
**DESIGN OF THE BULLDOZER CONSTRUCTION WHEN WORKING ON
HARD GROUNDS**

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Abstract. This article talks about the design of the construction of the bulldozer tipper when working on hard soils.

Key words: bulldozer, construction, hard soil, construction, soil, materials, energy density, technique, production, excavation.

Annotatsiya. Ushbu maqolada qattiq gruntlarda ishlashda buldozer ag`dargichni konstruksiyasini loyihalash haqida so`z yuritilgan.

Kalit so`zlar: buldozer, konstruksiya, qattiq grunt, qurilish, tuproq, materiallar, energiya zichligi, texnika, ishlab chiqarish, qazish.

Абстракт. В данной статье рассказывается об устройстве конструкции самосвала бульдозера при работе на твердых грунтах.

Ключевые слова: бульдозер, строительство, твердый грунт, строительство, грунт, материалы, энергоёмкость, техника, производство, земляные работы.

Bulldozers are the most common cyclic earth-moving machines designed for layer-by-layer development and movement of soils and materials, as well as planning work. They account for about 35...40% of the total volume of earthworks performed in construction. They are widely used in civil, industrial, transport, road, hydraulic engineering, mining, coal mining, agricultural production, and construction of oil and gas pipelines.

Improving the designs of bulldozer dump working bodies by intensifying their work processes is the most important direction for increasing the efficiency of these machines at relatively low material and financial costs. Moreover, the intensification of the working processes of bulldozers is achieved mainly by creating designs of dumps, which are mechanical systems that transmit energy through the movers of the base machines and destroy the soil using traditional methods, that is, cutting and digging. Therefore, the improvement of the designs of bulldozer blades based on the analysis of the patterns of their interaction with the soil is a priority task that helps to reduce the energy intensity of the bulldozer's working process.

General purpose bulldozers, as a rule, are equipped with fixed direct (frontal) blades (PO) as the most simple in design, reliable in operation and multifunctional for their intended purpose. At the same time, their efficiency significantly depends on the distance of soil transportation and decreases sharply with its increase due to losses in the side rollers.

Dumps with improved transport properties provide a larger drag prism and reduce soil losses during transportation.

This is achieved by giving their structures the appropriate shape in plan. Among the dumps for this purpose, hemispherical (PSO) and spherical (SO) dumps are currently most used, the dump surface of which consists of three sections: the middle one, located perpendicular to the direction of movement of the bulldozer and two extreme ones, rigidly connected to the middle one and installed at an angle of capture θ . A significant disadvantage of such structures is the sticking of the joints of sections during the development of plastic (wet clay) soils, which is accompanied by an increase in the energy intensity of the digging process.

In order to eliminate this drawback, the design of a hemispherical blade with disk sections (PSOD) is of practical interest, in which freely rotating obliquely mounted disk knives are used as extreme sections. Prototypes of such structures for bulldozers with a traction class of 30 and 100 kN, created at YaGTU and TsNIIS of the USSR Ministry of Transport, have shown their effectiveness in the development of soils of I.. II categories. However, the lack of a scientifically based method for calculating and choosing the rational parameters of a bulldozer with PSOD makes it difficult to solve design issues and determine the area of effective use of such working bodies.

A bulldozer is an industrial tractor (mainly caterpillar) equipped with a working body, usually of a moldboard type. These machines are used for excavating trenches, pits, canals with backfilling of soil into caves, erecting embankments of railways and roads, cutting slopes, backfilling cuts and trenches, perform rough site planning and loading and unloading operations [1, 2].

The scope of bulldozers, as a rule, is limited to earthworks associated with the development and movement (transportation) of soils of G.LP and partly IV categories without preliminary loosening. Soils of V.VSH categories are developed with preliminary loosening. The range of soil transportation depends on the tractive force, the mass and power of the bulldozer, the design of the blade and the type of soil being developed.

