A method for constructing standard-size series of quick couplers

E V Duganova¹ *, N S Sevryugina² and P D Kapyrin²

¹Belgorod State Technological University, Belgorod, str. Kostukova, 46, Russia
²Moscow state university of civil engineering, Moscow, Yaroslavskoye shosse, 26, Russia
*E-mail: crumb1202@mail.ru

Abstract. The article analyzes the effectiveness of the use of multifunctional machines when performing work in the field of urban planning and environmental design. It has been established that unification ensures a reduction in the cost of equipment operation and allows to increase the rationality of using the working bodies according to their functional characteristics. The authors evaluated the typical nomenclature rows of quick couplers. It has been revealed that the variety of quick couplers offered by manufacturers does not allow to determine a common design feature, and to use it for unification for various classes of machines. In this regard, the authors take its weight to the mass of the base machine during the unification of standard-size series, as a main parameter. The paper develops a technique for unification of quick couplers. Then, the authors modify the mathematical model for estimating the cost of standard sizes of quick couplers according to the exponents and proportionality coefficients. They propose a parametric unification for 14 rows of the main parameter of the quick coupler. Finally, the paper develops a model for estimating the range of parametric applicability of various quick coupler constructions.

1. Introduction

The constructive diversity of special machines is functionally justified by technological processes that should be performed with the least expenditure of both material and time resources. [1-4] At the same time, operations for performing works in the field of urban planning for landscaping are typical processes, which can be improved by creation of a new technique, new working bodies or modernization of existing ones [5-7]. The unification process allows to solve the problem of minimizing the costs of technological equipment by establishing a rational range of components of the machine, criterionally and functionally identical in the given parameters.

The typical hierarchical structure of the basic machine with different nomenclature of working bodies allows to set the level of unification of structural elements:

\[ K_{y3} = \frac{Q_{y3}}{Q_3}, \]  

(1)
where $Q_{u,3}$ – number of unified construction elements;
$Q_{3}$ – number of standard sizes of construction elements.

The tendency of design development for machines ensuring technological processes in the sphere of urban planning and environmental engineering follows the path of model assembly, which also requires the expansion of the nomenclature of unified elements. To reduce the cost of machines production we should assess the prefabrication, which is quantified as:

$$K_{c6} = \frac{U}{U + D},$$

(2)

where $U$ – the number of assembly units in the machine design;
$D$ – the number of details that make up the nodes and assembly units.

The task of unification, which is being solved at the design stage, emphasizes the shift of attention to increasing the functionality of machines by applying unified structural elements in the design of working equipment, i.e. the use of quick couplers as an additional element in the structure of the working equipment. [9-10].

Quick couplers are universal devices that allow to modernize machines on a functional basis, transferring them to the multifunctional category according to the working bodies used. Development of standard-size series for quick couplers will ensure the creation of techno-economically optimal nomenclature, built on the basis of parametric series of the main parameter.

2. Analysis of quick couplers design

Quick couplers have found wide application in various fields and in particular in the field of urban planning and environmental engineering.

According to their purpose, quick couplers provide a quick change of working equipment without the involvement of additional working personnel.

The key element of the design is the mechanism for gripping the working body and the method of its fixation for reliable operation of the joint.

For example, Wedgelock Equipment Ltd offers a reduced weight design that is reliable and controlled both hydraulically and manually. To increase the nomenclature, quick couplers are available with various types of fastening finger centers, with elements of safe lifting of loads. Bob-tach offers a frame design that provides automatic gripping of attachments.

The design of quick couplers can be divided according to the method of attachment: using holes, hooks, or a combination of them; and type of connection: with manual, semi-automatic and automatic.

The analysis showed that the variety of quick couplers proposed by the manufacturers does not allow to determine the general design feature, and to use it as unified for various classes of machines [8-11].

3. Development of methods for unification of quick couplers

The stages of work on the unification of quick couplers for machines operated in the field of urban planning and environmental engineering include an analysis of standard-sized series of designs from world manufacturers.

