The paper presents the concept of algorithmization of the new product process implementation under the conditions of mass production. It describes the methods and techniques in DFA methodology in the new product production implementation. It was discussed influence of these methods to improve the manufacturability of the complex product assembly.

KEYWORDS: production process design, construction manufacturability, mass production

Contemporary production processes, especially large-scale ones, are characterized by a progressive degree of automation of machining and development of cooperation services in the execution of individual components and complex, unified components of the unified components, tailored to the wishes of customers. For this reason, in managing the implementation projects for the production of new products, their design is more and more important considering their assembly technology (PdM) [4, 5].

Different methods are used to evaluate the assembly technology and determine guidelines for shaping the design process due to PdM. In the automotive industry, DFA (design for assembly) methods are widely used, proposed and described for the first time by G. Boothroyd and P. Dewhurst in 1983 “Design for Assembly, A Designers Handbook”[4].

Several methods of DFA [1–3, 5] have been described in the literature – the most commonly used in manufacturing practice are presented in table I [5].

Lucas DFA method

This method is used to analyze the manual and/or automatic assembly technology. The Lucas DFA rating is based on the definition of three indicators whose values are related to the relative measure of difficulty of assembly. Its purpose is to reduce the number of assembled components of the final product and to analyze assembly operations for difficulties, complexity and time consuming.

The Lucas DFA procedure is shown in figs. 1–3. The project is subjected to a functional analysis that evaluates the functions of the individual components and whether they are necessary. A feasibility study is then carried out, including analysis of the assembly and maneuvering of the assembled components and the method of assembly itself.

The $W_{op}$ efficiency index based on functional analysis is as follows:

$$W_{op} = \frac{L_{A}}{(L_{A} + L_{B})} \times 100\%$$  \hspace{1cm} (1)

where: $L_{A}$ – number of components A (fulfilling product function), $L_{B}$ – number of components B (not fulfilling product function, e.g. rivets or washers).

![Fig. 1. Lucas DFA functional analysis scheme][8]

### TABLE I. Summary and methodology of selected DFA methods [1, 7]

<table>
<thead>
<tr>
<th>Method</th>
<th>Year</th>
<th>Authors</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lucas DFA</td>
<td>1980</td>
<td>A. H. Redford, K. G. Switt</td>
<td>It is based on SSM – Assembly Sequence Diagram – evaluating assembly design</td>
</tr>
<tr>
<td>Hitachi Assembly</td>
<td>1986</td>
<td>S. Miyagawa, T. Ohashi</td>
<td>Assesses the product’s mountability and cost ratio to identify product design</td>
</tr>
<tr>
<td>Hitachi Assemblability</td>
<td>1988</td>
<td>G. Boothroyd, P. Dewhurst</td>
<td>It is based on an empirical study of the costs associated with manual or automatic</td>
</tr>
<tr>
<td>Evaluation Method (AEM)</td>
<td></td>
<td></td>
<td>assembly, including three criteria for reducing the number of components</td>
</tr>
</tbody>
</table>

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Maneuvering coefficient $W_{\text{man}}$ is defined by the formula:

$$W_{\text{man}} = \frac{I_{\text{man}}}{L_{KA}}$$

(2)

where: $I_{\text{man}}$ – maneuvering index, $L_{KA}$ – number of A components (fig. 2); $L_{PA}$, $L_{PB}$, $L_{PC}$, $L_{PD}$ – sum of points from segments A, B, C and D (according to fig. 3).

The model describing the results of the manufacturability coefficient $W_{\text{mon}}$ analysis of the Lucas DFA method (fig. 3) has the form:

$$W_{\text{mon}} = \frac{W_m + W_d}{L_{KA}}$$

(3)

where: $W_m$ – main activity indicator ($W_m = L_{mA} + L_{mB} + L_{mC} + L_{mD} + L_{mE} + L_{mF}$), $W_d$ – additional activity indicator, $L_{KA}$ – number of A components (fig. 1).

Example

A single-stage prototype design was subjected to the Lucas DFA (fig. 4). The construction was designed on a production basis. For the accepted production conditions, the assembly process is defined. For each mounted part and for each defined step (table II) of the assembly process, the $W_{\text{ep}}$, $W_{\text{man}}$ and $W_{\text{mon}}$ values were calculated:

$W_{\text{ep}} = 24/105 = 0,23 = 23\%$

$L_{KA} = 24$, $L_{AB} = 81$, $L_{KA} + L_{AB} = 105$

$W_m = L_mA + L_mB + L_mC + L_mD = 48 + 10,9 + 2,7 + 5,6 = 67,2$

$L_{KA} = 24$

$W_{\text{max}} = 67,2/24 = 2,8$

$L_{KA} = 24$

$W_{\text{mon}} = 284,2/24 = 11,84$

On the basis of such defined values of the index and coefficients, it is possible to proceed to shaping the design of the product from the point of view of technological assembly. Due to market demand, production costs and delivery times to the customer, general purpose gearboxes are designed in the form of series. The series consists of several gears with the same design but different geometric dimensions.

The results of the analysis for the assumed course of assembly are presented in Table. II. It contains selected operations assigned to the analysis: functionalities (in the form of components included in group A or B – fig. 1), maneuvering (within segments A, B, C and D – fig. 2), and mountability (according to major activity indicators A, B, C, D, E and F and additional operations. For additional operations, see the Sec column.)
In the illustrated example, the developed design (fig. 4) is non-technical in view of the potential for mass production. In the evaluation method used, the project efficiency index is $W_{ep} = 23\%$ (authors of the publication [8] report value of 60% as a minimum) and $W_{man} = 2.8$ and $W_{mane} = 11.84$ (according to [8], both indicators should be less than 2.5).

To improve the technology of gear assembly, following aspects should be considered:

- within the scope of application of the new construction: changing the structure of the body (for example, cast iron instead of welded steel body), analysis of the component minimization, unification of components included in the gear unit (gear elements, body cover, sight glass, fasteners – bolts, washers);
- regarding to the application of a new assembly structure: assembly of assemblies – e.g. shaft with mounted gear and bearings, pinion with bearings – using appropriate mounting equipment.

Although the Lucas DFA method presented in the article is related to the mass production, it can also be used in certain situations when it is less productive.

Conclusions

By analyzing the values of the parameters of technological evaluation of the gear assembly, it can be stated that:
- evaluation of parameter values (table II) may be the basis for the analysis of the design of the product design,
- assessment should take into account many other factors related to sales, service, availability of spare parts, production volumes, types of equipment, appropriate assembly techniques, level of automation, cooperation services, commercial components, crew technical culture, etc.

Lucas DFA analysis is one of several methods for evaluating the technology of a product's design – it allows assessment of assembly technology in terms of time criterion and thus assembly costs.

The method can be successfully applied also to smaller batches of manufactured products for the manufacture of a group of technologically similar products – e.g. general purpose gears.

The use of standardization of assembly operations is helpful in assessing construction – it makes it easier to determine the time of these operations.

The ability to evaluate the design is conducive to the creativity of the designers – procedure discussed in the paper can be carried out for the product and its components (assemblies, components, etc.).

REFERENCES