According to the nominal traction force, bulldozers are classified into: small-sized - with a traction force of up to 25 kN (weight up to 2.5 tons, power less than 45 kW); light - 25.80 kN (weighing up to 13.5 tons, power 45.120 kW); medium - 90.150 kN (weighing up to 30 tons, power 120.175 kW); heavy - 150.250 kN (weighing up to 40 tons, power 200.300 kW) and super heavy - more than 250 kN (weighing more than 40 tons, power more than 300 kW) [4].

Improving the efficiency of bulldozers is impossible without their qualitative improvement based on the widespread use of the achievements of scientific and technological progress, which is due to the general trends in the development of mechanical engineering, industrial construction technologies, fundamental sciences and computerization achievements.

- improving the reliability, technical level, competitiveness and environmental properties of machines;

- automation and robotization of machines based on the achievements of microprocessor technology and the use of computers;
- improvement of drive systems and power plants of machines due to their hydrofication and automation;
- creation and implementation of machines of increased unit capacity and productivity;
- improvement of the designs of the working bodies of machines by intensifying their working processes.

The main task of the first direction is to increase the reliability, durability, maintainability and implementation of technical service measures, which ultimately determines the competitiveness of bulldozers in the world market. The second direction is connected with the creation of automated systems that ensure the intensification of work processes, positioning of working bodies, and facilitating the work of the operator in controlling machines. An example of such systems is the space-based global positioning system GPS, which is currently used to control the operation of bulldozers and other earth-moving and leveling machines [6]. The third direction is due to the improvement of drive systems and power plants of bulldozers. For this reason, most foreign and domestic bulldozer companies equip bulldozer drives with hydrostatic and hydrodynamic gears.

However, it must be taken into account that these machines require the appropriate amount of work, and an increase in their power and mass has limits on expediency, limited by their price and transportation costs for relocating equipment from one facility to another.

In this regard, in the market of bulldozers, the price range of caterpillar bulldozers with an operating weight of 42.52 tons is from 11.4 million rubles. (DET-400, ChTZ) up to 26.97 million rubles. (D275, Komatsu), and weighing 60.70 tons - from 15.89 million rubles. (T-35.01Ya, Promtractor) up to 38.75 million rubles. (D10, Caterpillar). Therefore, the market share (in quantitative terms) for crawler bulldozers with a mass of 42.52 tons is 20%, and with a mass of 60.70 tons - 13%. Moreover, the latter are used at one facility with a constant presence of large volumes of work, for example, in the coal and mining industries.

The most demanded in construction are medium-sized bulldozers weighing 16.23 tons (the market share is about 50%). They provide high efficiency in most types of earthworks and have low transportation costs. The price range of these machines is from 3.27 million rubles. (SD16, Shantui) up to 11 million rubles. (D65 E-12, Komatsu). In this context, the improvement of the designs of bulldozer dump working bodies by intensifying their work processes is the most important direction for increasing the efficiency of these machines at relatively low material and financial costs, which is explained by their low weight and, the cost of working bodies in comparison with the mass (cost) of the machine as a whole. Overview and analysis of the designs of the working bodies of bulldozers. By design, these are working bodies of a dump-bucket type. As a rule, bulldozers are equipped with dump-type working bodies (dumps). The use of bucket-type

working bodies is limited to layer-by-layer development and transportation of light soils (sand, peat, etc.) and materials. An example of such a design is a double jaw bucket, which can operate both in the mode of a loading device and a bulldozer blade. To do this, it is equipped with front and rear jaws, hinged to each other, as well as two control hydraulic cylinders. The hind jaw is made in the form of a bulldozer blade, and the front jaw has a bottom with a cutting edge and side walls [10]. Bucket working bodies are installed on bulldozers-loaders of light and medium classes on pneumatic wheels. Bulldozer blades are classified according to their purpose, the design of the suspension mechanism and the shape (configuration) in plan. By purpose, dumps, like bulldozers, are divided into general and special purposes. General purpose dumps are used to perform the main types of earthmoving and auxiliary work in various soil and climatic conditions. Special-purpose dumps are used for the development of rocky soils, coal, peat, snow removal, garbage, wood waste, pushing scrapers. According to the design of the suspension mechanism, the dumps are made fixed and swivel in plan, as well as warped in the transverse plane.

