Korkut H., Eker U. Investigation of the effect of rake angle on main cutting force, – Int. Journal of Machine Tools and Manufacture, 44, no.9, 2004. – p.953-959. **6.** Molinari A., Moufki A, A new thermo mechanical model of cutting applied to turning operations. Part I. Theory. – International Journal of Machine Tools and Manufacture, Volume 45, no. 2 , 2005. – p. 166-180. **7.** Auchet S., Chevrier P., Lacour M., Lipinski P. A new method of cutting force measurement based on command voltages of active electro-magnetic bearings. – Int. Journal of Machine Tools and Manufacture, 44, no.14, 2004. – p.1441-1449. **8.** Croitoru I., Segal R., Cozminca M. Ordering the parameters with effects on plastic strain when cutting steel. – Bul. Inst. Politehn. Iaşi, tom XLIV (XLVIII), fasc. 3-4, secţia V, Construcţii de Maşini, 1998. **9.** Nakayama K., Arai M., Takei K. Semi-empirical equations for the three components of resultant cutting force. – Annals of the CIRP, 32, 1, 1983. **10.** Brown C.A. A Practical Method for Estimating Machining Forces from Tool-Chip Contact Areas. – Annals of the CIRP, 32 (1), 1983. – p.91-95. **11.** Yellowley I. Fundamentals of metal machining and machine tools. – Scripta Book Co., 1975. **12.** Amarandei D. Cercetări privind mărimea forţelor de deformare plastică şi de frecare la aşchierea cu viteze mari a oţelurilor carbon, Teza de doctorat, Univ. Tehnică "Gh.Asachi", Iaşi, 1996. **13.** Saturov G., Poduraev V. N. Opisanie izobreteniea, nr. 1207632 A, SU, 30.01.1986. **14.** Croitoru I., Cozminca M., Ungureanu C., Utilizarea metodei Saturov-Poduraev în scopul evaluării unghiului de frecare la aşchiere. – Conferinţa Ştiinţifică Int. TMCR' 01, Chişinău, vol.1, 2001. – p. 139-142.

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EXPERT SYSTEM FOR DESIGN FOR ASSEMBLY – THE KEY TO ASSESS COMPETITIVE PRODUCT

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Expert System for Design For Assembly (DFA) within a concurrent engineering environment is presented in this article. A prototype system that supports new techniques for design for assembly gives users the possibility to assess and reduce the total production cost at an early stage during the design process. Kappa PC development toolkit was chosen as toolkit for the development of the system. The system enables designers to minimize the number of components of a product, select the most economic assembly technique for that specific product, determine the cost and time of assembly through product analysis, and determine the design efficiency Knowledge Base System for Design For Assembly.

In Today's competitive product market the reduction of product manufacturing costs is of a great significant. As products become more complex and highly integrated. Designers or design teams find it increasingly necessary to have a system with a common language, independent of traditional engineering disciplines. There is no doubt of the impact of product design on manufacturing cost ,Therefore designer decision on product design will focus an important part of product manufacturing .It is estimated by researches that more than 70% of the product cost is defined during the product design phase [1].

In other words as shown in table 1, while design accounts for only 5% of the total cost of a product's development, that 5% investment in design for manufacture accounts for 70% of the product's final manufacturing cost. Obviously, great gains can be made through careful attention to product design or re-design [2].

Table 1. Comparison of influence versus cost of four key components of a product's manufacture

ITEM NAME	INFLUENCE	COST
PRODUCT DESIGN	70%	5%
MATERIAL	20%	50%
LABOUR	5%	15%
OVERHEAD	5%	30%
TOTAL	100%	100%

Design for assembly (DFA) is now a well established technique for cost reduction at the design-manufacture interface [3] and an accepted technique and used widely throughout many large industries including Lucas, GEC, and Mercedes Benz, NISSAN Motors, etc. Experience now shows that DFA analysis provides much greater benefits than simply a reduction in assembly costs. In fact, it appears that DFA is the key to very significant reductions in overall manufacturing costs . Numerous examples are now available which show that the product simplification brought about by DFA analysis often leads to parts cost reductions that are significantly greater than the reductions in assembly costs [4] [5] [6] [7].

