Unification of assemblies and units of sophistic technical complexes and systems

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Abstract. Unification means homogeneity based on a rational reduction in the number of types, types, and dimensions of products) of the same functional purpose. In the standards, standardisation is reflected in the size series, from which the main technical characteristics and rational parameters are derived. In the existing literature, there are different interpretations of the concept of unification of machines, products, parts; the available formulations are not contradictory, but are not exhaustive, as they do not cover the full range of tasks solved by unification. A prerequisite for unification is the development and approval of a prospective series of types and dimensions of products of similar purpose. The prospective size range of similar products should be considered approved only if it is included in the current standard.

1 Introduction

The basic unit in characterising the unification of machines and equipment is considered to be a part. Parts can be subdivided into unified, standardized, borrowed, purchased and original. Assuming that unification means development and approval of a long-term dimension range of products for the same purpose, a unified part is a part that is identical in its basic and connection parameters to the current dimension range and is used in two or more different machines or assemblies [1].

In the tasks of designing new vehicles and upgrading existing vehicles, mathematical models are needed to reflect the main properties of the vehicle and to predict the response and behaviour of the vehicle to environmental influences and impacts from the driver. In-depth theoretical research is important in order to adjust vehicle design at all stages of design and refinement and to make the necessary changes to the adopted technical solutions. When creating a mathematical simulation model of wheeled vehicle motion, the most important task is to reliably describe the physics of the interaction of a pneumatic tyre with the supporting surface to determine the forces acting in the contact patch. So, it is easy to see that even to create a mathematical model we need an understanding of the standard details that are used everywhere in design. Particularly when manufacturing or modernising series production machines.

Let's look at degrees of standardisation in more detail.

Standardised parts - parts for which the main and connecting parameters are defined in industry standards.

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Original parts - parts designed and applied to one specific product.

Borrowed parts - parts designed and applied initially as original parts for one specific application and then used in two or more products.

Purchased parts - parts that are manufactured by third parties and purchased to be fitted to production samples [2].

An assembly is considered standardised if it is used in two or more different machines. Depending on the ratio of standardised, borrowed, purchased and original parts in an assembly, it will be fully or partially standardised. A fully standardised sub-assembly must consist entirely of standardised parts and be identical to the current size range in terms of its basic and connection parameters.

A machine is considered standardised if it is constructed using standardised sub-assemblies, and the standardisation can be full or partial.

Thus, in order to implement harmonisation, the principles of interchangeability must be strictly adhered to [3].

2 Methodology for unification and interchangeability

Interchangeability is the property of a part to fit into an assembly without additional mechanical or manual work on it during assembly and to fulfil its function without violating the specified technical requirements for the operation of the assembly (machine, mechanism or appliance).

Interchangeability can be complete and incomplete. Full interchangeability is achieved by performing geometric, mechanical, physical and other parameters of parts with accuracy that allows the assembly (or replacement during repair) of any mating parts and assemblies without additional machining, selection or regulation while ensuring the required assembly accuracy and machine performance within specified limits. Incomplete interchangeability is characterised by the use of group selections, compensators or adjustments [4].

Interchangeability of parts, units and mechanisms makes it possible to organise the supply of spare parts, to facilitate repairs, especially in difficult conditions, reducing them to simple replacement of worn parts. Interchangeability underlies all the most important principles and forms of modern production organisation and is ensured by a set of organisational and technical measures covering design, manufacturing and control. Standardisation is the basis for interchangeability in the modern scale and principles of industrial production organisation. The terms base model and modification are often used when carrying out a set of works on unification [5].

A base model is understood to be an assembly (or machine) which is taken as the basic type representative of a range of products of similar application and on which the development of the entire range is based [1].

A modification is a variation of the basic model that is unified with it and differs from the latter in some non-core parameters [6].

Unified series is a set of products of the same or different functional and operational purpose on the basis of constructive commonality of their units and parts. It should be noted that in some cases the term "gamma", "family", etc. is used instead of the term "unified series", but the term "unified series" is more general and comprehensive.

Unification in mechanical engineering falls into the following four main categories, depending on the scope of coverage: 1) inter-agency, 2) multi-industry, 3) industry (departmental), 4) factory.

Harmonisation works carried out jointly by several agencies are categorised as inter-agency [7].

Multi-branch unification is one of the forms of unification works, providing the possibility to use the product of one standard size in the products manufactured by several industries. An example of multi-branch unification is the use of YaMZ diesel engine produced by Yaroslavl Motor Plant in products of different industries.

Sectoral standardisation involves a set of unified activities carried out on the scale of a single industry.

Factory homogenisation involves a set of initiative activities carried out on an individual plant scale

[8].

Unification work can be carried out in two ways: partial and complete (comprehensive).

The partial unification method is appropriate for products in production. However, the resolution of the unification issue through the use of the partial unification method is a half-measure and can by no means constitute a radical solution to the issue.

A radical solution to the unification problem can only be implemented in case of full (comprehensive) unification, based on the creation of specialized production of unified parts, produced in the required volume in accordance with the previously developed standard series of unified assemblies and parts of similar application [9].

Only full unification based on the use of parts and assemblies produced by a specialized production in accordance with previously developed and approved dimensional series, can fully solve the pressing issues of unification of parts, assemblies and machinery. The method of full (complex) unification is necessary to be widely used for the newly created products, which are prepared to put into production, because this method is based on a preliminary development of standard series of products of similar purpose.

Standardisation, irrespective of the methodological approach and the scope of the work carried out, is divided into the following four areas: 1) dimensional, 2) type, 3) standard, 4) modification.

Dimensional unification - unification between products of the same type with different basic or connection parameters.