In terms of shape, dumps are divided into straight, U-shaped, W-shaped, etc.

General purpose bulldozers, as a rule, are equipped with straight fixed (frontal) blades (PO), as the most simple in design, reliable in operation and multifunctional for their intended purpose. At such a blade, its cutting edge is perpendicular to the longitudinal axis of the base machine (tractor).

Bulldozers with rotary blades have a limited scope. They are used for development and lateral movement of soil (laying pioneer and temporary roads, cutting terraces on slopes and backfilling trenches), as well as for rough planning work. It is not recommended to use them for the development of soils with rocky inclusions. Analysis of scientific, technical and patent information in the field of bulldozer building allows us to identify three main areas for improving the design of bulldozer blades, which are due to: reducing the energy intensity of the digging process, expanding technological capabilities and improving transport properties. These trends are historically associated with the evolution of the development of the working bodies of earth-moving machines and reflect the achievements of scientific and technological progress at this stage in the development of earth-moving equipment and technologies [5, 6, 11]. The first two areas of improvement are mainly related to software design. Increasing the efficiency of bulldozer software is implemented by: optimizing their linear and angular parameters; reduction of resistance to soil cutting and movement of soil chips along the dump surface. It should be noted that the reserves for increasing the efficiency of bulldozers by optimizing the linear and angular parameters of the software have already been practically exhausted [12.15]. The reduction of resistance to cutting soil is realized in the constructions of software by adjusting the cutting angle, concentration of efforts and localization of energy on the cutting edge of such working bodies. The cutting angle is usually adjusted by tilting the blade in a longitudinal vertical plane using braces (screw or hydraulic). Blades

with adjustable angle of inclination of their cutting edge due to the complexity of the design are not widely used. The concentration of efforts on the cutting edge is achieved in the designs of dumps with: a skew mechanism; protruding middle knife; serrated cutting edge; special corner knives, as well as front and rear loosening teeth.

At present, bulldozers with a hydraulically driven blade tilt mechanism are most widely used. The tilt of the dump for such bulldozers reaches 12.18° , which makes it possible to develop up to 70% of all types of soils, including frozen ones, as well as rocks, which usually require preliminary loosening [16, 17]. The main disadvantage of such structures is the difficulty of trenching soils due to the slope of the side edge of the dump, as well as the contouring of ledges and side walls of the pits. Installing a protruding knife on the blade in its central part makes it possible to shorten the path of blade penetration into the ground, improves the conditions for the formation of a drag prism, and increases the stability of the digging process with a straight machine movement. A similar effect is achieved when using blades with a movable lower part, which provides mechanical adjustment of the degree of extension of the cutting edge of the middle knife relative to the main edge, depending on the properties of the developed soil. Forced extension of the middle part. The dump is carried out by double-acting hydraulic cylinders through a system of levers and rods. To achieve optimal digging conditions, the width of the retractable middle part of the blade should be 0.33 ... 0.5 of the width of the blade. In this case, productivity can increase by 1.2 times [7, 1]. Despite these advantages, such working bodies are not widely used due to the complexity of the design and the weakening of the central, most loaded part of the blade.

In this regard, the design of bulldozer equipment [2] is of interest, in which the blade 1 in the lower part is equipped with a rigidly fixed protruding middle knife 2, installed flush with the main knife 3. At the same time, blade 1 is pivotally mounted on push bars 4 and connected to them by means of hydraulic braces 5. This provides a change in the cutting angle of the blade part of the blade in the range of optimal values (30.55°) and simplifies the design of the mechanism for adjusting the reach of the middle knife.

Reducing the resistance to movement of soil chips along the dump surface of the working bodies of bulldozers is achieved by improving the shape of the dump surface, changing its profile, using dumps with transporting devices, as well as means that reduce friction and adhesion on dump surfaces.