Using the method of vertical unification, we set the main and basic parameters of the unification of the quick coupler. For quick couplers, the main parameter is the indicator of the ratio of quick couplers weight relative to the mass of the base machine. The rationale for this decision is the significance of this parameter, since it determines the overall size of the quick couplers, affects the stability of a multifunctional machine, has the stability of a physical value and is technologically linked to other key parameters and economic indicators of the quick couplers.

This main parameter does not depend on the pre-operational stages of the life cycle of the quick coupler.
The main parameters also include the geometric characteristics: the axial distance of the connecting dimensions and the specific permissible load perceived from the elements of the working equipment and the working body.

4. Modeling
The basic qualifying attribute of the methods for constructing standard series is the nature of the comparison of series and the type of modal analysis. There are elementary, classical and non-classical methods for constructing standard-size series.

After the performed analysis, we choose the method of complete sequential search through the series as a whole as the most applicable for constructing a parametric series of quick couplers. The search for the optimal series is carried out by comparing the total costs of implementing the life cycle stages on an annualized basis according to the output programs of all the members of three adjacent rows constructed by the series of preferred numbers R10 - R20 - R40.

Evaluation of the constructive diversity of quick couplers types produced in different countries confirmed the need to develop methods of unification, because the manufacturers indicate that the shape of the part does not correspond to the form adopted for unification [9-10].

The evaluation of the functional efficiency of quick-coupler resulted in the widespread use of hydraulic quick-coupler with two hooks, providing automatic connection with the working body. The classic design is with the mounting and non-mounting plates, which share the range of application of the working body of the base machine.

For the compilation of the unification model, we adopted design parameters for quick couplers of both versions.
We propose to use the method of limited unification and optimization of the standard nomenclature of quick couplers.

The calculation of the cost of standard sizes of quick couplers \( C_i \) is carried out on the basis of regression processing of the database of standard-sized quick couplers series with the definition of the exponent and the proportionality coefficient:

\[
C_i = K_i A_i^x V_i^y \left( \frac{1}{R} \right)^w P^n N_i^m ,
\]

where \( K_i \) – coefficient of proportionality, takes into account the type of a detail and design implementation;

\( A_i \) – the main parameter;

\( R \) – geometric characteristic of the mount, as the main parameter;

\( V \) – axial parameters of quick coupler according to the characteristic of stability of base model;

\( P \) – metal intensity of quick coupler, in monetary equivalent to metal intensity of base model;

\( N_i \) – the annual program for the release / modernization of quick couplers;

\( u, v, w, x, n \) - the exponents calculated by the method of regression analysis of the corresponding initial statistical aggregates.

The modal analysis with a number of transformations made it possible to obtain a logarithmically linear model of relation of influence parameters:

\[
\log C_i = \log K_i + u \log A_i + v \log V + w \left( \frac{1}{R} \right) + x \log P + n \log N_i ,
\]

As mass and geometric characteristics of quick couplers parameters are set as key, then to determine the cost of metal quick coupler it is necessary to take into account, along with the value of the main parameter, the value of the axial connecting size.

Analyzing the method of the quick coupler installation, we found a multiplicative effect of the dependence of the main parameter — mass on the parameters of height, width and length of the quick coupler as a whole, geometry of connecting elements and stability of the base machine, etc. Accordingly, in order for the ratio \( \frac{m^u_{q-k}}{m^m} \) to be within the recommended limits, it is required to set the value of the axial mounting dimensions \( b \).

In this case, the mathematical model (3) will have a modified form:

\[
C_i' = K \cdot \left( \frac{m^u_{q-k}}{m^m} \right) \cdot b^v \cdot \left( \frac{1}{R} \right)^w \cdot P^n \cdot N_i^m ,
\]

where \( \frac{m^u_{q-k}}{m^m} \) – the transformed expression of the main parameter, with known values of the masses;

\( b \) – cross-axle mounting dimensions of quick coupler providing stability of the base model.

Analysis of the applicability data provides a reduction of the range of sizes for each of the selected types of quick couplers by a combination of the main parameters of the quick coupler and the base machine, i.e. their masses.