If, for example, a product of type "X" produced by industry or to be put into production originally had "n" variations in the main or connecting dimensions, and as a result of unification this number has been reduced to "n-k", then in this case work has been done in the direction of dimensional unification [10].

Dimensional unification therefore involves a rational reduction in the dimensional parameters of products of the same type and function.

Standardisation - the unification of products with similar values of the main parameters, but which differ in their design.

If, for example, product "Y" produced by industry or to be launched initially had "m" type representatives with equal values of the main parameters, and as a result of unification the number of types was reduced to "m-p", in this case work has been done in the direction of type unification [11].

Thus, standardised unification involves a rational reduction of product types with a similar functional purpose.

Dimensional unification - unification of products of similar functional purpose, which do not have structural similarity and differ in dimensions of main parameters, i.e. dimensional unification combines both dimensional and type unification works simultaneously,

If, for example, "Z", which has "n" varieties of basic parameters and "m" design variants, is reduced in nomenclature to "n-k" varieties of basic parameters and "m-p" design variants after unification, then this is the direction of dimensional unification [12].

Modification unification is the unification between a basic model and the structural modifications made on the basis of this basic model. This is the most common for machine-building plants,

Depending on the nature of the objects under study, the work carried out on unification can be classified into four divisions: 1) finished parts; 2) assemblies; 3) machines; 4) technological.

Thus, sub-assembly unification is inextricably linked to work aimed at rationally reducing the range of parts in production and operation, while sub-assembly and machine unification of assemblies and mania, respectively.

Technological unification is related to works aimed at rational reduction of the existing standard technological processes, nomenclature of applied materials, semi-finished products, equipment and tools in production and operation [13].

Due to the fact that standardised systems of wheeled vehicles in most cases comprise units and assemblies which have no structural similarity and differ in their basic parameters, it is advisable to firstly consider standardisation in more detail among all the areas of standardisation.

The work involved in the standardisation of wheeled machine units at any level (local, branch or

inter-branch), irrespective of the method (partial or complete standardisation), comprises the following steps:

1. analysis of parts, sub-assemblies and assemblies of unified systems used. This analysis provides for:

a) Review and study of structural, structural, kinematic diagrams of assemblies and units.

b) Classification of component assemblies, sub-assemblies and system components according to functional, design and technological features.

c) Identification of signs of functional, structural and technological similarity of parts, sub-assemblies and assemblies of systems.

d) Selection of the most technically advanced units and assemblies in terms of performance.

e) Feasibility studies for borrowing parts, units and assemblies [14].

If similarity in geometry and relative location of parts and similarity in their kinematic connections are found in units and assemblies of compared systems of wheeled machines, the question of expediency of use of parts, units and assemblies of different systems of wheeled machines is finally decided after economic analysis. Unified in accordance with the considered direction nodes and units can be used on wheeled machines of various functional purposes, including considered two-link wheeled trains.

2. Establishment of optimum dimensioning and development of parametric standards for parts, sub-assemblies and assemblies.

The unification of components within a two-link wheeled train system must first and foremost be in the dimensional direction (dimensional unification). This will ensure that interchangeable components and assemblies can be used on the tractor and trailed unit [15].

The various industries use various indicators to determine the effectiveness of the standardisation work carried out, which characterise the degree of standardisation of the products being produced and those being prepared for production. These indicators include the following:

1) Unification factor by number of parts (K_{sp})

$$K_{sp} = \frac{\sum sp}{\sum p} \quad (1)$$

where $\sum sp$- the number of standardised parts in the product; $\sum p$- total number of parts in the product.

2) Unification factor by weight (K_{unif})

$$K_{unif} = \frac{\sum unif}{\sum w} \quad (2)$$

$\sum unif$- unit weight; $\sum w$- dry, total product weight.

3) Unification factor by weight (K_{ut}) [6].

$$K_{ut} = \frac{\sum ut}{\sum t} \quad (3)$$

$\sum ut$ - labour input for the production of standardised parts; $\sum t$ - total labour input into the manufacture of the product. The term 'standardised parts' here refers to standardised, borrowed and purchased parts.

$$\sum sp = \sum st + \sum pr + \sum pd \quad \text{st-} \quad (4)$$

$\sum st$ - the number of standardised parts in the product; $\sum pr$- the number of borrowed parts in the product;

$\sum pr$ number of purchased parts in the product.

But, at the same time, the traditional way of accounting for uncertainty based on probabilistic and statistical modelling is often inadequate to the task at hand and can lead to incorrect results, since the functioning of complex organisational and technical systems is in practice characterised by uncertainties of various types [16-33].

3 Conclusion

Thus, substituting the equation (4) into (1) gives

$$K_{sp} = \frac{\sum_{st} + \sum_{pr}}{\sum_{p}} \quad (5)$$

Similarly, by substituting equation (4) into (2) and (3), we obtain the final formulas for determining the unification factor for weight and labour intensity, respectively. However, any of the above formulas gives a one-sided characteristic of the degree of unification of the product, which is their significant disadvantage. A more complete characteristic of the degree of unification of the product can be given by replacing all of the above indicators with one general complex indicator, which would reflect the characteristic aspects of the unification of this product. Such a complex coefficient of the degree of unification K_u can be represented as follows:

$$K_u = \frac{\sum_{unif} C_{unif} + \sum_{ut} h}{\sum_{w} C_w + \sum_{t} h}$$

where C_{unif} – the average cost per unit weight of standardised parts in a product; C_w the average unit cost of the total weight of the product; h - average cost per man-hour.

Thus K is the ratio of part of the production costs of producing uniform parts to the production costs of producing the whole product.

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