Use of electronic catalogues for planning of machining processes

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Analysis and modelling

ABSTRACT

Purpose: The paper presents the electronic catalogs for selection of tools and cutting conditions, their advantages and disadvantages. The tool makers most frequently offer the data on their tools and the relevant cutting conditions in the form of catalogs. Recently the data on the tool of the individual makers on compact discs have appeared. Electronic catalogs of tools contain the data on the tools of different makers. The further development is so oriented that the tool user will obtain all the necessary information through Internet. The Internet can be efficiently used in modernly organized computer-supported system for tool management.

Design/methodology/approach: A home page has been made that contains the interconnections to web pages of the cutting tool makers and to some catalogs for selection of cutting tools, accessible through Internet. It is accessible on the server of the Laboratory for cutting at the Faculty of mechanical engineering in Maribor under the URL address: http://www.fs.uni-mb.si/si/inst/ips/labod/start.htm

Findings: The contribution proposes an expert system for optimization of cutting parameters from commercial data bases.

Research limitations/implications: The OPTIS expert system serves for optimization of cutting conditions with respect to minimizing the manufacturing costs by taking into account the cutting process limitations. The programme is applicable only for turning.

Practical implications: The OPTIS selects optimal cutting conditions with respect to the tool maker, workpiece material, type of machining, machine, smallest and greatest cutting conditions, tool, data on series, type of clamping and workpiece geometry.

Originality/value: By means of Internet it is possible to follow up particularly the products and novelties of the individual tool makers and to become familiarized with their ranges of products sold.

Keywords: Expert system; Internet; Electronic catalog; Tool management system; Tool maker

1. Introduction

The requirements for ever-increasing productivity, higher quality of products and the strong competition on the market dictate the technological progress in production [1]. It is necessary to meet two extreme requirements:

- the price of manufacture of the product must be as small as possible,
- the time of manufacture of the product must be as short as possible.

These requirements can be met only be increasing the degree of automation of production [2].

In machining with cutting the automation takes place by introducing the numerically controlled machines (NC, CNC), the system of automatic change of workpieces and the system of tool management assuring trouble-free supply of tools to metal-working machines. The tool management system involves the computer-supported management and organization of the flow of tools and the data on them [3]. For automation the computers are being introduced into all segments of the production process from planning to production (CAD, CAM, CAPP, CAQ, PPC).

In computer integrated manufacture (CIM) as well as in the system CAD/CAM the data bases are of very great importance. These are in particular the bases of technological data required during preparation of the work and in the process of manufacture of a product [4].

2. Survey of state and development orientations

The tool makers offer many tools from different cutter materials and of different geometries in more or less clear book catalogs. That great quantity of tools changes, since new tools are introduced and the old ones abandoned. Therefore, the life expectancy of catalogs is only 2 to 3 years [5].

The users wanting to follow up the novelties must have a well organized tool supply service or they have to rely on the tool supplier [6]. There are no international standards for issuing of catalogs, therefore they differ in appearance, clarity and basic approach.

The use of computers in production ensures the use of media capable of replacing the book catalogs used so far. Some tool makers already offer the technological data on compact discs. In the near future it can be expected that the users will be able to obtain all the necessary information about tools through Internet [7].

3. Types of electronic catalogs for selection of cutting tools through Internet

An ever-growing number of tool makers offers on their home pages the electronic catalogs for selection of tools. Today different catalogs for tool selection are accessible through Internet [8]:

- HTML catalog,
- FTP catalog,
- Catalog in PDF format.

3.1. HTML Catalog

This is an electronic catalog in the form of World Wide Web. From such a catalog it is possible to select tools only through Internet by means of Web browser, such as the Internet Explorer or Netscape Navigator.

Advantages:
- automatic up-dating of information,
- they do not occupy the space on the disc of the local computer,
- no other program is necessary additionally to the Internet browser.

