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METHODICAL DESIGN USING DFA METHOD

Summary. Design for Assembly (DFA) is regarded as an important tool for application of Simultaneous Engineering strategy. The development of computer technology enabled to use well known algorithms, assembly design principles and some statistical data, obtained from American industry, in a computer package called DFA. The use of DFA program created by Boothroyd and Dewhurst is examined in this paper. Each step of DFA analysis is described on the basis of example ball valve assembly analysis. Results are shown of DFA analysis in industry and possibilities of future development of expert systems based on DFA methodology. Importance of introduction of DFA principles to Polish industry and Universities is emphasized.

1. Introduction to Design for Assembly (DFA) methodology

Simultaneous Engineering is widely considered as a foundation of improvement in industrial productivity. It relies on team approach and adoption of certain specific techniques. One of these techniques is certainly the DFMA - Design for Manufacture and Assembly, the Boothroyd and Dewhurst's approach and software tool. Simultaneous Engineering demands that more time is spent in defining the product than at present and that planning is much more thorough in the early stages of design. Simply several issues concerning the product manufacturing, assembly, use, service and recycling should be built into design process. This principle is also the main philosophy of DFMA and especially of the part of it called DFA -Design for Assembly. DFA is a system that analyses the assembly and assesses it for ease of assembly. As a general rule, a good assembly is one that has few components, since it will take less time to assemble, is less likely to be assembled incorrectly, and is less likely to fail in service.

2. Product assembly analysis with the aid of DFA programme - case study

The usage of DFA software is presented in this chapter. The example product being subject to assembly analysis is a ball valve produced by company A (Fig. 1). Let's assume that marketing services ask the manufacturing people to investigate possible cost savings. They say that competition - company B - is winning more and more market share with their cheaper ball valve. One area where savings are supposed to be significant is assembly.

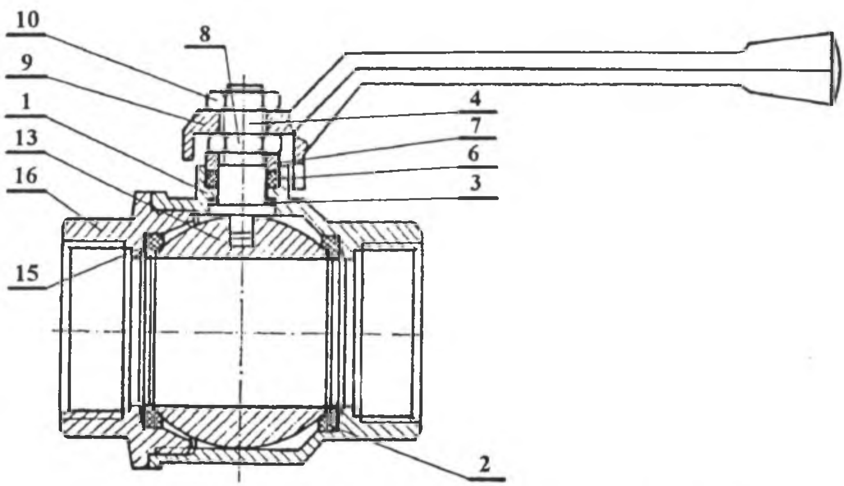

Fig. 1. Ball valve assembly (parts numbers refer to theis numbers on worksheet - see Fig. 2)

So, to reveal possible savings the assembly analysis of the ball valve is performed with the aid of BDI (Boothroyd&Dewhurst Inc.) software. The ball valve is assembled manually so the analysis is performed with the aid of Design for Manual Assembly module. At the first stage, a programme is provided with the name of product and hourly labour rate. In this example hourly labour rate is set to 10. On the basis of these data the system builds the structure of assembly. The designer must name all the items, i.e. all the components and operations in disassembly or assembly order. At the same time the type of item must be characterised (part, PCB, subassembly, standard operation, reorientation, user operation, user item) and a securing category must be selected (not secured on insertion, securing itself or other items on insertion, secured after insertion or by separate operation). Accordingly the valve body (item no 1) is added to worksheet as the first item. In that case the item category is set to 'part' and securing category is set to 'Not secured on Insertion' (Fig. 2). Next is a large teflon gasket (item no2). Item category is set to part and securing category is set to 'Securing itself or other items on insertion'. Simultaneously, a securing operations is selected from a standard list in this case 'push fit'. Successively, a small internal gasket (item no 3) and spindle (item no 4) are added to the worksheet. So as to proceed with next assembly operations the orientation of the valve body must be changed. Therefore the next item is 'Reorientation'. Following 'parts' are added to the worksheet: a small external gasket (item no 6), distance sleeve (item no 7), nut (item no 8), hand lever (item no 9) and nut (item no 10). In order to place the ball in the valve body 'Reorientation' is required (item no 10). It is necessary to apply grease to the ball. before placing it in the valve body. Therefore User operation is selected and an 'apply grease' operation is retrieved from the library and added to the worksheet. If not found, it is possible in User operation library to define a particular operation by providing a specific formula calculating the time of operation. Now the ball (item no 13) can be put into the valve body. The last item is a nut subassembly (item no 15) but before the item is added, an 'apply adhesive' operation (item no 14) is retrieved from User operation library and added to the worksheet. Nut subassembly is assembled separately (consists of a nut and large gasket) and then is added to the main assembly.

