in the turning position, causing additional bending moment.

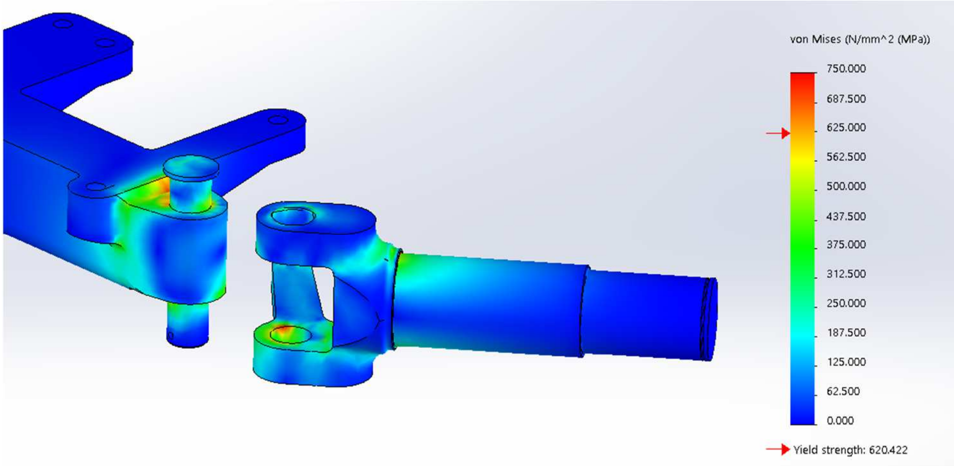

Figure 10 Front axle simulation

Parts of the front axle are strong, normal stress levels in the extreme case are around 400 MPa, the maximum of 750 MPa does not really occur, is given by the coupling. In normal operation, the values fall by half.

5 Conclusions

The task of means for inter-operational transport and handling is to ensure material flow between individual assembly workplaces and systems. An important role is played by the handling of heavy equipment, such as large-size injection moulds for the manufacture of plastic mouldings such as the dashboard, car door trim and the like.

The design of the transport equipment used to transport large-scale moulds plays an important role. The designed handling trolley is able to easily and safely secure moulds of various sizes and transport them from the press, to the mould store, or vice versa from the mould store to the injection moulding machine. The proposed load-bearing structure is sufficiently rigid, due to large bends and additional loads, and is not too heavy. Suspended rigid axles have been designed that are able to withstand double the overload of the structure without damaging them. The front axle steering has been designed according to the principle where the wheels follow Ackermann's geometry when turning. Mechanical adjustable locking of the injection mould preparation of various sizes has been proposed. The strength calculation of the designed structure was done using the finite element method.

The impact of a change in the application of the proposed transport equipment on the solution for inter-operation transport system is further research direction.

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Review process

Single-blind peer review process.

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