Disadvantages:
- connection to Internet is necessary for functioning,
- they can be very unclear,
- they do not function in case of a defect or maintenance of the server,
- they are slower than other catalogs,
- speed of searching for data depends on the speed of connection to Internet.

3.2. FTP Catalog

Such an electronic catalog is in fact an ordinary programme that can be transferred in the form of an installable data file into the local computer by means of the FTP protocol.

The FTP (File Transfer Protocol) is a protocol for transfer of data through Internet. After the transfer usually the installation of the programme is necessary.

Advantages:
- high speed,
- connection to the Internet is not necessary during the use,
- they are very clear,
- additional programs are not necessary for the use.

Disadvantages:
- they occupy the space on the disc of the local computer,
- installation of the program is necessary,
- there is no automatic up-dating of data,
- repeated transfer of the entire program is necessary in case of up-dating of data.

3.3. Catalog in PDF format

This is an electronic catalog in the form of documents of PDF format. For it the installation of the programme called Adobe Acrobat Reader is necessary.

Such a catalog can be used through Internet; it is however possible to transfer the data files to the local computer by means of the FTP protocol.

Advantages:
- the use of the catalog through Internet is possible or the files are transferred to the local computer.

Disadvantages:
- they are very unclear,

- the transfer and installation of the additional program Adobe Acrobat Reader are necessary for the use,
- installation of the program for the use of the catalog in Netscape browsers is complicated,
- the files are rather large, which results in slow connection to Internet.

4. Iscar HTML Catalog

The Iscar HTML catalog for selection of tools can be found in the web pages of the company Iscar. It can be found on the URL address: http://www.iscar.com/

There the link E-Catalog can be retrieved.

Fig. 1 shows the initial page of the Iscar HTML catalog.

Iscar's HTML catalog offers a rather good selection of tools, since it contains Iscar's complete production program.

It also has some disadvantages. One of them is the slowness of selection of data due to abundance of pictures.

The greatest disadvantage of the catalog is that it is often inaccessible due to maintenence of the server on which it is located. Recently, functioning of this electronic catalog has improved very much.

5. CoroKey PC 98.1 – FTP Catalog

CoroKey PC is FTP catalog for selection of tools. It is located on Sandvik Coromant's web pages.

Fig. 2 shows the FTP catalog Sandvik Coromant CoroKey PC 98.1.

This catalog is one of the best catalogs for selection of tools. It is very simple, clear and fast.

6. Seco PDF Catalog

Seco PDF is a catalog for selection of tools in the form of PDF files. It can be found on the Seco company's home page.

Seco PDF is located on the URL address: http://www.secotools.com/

The structure of files in the Seco PDF catalog is shown in Fig. 3. Because of fastness of selection it is recommendable to transfer the files to the local computer.