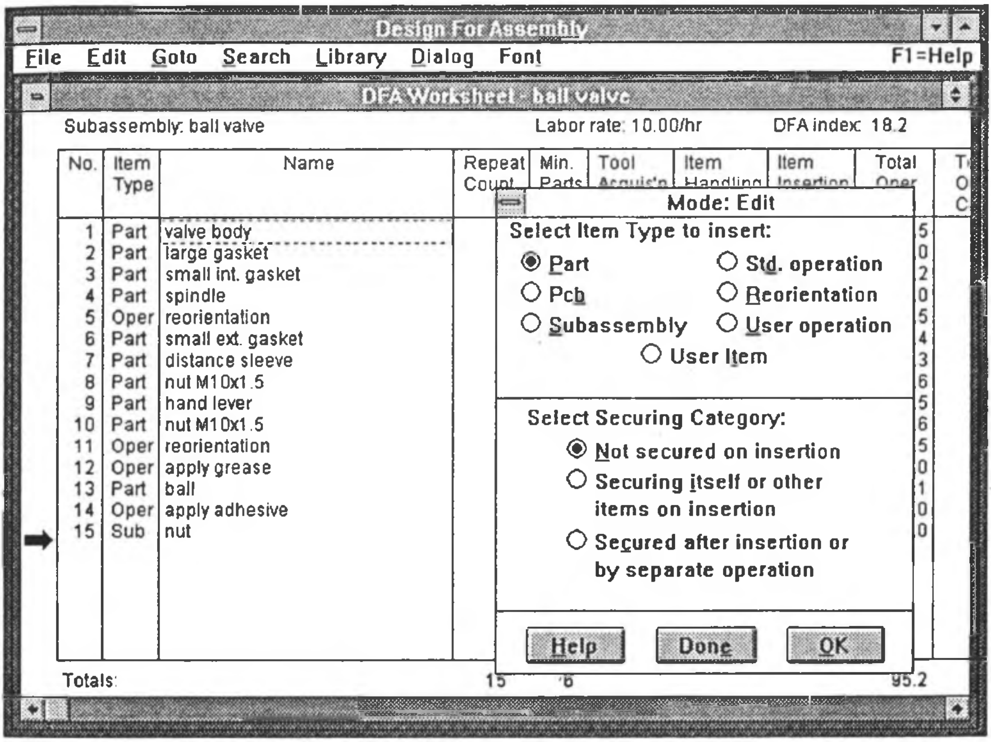

Fig. 2. Worksheet for ball valve

2.1 DFA questions

In the next stage each item is examined by asking several DFA questions (Fig. 3) about:

- minimum part criterion,
- shape classification (rotational, non rotational and dimensions),
- symmetry,
- handling difficulties (e.g. flexible, fragile and so on, the need of grasping and manipulating tool or handling assistance),
- insertion difficulties (e.g. restricted view of mating location, not easy to align or position during insertion).