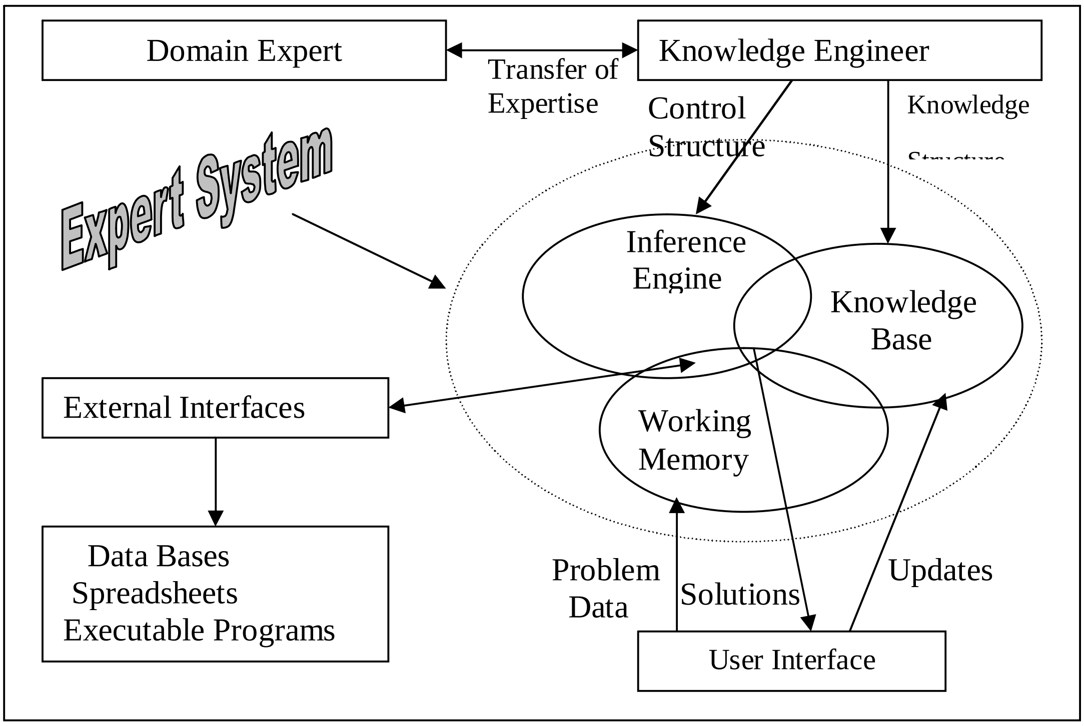

Fig. 1. Integration of Expert Systems Components

By applying a DFA tool, communication between manufacturing and design engineering is improved, and ideas, reasoning, and decisions made during the design process become well documented for future reference. Previously, work has been carried out in developing methods and tools for DFA [8] [9] [10] [11]. In the present paper we present a new approach to design for assembly using computer technical such Expert System (ES) to help Designer or user to quantify Reduce the number of the parts, Select the right method of assembly, Determine the cost and time of assembly through product analyzing, and Determine the Efficiency design.

The structure of the proposed system. The structure of the proposed system consists of four stages, Acquisition Knowledge, Knowledge programming, user interface and decisions and advisement for DFA.

- Acquisition knowledge, that includes different sources of knowledge such as experience people in DFA (Boothroyd, Dewhurst) those implement developed data for DFA, Formula and equations to calculate the cost of assembly and design efficiency , constraints such as system analyze part size from 1 to 250 mm and many researchers for DFA used widely throughout many large industries.
- Knowledge representation, After discussions with experts who have experience of Knowledge -based Systems, tools and gathering the knowledge related to DFA. KAPPA-PC was chosen as a suitable expert system development tool for the particular task by using Kal language.
- User interface
- Decision and advisement for DFA after interfacing between user and computer system enables him/her to decide on proper time.