Solving the production problems of manufacturing quick couplers, one should take into account the costs of service life according to the annual production programs of each of the selected basic i-th sizes, counting changes in the cost of individual structural elements, costs of technical re-equipment and technological reconstruction [12-13].
As shown above, the modification of mathematical models makes it possible to transfer the unification problem to the level of a multi-criteria solution of the problem, combining and simultaneously optimizing the initial series of sets of specific numerical values of the main parameters of the details [14-15].

5. Parametric unification

Analysis of the design characteristics of quick couplers from different manufacturers allowed us to establish the quantitative ratio of the values of the main parameter. We distinguish 14 rows of the rational range of the unification of the main parameter from 160 to 1000 kg.

We built a histogram of the field of application of quick couplers on the base model based on the main parameter.

![Figure 2](image)

**Figure 2.** The area of combination of quick couplers’ main parameters used with machines of urban planning and environmental management with the rationing of the main parameter of quick coupler according to the maximum (2) and minimum (1) values within the limits of the tolerance region.

The infogram shows that 90% of the rows have the structure of regular geometric progressions (stepped geometric rows with thickening to a larger parameter value), and 10% - the structure of “irregular” stepped geometric progressions.

Taking into account the step view of the row - the first three mass numbers in the R10 row, and the rest in the R20 row, the optimal standard-sized quick coupler row is set according to the main parameter, with the following mass numbers: 160/180/200/250/280/320 / 360/400/450/500/560/630/710/800.
6. The practice of assessing parametric applicability of quick couplers

The compilation of a table of optimal standard-sized rows of quick couplers is carried out taking into account the adopted limitations in the standard-sized series of all values of the optimized row of the main parameters and the unification range.

As a result, a model was obtained for estimating the range of parametric applicability of various designs of quick couplers, taking into account the consistency of the values of the main and basic parameters (Table 1).

Table 1. The range of applicability of quick couplers on the level of consistency of the values of the main and basic parameters.

| Main parameter | Basic parameters |
|----------------|------------------|
| Mass of quick coupler, kg | Mass of base machine, tons |
| Geometry of connection, mm | Length, mm |
| Height, mm |
| 160 | 3-5 | 230 - 320 | 960 | 480 |
| 200 | 5-7 | 270 - 350 | 1000 | 490 |
| 250 | 7-9 | 290 - 380 | 1030 | 500 |
| 280 | 9-12 | 320 - 430 | 1050 | 510 |
| 320 | 12-16 | 340 - 450 | 1070 | 530 |
| 360 | 16-19 | 370 - 480 | 1100 | 550 |
| 400 | 19-25 | 400 - 500 | 1130 | 570 |
| 450 | 25-30 | 430 - 540 | 1150 | 590 |
| 500 | 30-35 | 460 - 570 | 1170 | 620 |
| 560 | 35-40 | 500 - 620 | 1200 | 640 |
| 630 | 40-45 | 550 - 670 | 1230 | 650 |
| 710 | 45-50 | 590 - 750 | 1250 | 660 |
| 800 | 50-55 | 600 - 780 | 1270 | 665 |

7. Conclusion

We analyzed the quick couplers types for constructive and functional diversity;

We compiled the methodology for developing the standard series of quick couplers;

The main parameter is justified as the ratio of the weight of the quick coupler to the weight of the base machine, and the basic parameters are the geometric characteristics of the connecting elements of the quick couplers as with the working equipment and the working body;

We introduced a modified model for calculating the cost of a quick coupler, taking into account the main and main parameters;

We got an optimal number of quick coupler with mass values: 160/180/200 / for the R10 series and 250/280/320/360/400/450/500/560/630/710/800 for the R20 series.

We developed a model for estimating the range of parametric applicability of various quick coupler designs, taking into account the consistency of the values of the main and basic parameters.

8. Discussion

The practice of applying basic methods of maintaining the functionality of machines throughout the entire operational period shows their temporal limitations due to rapid obsolescence. Scientific and technical support allows us to quickly make adjustments to the basic techniques, taking into account innovative trends in the development of both the mechanical component of the structure and the drive elements: electrical, hydraulic, and digital control systems, in particular, the possibility of flexible adjustment of the standard-size rows of machine components unification, reducing operating costs and increasing functionality [14-18].
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