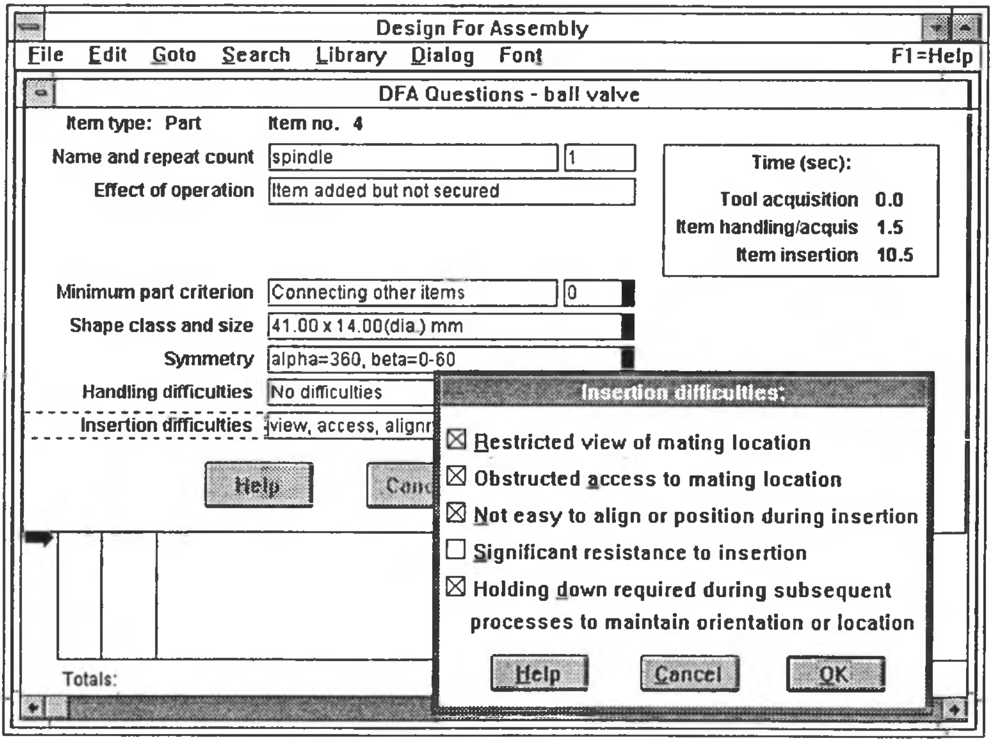

Fig. 3. DFA questions

Answering DFA questions helps designer to reveal the most serious problems with assembly. In case of the ball valve produced by company A spindle insertion causes assembly problems (Fig. 3). Due to restricted view and obstructed access to mating location (for a small internal gasket) it is difficult to align and position the spindle during insertion (Fig 4). So, to compare competitive products, DFA analysis is performed. Both products are much the same, so the assembly process is assumed to be alike as well.

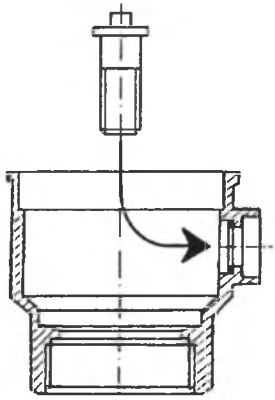

Fig. 4. Spindle insertion in company A's ball valve

The DFA analysis of the competitive product revealed, that in the case of the spindle and small gasket assembly is much easier in company B ball valve (Fig. 5).

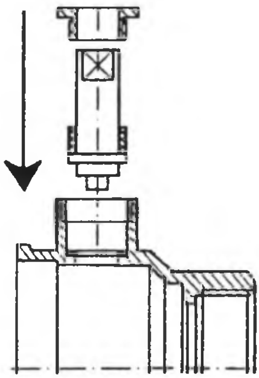

Fig.5 Easier way of spindle and gasket assembly in company B' ball valve

Concerning minimum part criterion the item function must be specified. The component is suggested to be eliminated if it is a fastener or a connector. If it has a different function then following questions are asked:

- Does it move relative to other parts?
- Does its material need to be different from those of the others?
- Does it need to be a separate component, or could it be combined with another without affecting functionality?

If answer is 'no' a component should be eliminated as well. In the case of Company A valve the distance sleeve is intended for elimination. In company B valve the distance sleeve is not present so it has one part less. Apart from suggestions about the component elimination results of DFA analysis provide a designer with cost and efficiency information. The efficiency of design called the DFA index is calculated according to the algorithm presented in the DFA manual [1] and is used to compare the assembly variants. The cost of assembly incorporates costs related to time of handling, insertion and time of standard and user operation. The handling and insertion time is estimated on the ground of answers to DFA questions and some experimental data. The final results of DFA analysis for competitive products show that valve A scored the DFA index 18.4% and valve B - 21.3%. Accordingly times of assembly are 110 sec. and 94 sec. In this case DFA analysis revealed a substantial gain of the competitive product in assembly efficiency. It could be one of reasons why the competitive valve is cheaper. If company A has some quality problems which have to be resolved during assembly process the DFA index would be even lower and time of assembly much longer.

2.2 Conclusions

As can be seen from the case study BDI DFA analysis does not attempt to redesign components. That is left to the designer. It prompts the designer which parts can be combined or eliminated and shows him or her the possible benefits. As a result of DFA application designer's work becomes more systematical than before. It forces a designer to consider all aspects of assembly at an early stage of the product development. The result is almost invariably fewer parts and shorter assembly cycles. Summary results for valve A and valve B show figures 6 and 7, respectively.

