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Heuristic Method of Design of The Load Gripping and Manipulating Devices For Work In Special Conditions

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Abstract

The article presents the design decisions according to the new concept of the transport equipment in the course of design in the device for working in special conditions by "The principle of a spider" and "The principle of an ant". Also the direction of advanced technology of design process is discussed. Heuristic examples of search of the best technical solutions at design of load gripping and manipulating devices for work in extreme conditions are used.

The article describes "The principle of a spider" when designing load gripping devices working with the additional weight which carries out the functions of the object capture while its vertical motion. "The principle of an ant" is described schematically; however it is quite enough for its use in design work. It is expedient to apply the presented examples at design of load gripping and manipulating devices for heavy and atomic power engineering, for radioactive equipment dismantling, for work in emergency conditions such as earthquakes, fires, floods, consequences of military operations during rescue and emergency recovery operations. The presented examples show the direction which can provide inventive examples with simple and reliable engineering decisions.

Keywords: Inventive methods, load gripping and manipulating devices, the principle of a spider, the principle of an ant, extraordinary conditions, designing.

Introduction

The necessity of dismantle of hundreds of nuclear power reactors in conditions of the objects increased radioactivity [1], rescue and emergency recovery operations in case

of emergency situations such as natural disasters, earthquakes, fires, floods on land, rescue missions on and under water, consequences of military operations demand new approaches to solution of the problem of creation of the most optimal technologies to convey objects and transport equipment.

Traditionally transport systems and their elements are designed taking into account the known scientific and technical achievements having been introduced in production and tested in operation.

Imperfection of traditional engineering decisions is shown on the example of the analysis of the construction of fuel-handling machine for WWPR reactors [2].

Application of traditional design methods without using inventive approaches results to creation of complicated, massive large-size transport vehicles, and their weight increases in connection with the growth of coefficients of safety factor, stability, non-failure operation and other parameters providing systems reliability.

Work in special conditions demands highly reliable equipment.

The application of principle of simplification combined with inventive methods is considered to be a perspective direction in design of transport systems for special conditions.

The new concept of heavy and atomic power engineering [3] shows the benefits of substitution of heavy crane lifting transport equipment for the floor transportation and manipulation of the processed objects. Crane bridges are characterized by big weight owing to their operation in bending.

According to the rules in the field of materials resistance, we should use the material working for axial tension or compression. In such cases we have the minimum discharge intensity of the constructional material. The processes of tension and compression are well studied theoretically and experimentally; and factors of safety, stability and reliability are proved at rather high level.

Invention has many methods the using of which leads to non-standard and simple solutions; and the process itself is approximately estimated as the exact science [4, 5].

One of the most widespread methods is using the analogies available in wildlife.

We know “the principle of a spider” hanging on a web with high specific strength and capable to hoist the objects considerably exceeding the spider’s weight. This principle is used by fishermen. It allows catching fish weighing tens and even hundreds of kilograms by means of rods with fishing line diameter of a few millimeters.

This principle is presented by a simple scheme in Figure 1. The Scheme **a)** in Figure 1 represents the spider 3 hanging on the web 2 and interacting with the object 4 in the form of a cylinder with a vertical axis. The cylinder is installed on its end surface on the rack 1. The rack 1 is designated by hatching as it is usually accepted in the theory of mechanisms and machines. The hanging spider is an actuating mechanism. In order to move the massive object 4, it is required to strengthen the web 5, to increase the weight of the spider 6, to strengthen the gripping elements 7 interacting with the cylindrical surface of the object 8 as it is presented in figure **1 (b)**.

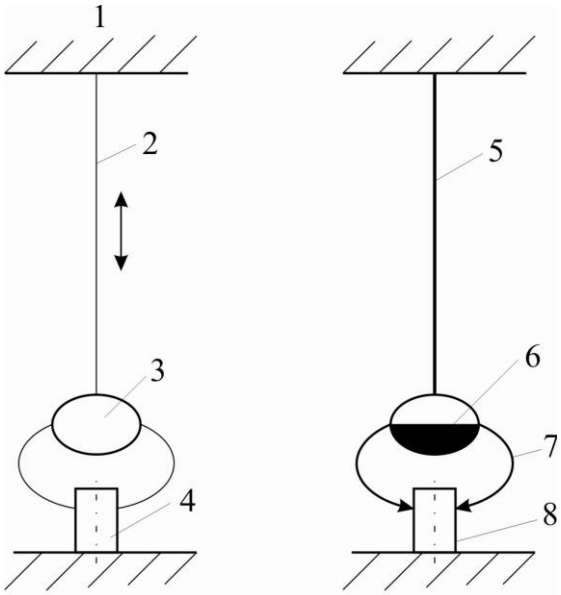

Figure 1: Scheme “the principle of a spider”

1 – rack; 2 – web; 3 – spider; 4 – object; 5 – strengthen web; 6 – “weighted” spider; 7 – strengthened gripping elements; 8 – lateral cylinder surface of the object.

The object is accepted in the form of a cylinder conditionally.

It is much more difficult to take and move this object to the required technological position than horizontally located object in the form of a bar, tube, rope [6].