  - **Analysis process for DFA.**

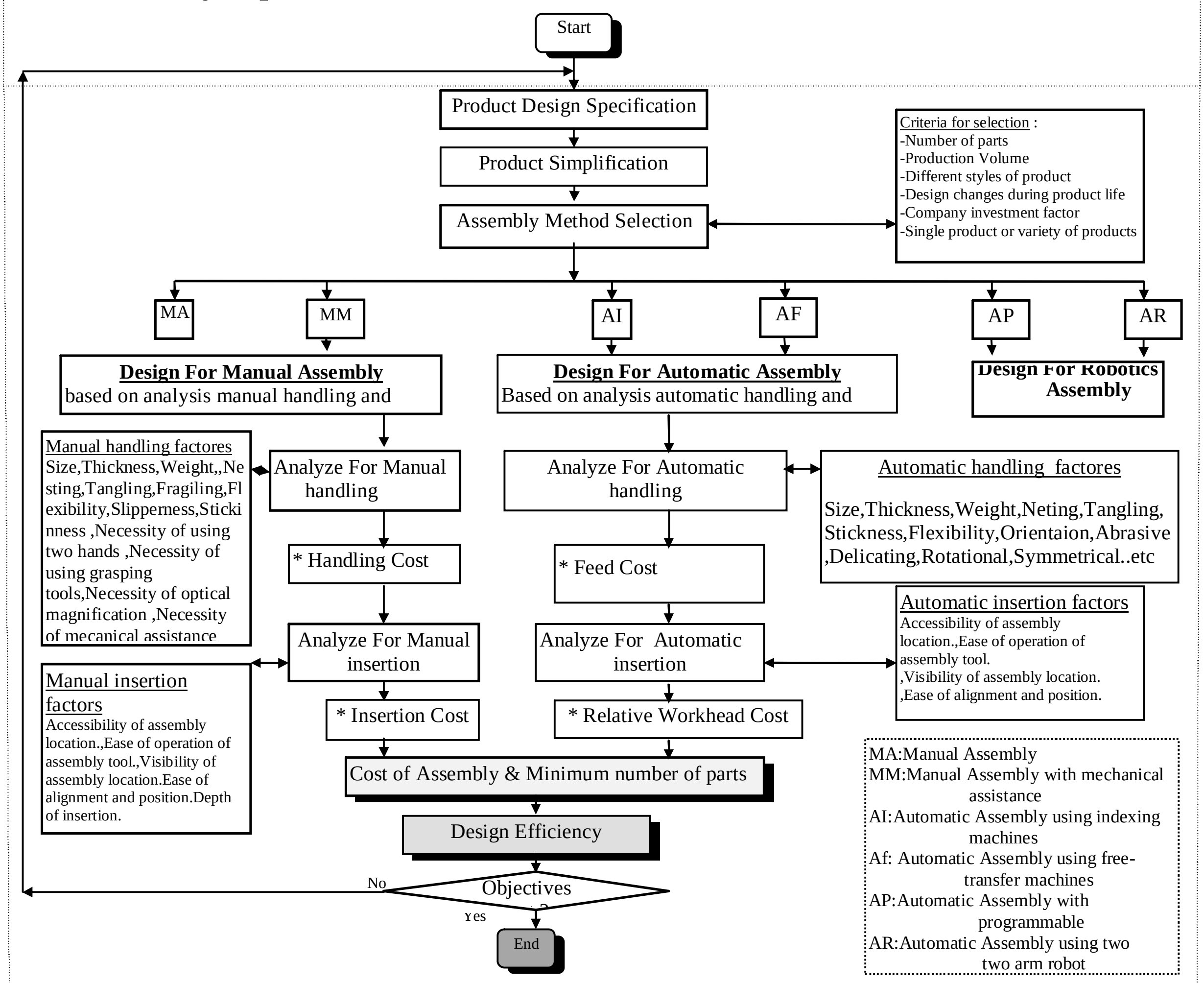

Fig. 2 Proposed analysis process for DFA

The developed system was designed in such a way to allow designers to analyze and/or modify the product at any stage during the design process. It works in a full interactive mode and information associated with a particular subject such as product structure, number of components, component design and component material are incorporated into the system. The system operates by guiding its users through five main stages as shown in fig.2. Product specification, product Simplification, assembly methods selection stage, time and cost estimation through component analysis and Design Efficiency Estimation, each of module achieved by proper rules and Knowledge representation carried out to help user to quantify the objectives of this research [13]. The operation scenario of the five stages can be summarized as follows:

- **Product specification:** a user has to input the geometrical attributes of the part features; this information is then used for DFA analysis.
- **Product simplification:** The designer should always keep in mind that each combination of two parts into one will eliminate at least one assembly operation. In order to aid the identification of these components which are candidates for elimination or combination with other components, several criteria are used to be separate from its mating parts by asking questions about each part such as [6] :
  - Does it move with respect to all the other parts already assembled ?
  - Must this part be different material ?
  - Must this part be separate for disassembly ?