Selection of tools from the Seco PDF catalog is rather simple, but the catalog is very comprehensive. It provides the data on a great variety of tools and on the relevant cutting conditions, which is very convenient.
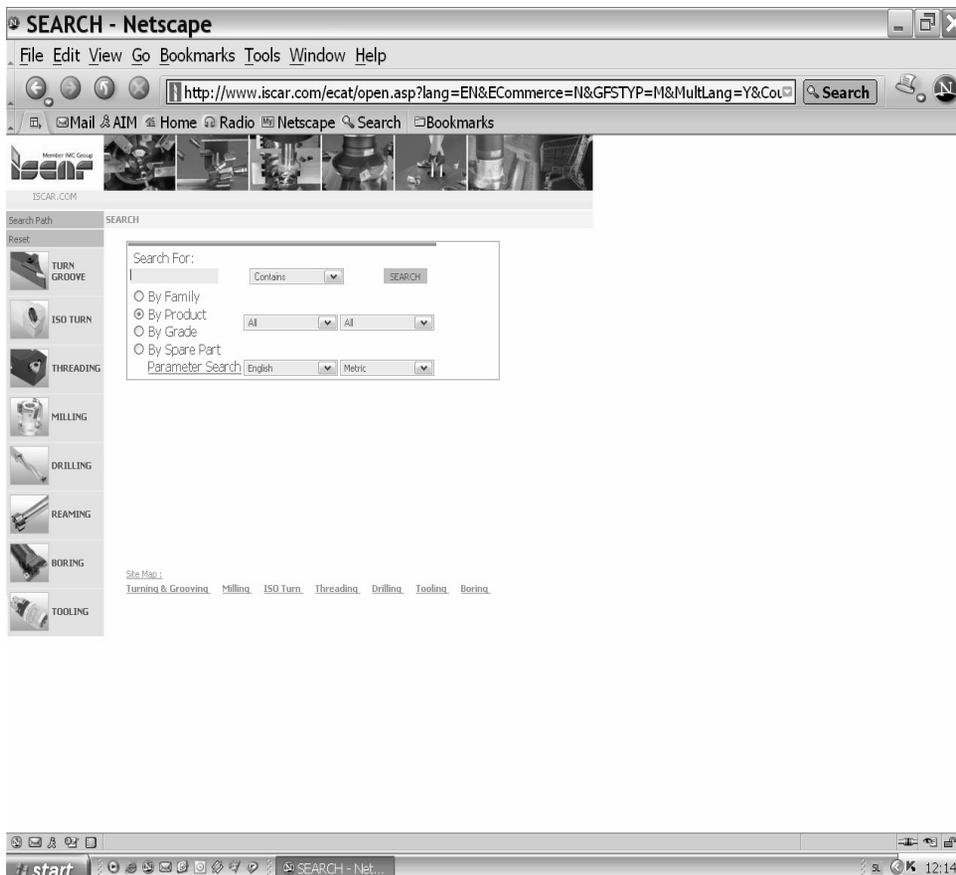

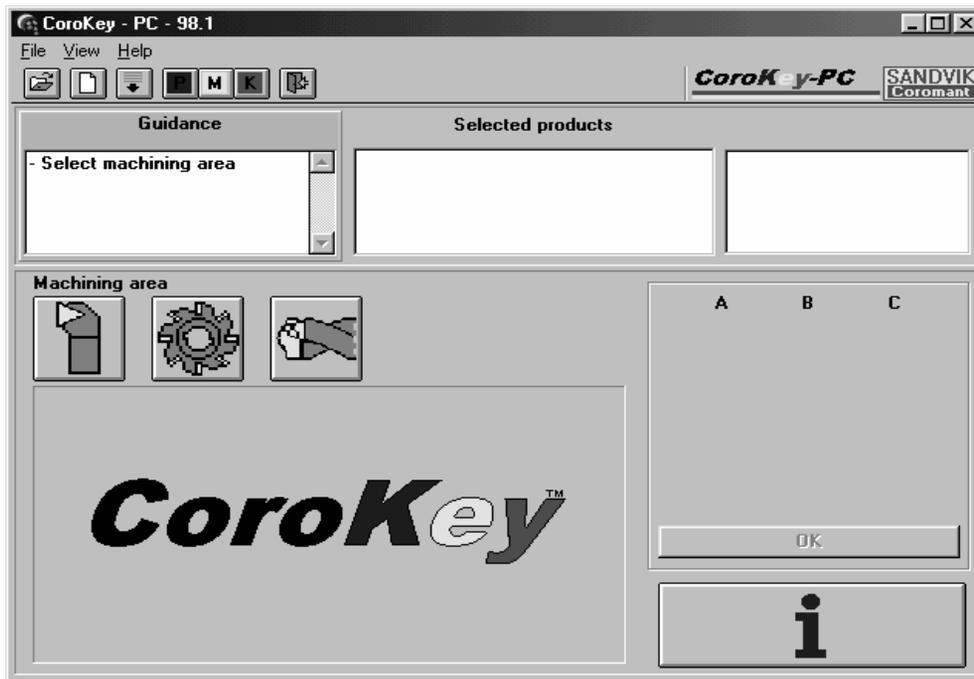Fig. 1. Initial page of Iscar HTML catalog

