CONTROL OF UNIFICATION LEVEL IN DESIGNING AN APPARATUS

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Abstract

The paper describes the effect of unification in the process of the designing. The cost calculations and the definition of unification effect makes possible the judgement of the technological and economical solution. The paper gives an example to the reduction of expenses, demonstrating the recommended process expressively.

The general aim of standardization lies in the limitation and reduction of irrational variety [1]. The reduction of elements' variety in relation to the variety of systems produced from them is called unification. Some authors use the terms standardization [1] or simplification [2] in the same sense.

Thus, a unified element is an object used in several different systems. For example, one and the same unified detail can be found in several different products. Unification makes possible, by production specialization, to get a substantial economic effect [3]. In case of the unification level's growth, production becomes cheaper. In order to purposefully make use of unification in designing (i.e. using unified details and products), it should be possible to evaluate the above mentioned effect exactly. Evaluation is made more difficult by the fact that a unified element as a universal one, i.e. being used in several different situations, is always technically a little more complicated than the corresponding original element, i.e., the element, which has been specially designed for one kind of utilization. Generally speaking, a unified element often comprises certain superfluity [4] that diminishes the available unification effect.

Below the methods are described that make possible, when designing a product, to evaluate unification's expediency in figures, proceeding from its economic effect and considering the complexity of a unified element.

Fractional cost saving, depending on variety reduction, has been throughly analyzed by Prof. Siro Matuura [2]. Having generalized the corresponding bibliography data concerning car and shipping industry in the USA, car industry in Great Britain [5] and the Soviet Union's industry [6, 7], he gives the following dependence

$$\frac{C_x}{C_1} = \left(\frac{P_1}{P_x}\right)^{-z},$$

where C_x is unit cost after variety reduction
C_1 is unit cost before variety reduction
P_1 is variety reduction ratio
P_x
z — exponent whose value is within the limits of 0.25—0.3.

As in the case of variety reduction, e.g., when limiting the products' nomenclature, i.e., when unifying the products, the single type's production volume is inversely proportional to the number of products' different types, as to unchangeable general production volume i.e., $\frac{P_1}{P_x}=\frac{R_x}{R_1}$ so we can write the above mentioned dependence in the following form

$$\frac{C_x}{C_1} = \left(\frac{R_x}{R_1}\right)^{-z} \tag{1}$$

where C_x is the unit cost after unification,
C_1 is the unit cost before unification,
R_x is the unified product's output volume,
and R_1 is the output volume of original products. If we mark

$$\frac{C_x}{C_1} = y \tag{2}$$

and

$$\frac{R_x}{R_1} = x \tag{3}$$

the expression (1) takes the following form

$$y = x^{-z}. \tag{4}$$

When $R_1=1$, the corresponding C_1 is the unit cost, in case we make only one product. Let us call C_1 the product's *complexity evaluation*, for it depends only on the product's technical complexity (material, configuration, dimensions, accuracy, surface roughness, etc.)

It follows from the expression (3) that $R_x=R_1 \cdot x$ and when $R_1=1$, $x=R_x$, i.e., we can regard the argument x in the expression (4) as the products' manufacturing volume or *seriality*. Usually, when we characterize seriality in figures, we consider annual output volume. The dependence (4) can now be interpreted as *seriality law*, which determines *cost saving factor* y, depending on the product's seriality.

From the expression (2) we can write 3 formula for calculating the unit cost, depending on the product's seriality and technical complexity

$$C_x = C_1 \cdot y. \tag{5}$$

Making use of unified elements (details, assembly), in essence, we increase the seriality of product's elements, when designing a product. The formula (5) enables us to calculate the unit cost's change at the same time, taking into account the element's technical complexity through C_1.

The unified element's characteristic criterion

$$x_y > x_{or}$$

proceeds from its quality of being applied in several different systems.

The unified element's output volume called the *general quantity* and marked as x_y, is always greater than the need for this element in the given system called the system's *own quantity* and marked by x_{or}.

Cost reduction S, gained by unification, is the unit cost difference, (formula (5)) if the cost saving factor y (formula (4)) has been calculated according to its own quantity x_{or} and general quantity x_y.

$$S = C_{or} - C_y \tag{6}$$

where

$$C_{or} = C_1 \cdot y(x_{or})$$

$$C_y = C_1 \cdot y(x_y).$$

If the system has n unified elements, where each of them can appear a times in the system, then

$$S_\Sigma = \sum_{i=1}^{n} a^i (C_{or}^i - C_y^i) \tag{7}$$

where $i = 1, 2, 3, \ldots, n$.

It is expedient to characterize the unification level by the *unification effect* $\ni_y$ [3], which shows the reduction of manufacturing expenses in percentage when using unified elements, as compared to the system containing only original elements.

$$\ni_y = \frac{S_\Sigma}{\sum_{i=1}^{m} a^i C_{or}^i} \cdot 100\% \tag{8}$$

where $i = 1, 2, 3, \ldots, n$ unified elements

$i = n+1,\ n+2,\ n+3,\ \ldots,\ m$ original elements.