- **Selecting the right assembly method**

Surprisingly, the least costly assembly method can be identified early in design stage .If the product is then designed for that process, manufacturing cost can drop 20 to 40% and assembly productivity rise 100 to 200% [14]. It is important to decide at early stage in design which type of assembly method is likely to be adopted ,based on the method yielding the lowest costs .This Section allow the designer to decide from the values of basic product and company parameters(production volume, number of parts, etc.) which assembly method is likely to be the most economic .

In addition, for example, a product or assembly where only 1,000 per year are required would obviously be assembled manually .For a product where several million per year are required, the purchase of special-purpose automation equipment (high-speed automatic assembly) would almost certainly provide excellent return on investment.

The cost of assembling a product is related to both the design of the product and the assembly method used for its production .The lowest assembly cost can be achieved by designing the product so that it can be economically assembled by the most appropriate assembly method.

Investment factor (R_i:) that one of factors for selection can be calculated by (1):

$$R_i = S_n \cdot \frac{Q_e}{W_a} \tag{1}$$

where, R_i : Investment factor, Q_e : Capital expenditure allowance to replace one operator on one shift, S_n : Number of shifts, W_a : Annual cost of one assembly operator

Analyzing the selected method and cost estimation of assembly. System analysis the required product to assemble through the selected appropriate method of assembly i.e. manual, robotics or high-speed automatic.

An analysis is carried out using a design for assembly data and tables. Each of three technologies has its own special data and tables, Regarding the design of parts for ease of assembly, experimental and theoretical analyses were performed [15] [16] and have been widely published over a number of years on the effect features of part on assembly operations such as part Dimensions, chamfer design, part symmetry, part weight, avoid jamming, part geometry, obstructed access, restricted vision, etc.[17] analyze features of the part and its effect on machining cost. Fig. 2 shows the processes of cost estimation for automatic assembly.

Design Efficiency Estimation. An essential ingredient of the DFA method is the use of a measure of the "assembly efficiency" of a proposed design. By estimation efficiency of design designer can easily compare between alternative designs [18]. Design efficiency for manual assembly is obtained from (2):

$$E_m = \frac{3N_m}{t_m} \tag{2}$$

where, E_m: design efficiency for manual assembly, N_m: theoretical minimum number of parts, t_m: total assembly time.

Design efficiency for automatic assembly is obtained from (3):

$$E_a = 0{,}09 \cdot \frac{N_m}{C_{AA}}, \tag{3}$$

where, E_a: design efficiency for automatic assembly, N_m: theoretical minimum number of parts, C_{AA}: cost of automatic assembly.

Expert system for design for assembly has been developed in this research article. The developed system has the potential to reduce the overall product manufacturing costs. Since it advise users concerning how to minimize the number of parts of a product without any compromise on the quality. The developed prototype has been tested on a particular product and a cost reduction of 33.78% were achieved.

References: 1. Andresen, M. M., Kahler, S. and Lung, T. (1983). Design for assembly. IFS (Publications) Ltd./Springer Verlag. P. 432. **2.** Vincent Chan and Filippo A. Salustri (2003) "Overview of DFM" Design for Manufacture, Munro & Associates. **3.** E Appleton; J.A. Garside (2000) " A team- based design for assembly" Emerald Group Publishing limited. Vol. 20, No.2, p. 162- 170. **4**. Sukhan Lee, Chunsik Yi and Raul Suarez, (1997) "Assemblability Analysis with Adjusting Cost Evaluation based on Tolerance and Adjustability" Proceedings of the 1997 IEEE, International Symposium on Assembly and Task Planning. **5.** Stone, R B., A (2004) "product architecture-based conceptual DFA technique" Design Studies 25 pp. 301-325. **6.** BOOTHROYD, G. and DEWHURST, (1987). Product Design for Assembly Handbook. Wakefield, RI.: Boothroyd Dewhurst, Inc. **7.** KR M.; DG B.; BC R.; P C.; WM C.; PG M.(2003) Design change impact analysis during early design specification International Journal of Computer Integrated Manufacturing, Numbers 7-8/October-December 2003, vol. 16, no. 7-8, pp. 598-604. **8.** Ikonopisov, Hassan Abdalla and J A G Knight (1998) "A concurrent engineering approach to design for assembly and manufacture" Ph.D. theses, Mechanical and Manufacturing Engineering, De Montfort University. **9.** Michael Egan "Concept design for Assembly-A design theory perspective" Proceedings of the 1997 IEEE, International Symposium on Assembly and Task Planning. **10.** Nan-Shing Ong, Chee-kai chua and Eng-Wah Lee, (1997) "Geometric analysis of parts from a 3-D solid model for manual assembly times" Integrated Manufacturing Systems, 8/3,137-