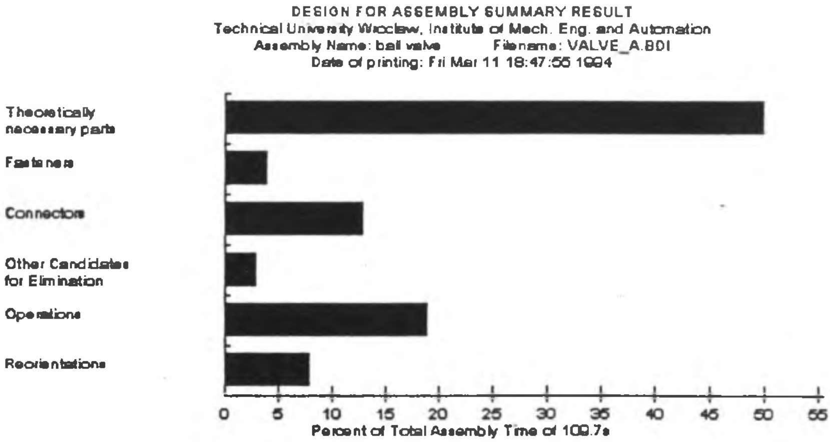

Fig. 6. Summary report for valve A

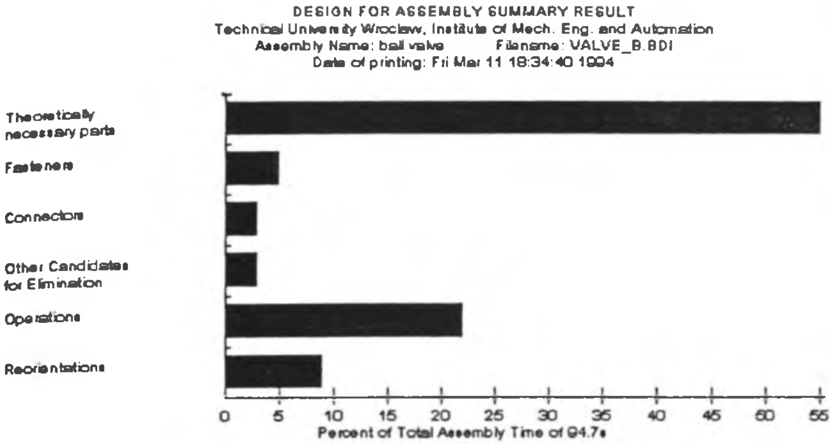

Fig. 7. Summary report for valve B

3. Results of `DFA implementation

DFA has been used in several hundreds of companies especially in USA but also all over the world. Ford, one of the big exponents of DFMA, has found that it reduces parts count by about one-third [2]. Ford of the USA has trained 10000 engineers in Boothroyd and Dewhurst's DFMA and claims it saved $1.1 billion in the first four years of production of the Taurus car. For example windshield wiper assembly was redesigned so the number of parts was reduced by 36%, and assembly costs cut by 65% [2]. A lot of examples of products redesigned with the aid of the DFA analysis have been presented in journals, magazines and books. The result is usually 20-60% fewer parts and 30-60% less cost.

4. Prospects of DFA methodology development

Although present DFA programmes enable designers to do their work more systematically, they have some substantial shortcomings:

- DFA programmes do not perform direct analysis of product but rely only on answers given by a designer so the crucial decisions concerning product redesign depend on designers' knowledge and experience.
- Product assembleability analysis does not take into account such manufacturing aspects like tooling, assembly machines and other specific conditions present in particular company. Therefore a full link between design and manufacturing functions does not exist.

- Results of DFA analysis are qualitative and do not present any alternative solutions to assembly problems.

Expert systems based on DFA methodology are an answer to these problems. The expert system consists in that case of four modules [3]:

DFA

CAD

CAAPP (Computer Aided Assembly Process Planning)

Knowledge Base

CAAPP module on the basis of CAD parts models sets an assembly order. The assembly order is then verified by DFA analysis and possible redesign suggestions affect parts models in CAD module. Indispensable part of expert system is Knowledge Base which enables to rely not solely on designers skills and experience.

6. Final notes

In reference to above mentioned advantages of DFA analysis, it seems reasonable to introduce that methodology to Polish industry and technical universities. Assembly process has been regarded as less important than other manufacturing processes so far. However it is assembly process that has substantial impact on product final quality. Appropriate design for ease of assembly often determines product saleability. For that reason it is justified to do research work on expert systems development based on DFA methodology.

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[3] E. Molloy, H. Yang, J. Browne, B. J. Davies: "Design for Assembly within Concurrent", Annals of the CIRP, Vol. 40/1/1991.

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