The frontal surface of a traditionally designed TD has a profile built taking into account the patterns of movement of soil chips along the moldboard surface and the formation of a drawing prism. The advantages of a blade with a profile of variable curvature increasing towards the bottom were experimentally established, which can be interpreted, for example, as a section of a logarithmic spiral [1]. Currently, cylindrical dumps with a constant radius of curvature have received the

greatest use as the most technologically advanced, simple in design and efficient in various soil conditions.

The group of dumps with a variable shape of the dump surface includes two- or three-section articulated dumps, as well as dumps with a flexible frontal surface made in the form of a conveyor belt. They have the properties of adaptation (the cutting angle changes, the slope and curvature of the moldboard surface) during operation, which ensures the stable formation of a drawing prism with a decrease in soil losses during transportation to the side rollers. Studies have established a decrease in the energy intensity of digging with such dumps by 10-15% compared to traditional ones [1].

Dumps with a frontal surface made in the form of a belt conveyor consist of a carrier frame with a knife, on which rotary drums are fixed, which are bent around by a conveyor belt with its tension mechanism [2]. This makes it possible to reduce the digging resistance by replacing the friction forces of the soil sliding on the moldboard surface with the forces of rolling friction. More complex structures for the same purpose are dumps with transporting devices equipped with a belt conveyor, drive screws or rollers [3, 4]. Such dumps have not found practical application due to their large mass and complexity of design. Of practical interest are the working bodies of earth-moving machines equipped with devices that reduce friction forces and adhesion, i.e. adhesion or freezing of soil to work surfaces. With regard to bulldozer blades, this is the use of gas-air and liquid lubrication, as well as the application of hard coatings [5].

The application of solid anti-friction coatings (polymeric materials) on the surfaces of the working bodies of earth-moving machines makes it possible to reduce the adhesion forces by 1.5-3 times for wet soils of various consistency. The disadvantage of such coatings is their fragility and increased consumption in operation.

Anti-friction coatings can also be obtained by applying liquid lubricants to the surfaces of the working bodies of earth-moving machines, which can be used as: mineral oils, solutions of petroleum products, aqueous suspensions, etc. The main disadvantage of liquid lubricants is the need for their frequent renewal, which is possible only with a mechanized, fine spray.

Dozer blades with air-gas lubrication do not have this disadvantage. For such working bodies, air from the compressor is supplied to the dump surface through a system of holes above the cutting edge. Gasostatic lubrication makes it possible to reduce the soil digging resistance by 20–30% and eliminates sticking of the frontal part of the blade [5]. However, the need for a compressor hinders the use of such structures.

The expansion of the technological capabilities of bulldozers has led to the emergence of dumps that perform auxiliary work unusual for these machines, for example, clearing construction sites from debris, carrying out loading and unloading operations, etc. These dumps are equipped with cargo forks, crane

equipment and jaw grippers for various purposes. Usually they are made as additional replacement equipment for bulldozers with software.

Analysis of the majority of technical solutions for bulldozer blades that implement the first two directions for improving their designs shows that such working bodies do not find wide practical application because of their complexity, low reliability and large mass.

It should be noted that the digging process is not decisive in the working cycle of bulldozers that perform the main types of excavation work characteristic of these machines. The productivity of bulldozers with conventional design mainly depends on the distance of soil transportation and decreases sharply with its increase due to soil losses in the side rollers. At the same time, the cost-effective transportation range of software does not exceed 80 m [6].

In this regard, the most important reserve for increasing the efficiency of bulldozers is the improvement of the transporting properties (accumulative and holding) of bulldozer blades.

Bulldozer blades with improved transport properties. Dumps with improved transport properties provide a larger drag prism and reduce soil losses during transportation. An increase in the transporting (accumulative and holding) properties of such dumps is achieved by giving their structures an appropriate shape in plan, as well as increasing their size (for example, PO stackers for peat and other light bulk materials).

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