146. **11.** Goodman, C., Brooy, Rand Travella, L. (1991).A User Friendly Pakage in Design for Assembly. Vol. 16, part 2, 17-122. **12**. Badiru, A.B.(1992). Expert Systems applications in Engineering and manufacturing. New jersey: Prentic hall. **13.** Filonov I.P., Kourtch L.V.,Daabub A.M. (2004) “Cost reduction through DFA analysis with expert system construction” Тезисы докладов// Машиностроение: Республиканский межведомственный сборник научных трудов, Вып.20 в двух томах. Т.1/ Под ред. И.П.Филонова.-Мн.: УП “Технопринт”, 2004.-398 с. ISBN 985-464-607-6(Т.1). С. 81-83. **14.** Boothroyed and P. Dewhurst, (1983) “Design for assembly: selecting the right method , Machine Design, pp. 94-98. **15.** Nourredine Boubekri and Srinivasan Nagaraj, (1993) “An Integrated Approach for the Selection and Design of Assembly Systems” Integrated Manufacturing Systems, Vol. 4, No. 1, pp. 11-17. **16.** Georg Strobel and Dieter Dodenhoft, (1992) “DFA-XPRT: A Knowledge-Based Approach for Design Analysis In Mechanical Engineering” Computer and Artificial Intelligence, Vol. 11, No. 5, pp. 425-456. **17.** Abdalla H and JAG Knight (1994) “A Featured based Design Environment for Concurrent Engineering” Proceeding of the International Conference on Concurrent Engineering and Electronic Design Automation (CEEDA ‘94), ed. Medhat. **18.** Alan D’Cruz, Rover Group (1992) “Design for Assembly-Optimum Efficiency” Manufacturing Breakthrough March/April.

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INFLUENCE OF WORKPIECE RUN OUT ON CHANGE OF RADIAL CUTTING FORCE IN A CYLINDRICAL GRINDING

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The workpiece run out at its grinding on cylindrical grinder influents on grinding wheel wear and stability of grinding. This paper is intended for analysis of instantaneous change of cutting force at every revolution of the running out workpiece. The cutting force increase is evaluated by the rate of the instantaneous cutting force and stabile force at cutting with a constant allowance.

At analysis of workpiece grinding on a cylindrical grinders researchers the run out evaluated as a static factor which depending on allowance variation changes the grinding force strait proportional to change allowance value and in dependence on rigidity of a technological system either increasing the form error of the workpiece or grinding time necessary to correct the form accuracy [1, 2]. The notice was not fixed that the form error can act as a factor sharply changing the grinding force not straight proportional to change of allowance but in a greater degree. Wear of a grinding wheel and especially its waviness propagation may markedly increase. Grinding stability decreases.

The cross section form error of the workpiece being ground may be different, but at use of turned blanks the biggest value has the run out associated with eccentricity of the turned cylindrical surface of the blank and center marks of the piece. We shall not analyze the reasons of it, but it is possible to say that the run out can achieve tenths parts of mm. The phenomenon of grinding such eccentric parts is analyzed in this article. We in this paper did not set task to analyze in full the dynamics of response of a technological system on a stepped force increase, but only to show the problem of the phenomenon.

At grinding with constant allowance the grinding force falling to a width unit of the grinding wheel is straight proportional to product of allowance value u and workpiece