Parameter's $\ni_y$ integral nature allows, to characterize not only every system's or final product s unification level separately, but also to evaluate unification's economic effect that has been achieved in the design bureau, plant or firm as a whole. Continual observation of $\ni_y$ value for the entire firm, for example, by means of a computer, makes it possible to evaluate the outcome of the firm's standardization and unification activities at every moment of time and thus operatively manages the firm's engineering activity in economically expedient direction.

In order to illustrate the given calculation methods, we present an example for calculating the design of a pressure sensor that will be rational according to unification standards.

The pressure sensor shown in the drawing is a constituent part of the transducer-pressure switch, which consists of housing 1, bellows 2, rod 3, packing 6, plate 5, membrane 7 and screws 4, which fix it to the transducer-pressure switch frame. Pressure change in housing deforms the bellows and the corresponding displacement of the rod switches on the contacts by levers. (Fig. 1.)

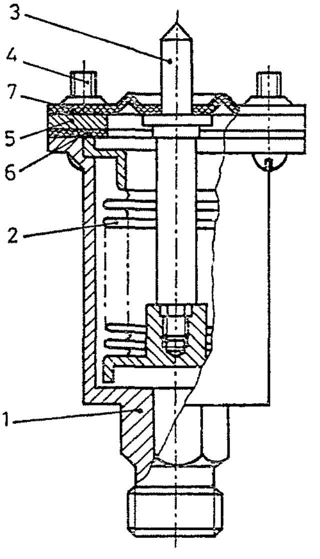

Fig. 1

Technical specifications for the transducer-pressure switch being designed (the production volume being 100 per year) are such that it is conceivable to use in its pressure sensor the bellows of the existing transducer-pressure switch D 220 A—13 — 10,000 of them manufactured annually.

If we decide to design new, original bellows, we should make them simpler (shorter) than the present ones in the switch (D 220 A—13), but then again we lose the utilization advantages of the unified element produced in a large series.

The methods presented in the paper enable us to evaluate the economic effect of the unified elements' utilization and thus to give a proper answer to the question whether it is economically expedient to use a unified element or an original one.

The data concerning the pressure sensor's elements are presented in the Table 1., as well as the calculated quantities: the element's number (column 1), name (2), complexity evaluation (3), the corresponding element's amount in the product (4), own quantity (5). Into column 6 we calculate the cost saving factors by the formula (4), into column 7 we calculate the product's manufacturing expenses of originally utilized elements (formula 5), and column 8 is the product of the 4th and 7th columns. The sum of values in the last column is the formula's (8) denominator.

I	Name	C_1	a	x_{or}	y	C_{or}	$a \cdot C_{or}$
1	2	3	4	5	6	7	8
1	housing	$C_1^1 = 7\,422.45$	1	100	0.316	2345.49	2345.49
2	bellows	$C_1^2 = 11\,000.00$	1	100	0,316	3476.00	3476.00
3	rod	$C_1^3 = 539.30$	1	100	0.316	170.42	170.42
4	screw	$C_1^4 = 10.67$	4	400	0.224	2.39	9.56
5	plate	$C_1^5 = 121.62$	1	100	0.316	38.43	38.43
6	packing	$C_1^6 = 120.44$	1	100	0.316	38.06	38.06
7	membrane	$C_1^7 = 14.20$	1	100	0.316	4.49	4.49

$$\text{Sum} \sum_{i=1}^{m} a^i \cdot C_{or}^i = 6082.45$$

In case we use in the designed pressure sensor unified bellows (element $i=2$) instead of original ones from the transducer-pressure switch D 220—A—13, their complexity evaluation

$$C_1^{2y} = 13\,022.84.$$

will be greater than the original ones $C_1^2 = 11\,000.0$ (See the Table), i.e.

$$C_1^{2y} > C_1^2$$

as is typical of the unified element. Unified elements always contain some kind of excess [4] (something superfluous), due to which their complexity evaluation is higher, when compared to that of the original element.

While utilizing the unified bellows from the switch D 220 A—13, the general quantity of the bellows is

$$x_y = 10\,000 + 100 = 10\,100$$

and the manufacturing costs are according to the formulae (4) and (5)

$$C_y^2 = C_1^{2y} \cdot y(x_y) = 13\,022.84 \cdot 0{,}0997 = 1298{,}38$$

Reduction of expenses on account of unification (formula 7)

$$S_\Sigma = C_{or}^2 - C_y^2 = 3476.00 - 1298.38 = 2177.62$$

and unification effect (formula 8)

$$Э_y = \frac{2177.62}{6082.45} \cdot 100 = 35.81\%$$

Consequently, while manufacturing the pressure sensor (shown in the drawing) of a new design, the use of one unified element ($i=2$) makes it possible to diminish the manufacturing expenses of the pressure sensor by 35.81%, regardless of the fact that element 2 as an original one would be technically simpler and its manufacturing expenses, when making only one product, would be smaller by ~18% than in the case of a unified element

$$C_1^2 = 11\,000.0 < C_1^{2y} = 13\,022.84.$$

The given example makes unification's main aim more expressive — that being production efficiency growth by means of production specialization.

As we have taken only one unified element in our example for the simplification of the situation, we could have calculated the unification effect on this one element by the formula (6). Usually, besides original elements in the product, there are a number of unified elements there, and in this case it will be more expedient to calculate by the formulae (7) and (8), as has been done in the given example.

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