The object can be of different forms and in various positions that will demand creation of special design schemes to provide the conditions of its capture, manipulation, clamp, reliable conveyance and installation to the required position. First of all it is necessary to consider the presented schemes and models.

The development of “the principle of a spider” constructive model is shown in Figure 2. The constructive model is presented schematically.

The rope hoist with the drive gear 2, the rope 3 and the pulley block 4 replaces “the principle of a spider” in the part of “web”. Functions of the "spider" body are carried out by the basic case 6, the cylinder 7 with the load additional mass **M** connected by means of the rod 5 to the lifting block 4. In the case 6 there is the key slot 9 in which the key 8 moves. The key 8 is fixed in the cylinder 7. Thus the cylinder 7 in the basic case 6 moves strictly down the vertical line without rotation about the vertical axis.

The sleeve 10 is multipurpose. Its geometrical version depends on the target function of “the spider” – a capture, turning movement, clamp, conveyance, objects manipulation depending on type of the sleeve 10 interaction with the object 12 contact surfaces: $K_т$ – end surface, $K_б$ – lateral surface, $K_о$ – surface of a hole, $K_в$ – surface of a projection.

The contact surface $K_н$ and the guiding cone 11 with the sensors of targeting and contact with the object are presented conditionally. “The spider” works due to the cylinder 7 and the load additional mass M motion down the vertical line. The features of the sleeve 10 design are not presented here since they are "know how" and in each particular case can contain the principal features of a declared invention.

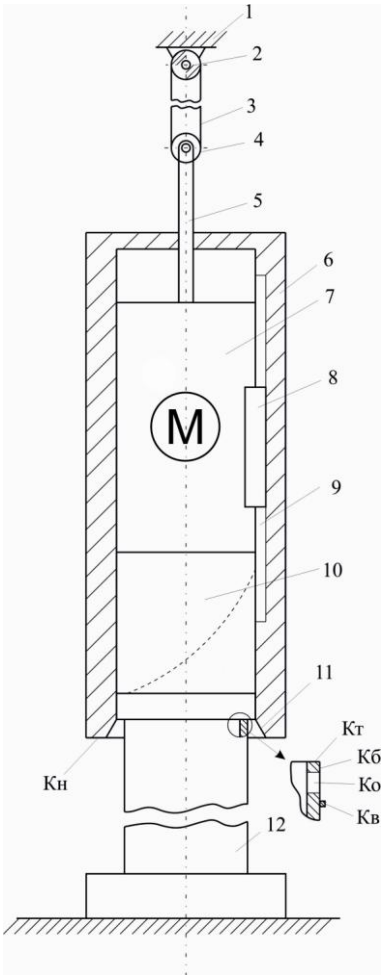

Figure 2: Constructive model of “The principle of a spider”

1 – rack; 2 – rope hoisting drive; 3 – rope; 4 – pulley block; 5 – rod; 6 – basic case; 7 – load additional mass *M*; 8 – key; 9 – key slot; 10 – sleeve; 11 – guiding cone; 12 – object; $K_т$ – object end contact surface; $K_б$ – object lateral contact surface; $K_о$ – object hole contact surface; $K_в$ – object projection contact surface; *Кн* – contact surface of the object guidance and contact. “The principle of an ant” is applicable to the process of optimization of massive large-size objects motion on a horizontal or slightly sloping surface as it is presented in Figure 3.

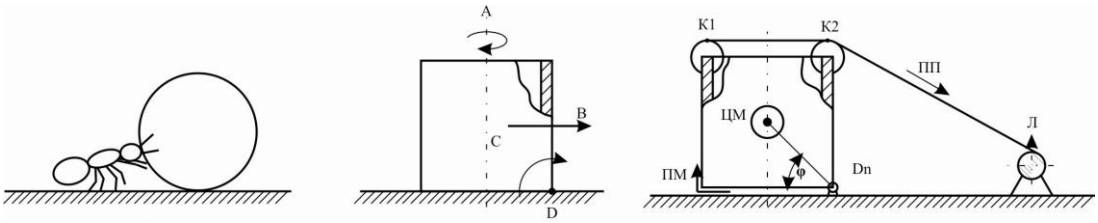

Figure 3: "The Principle of An Ant" Application Scheme

a) – the scheme of a fragment from wildlife; **b)** – large-size massive cylinder course; A, B, C – the possible directions of the object motion; C – the direction of the object rotation about the motionless point D. **c)** – initial constructive scheme: ПМ – "the principle of an ant" – the hoisting device with a hydraulic actuator; ЦМ – the object mass center; Dn – the axis of the object rotation on angle φ; K1, K2 – additional contact safety elements; Л – rope winch; ПП – rope driving direction by "the principle of a spider".

As an example we chose the object in the form of the thick-walled cylinder course because in order to change its position being "on the end" for the position "on the moving line" requires additional devices due to the fact that this process is followed by considerable dynamic change of efforts and moments, particularly in position $\varphi = 90^{\circ}$ when the application of the brake mode is required.

The above mentioned schemes and models are presented as design drawings. They are prototypes on the basis of which it is much easier to search others, most optimal design decisions.

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