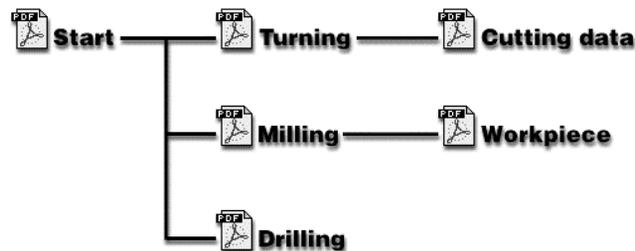Fig. 2. FTP catalog Sandvik Coromant CoroKey PC 98.1

Fig. 3. Structure of files in Seco PDF catalog

7. Electronic catalog of tools CIMSource FormBase on CD

The electronic catalog of tools CIMSource FormBase of the company CIM GmbH in Aachen, Germany has been issued since 1995 and contains the technological data on 90000 tools of 13 makers [9].

The tools needed for production can be watched on the CD and then ordered from the maker. From the catalog it is possible to select the recommended cutting conditions for the tools selected. It also contains the tool management system. There are three versions of this program:

- **Demo version** is free of charge and serves only for presentation of the catalog,
- **Limited version (CIMSOURCE Limited)** contains the pictures of all tools, price lists and component parts,
- **Complete version (CIMSOURCE Complete)**, in addition, contains the technological data, cutting conditions and

installation of tools. The installation module ensures assembling of compatible tool parts even though they are made by different makers. By means of the technological module it is possible to select the tools depending on our specific cutting conditions.

The complete catalog thus contains: more than 90000 tools of 13 makers, tool drawings, price lists, component parts, technological data, cutting conditions and tool installation [10].

8. Internet - latest data base

Recently, the computer network Internet with the offer of information systems has experienced a great expansion. Internet becomes a more and more important tool in everyday research and development work.

Today, millions of people have access to the Internet. The Internet network is a worldwide matrix of interconnected

networks capable of communicating, exchanging post, programs and data.

In order to find precisely determined information on the Internet it is necessary to know and/or enter a certain URL (Uniform Resource Locator) precisely determining where the information is. This is similar to a post address or phone number.

Internet is a new access to information. Today there is almost no company that does not have its computers connected into **LAN** (**L**ocal **A**rea **N**etwork) or **WAN** (**W**ide **A**rea **N**etwork). Two computers are interconnected if they can exchange information.

8.1. Use of Internet in tool management system

The Internet can be efficiently used also in the modernly organized computer-supported tool management system [11].

By means of the Internet it is possible to follow up in particular the products and novelties of the individual tool makers and to have a look at their ranges of products sold.

The access to information is easiest if a certain URL, obtained in technical magazines, catalogs or CDs of the individual tool makers, is known [12]. Through Internet the tool makers offer mainly general data from their area. In the tool management system the Internet is usable particularly in the area of planning of the production process [13]:

- selection of tools and determination of cutting conditions by means of electronic catalogs accessible through Internet,

- following-up of novelties and changes in the production programme, in the World Wide Web of the cutting tool maker,
- information about correct use of tools,
- technical support by means of electronic mail,
- possibility of ordering of tool catalogs, price lists and other literature of the maker by means of electronic mail.

9. Presentation of concrete products through Internet

Sandvik Coromant is the world's largest maker of tools and hard-metal inserts for turning, milling and drilling as well as of tool holders and assembly modules for lathes and manufacturing systems.

The selection of suitable tool is not simple due to abundance of products. Therefore Sandvik Coromant offers its product line (about 25000 products) through catalogs, CDs and/or electronic catalog and also by the newest method through Internet.

Sandvik Coromant is introduced on the Internet by its address and/or relevant URL: http://www.coromant.sandvik.com/

When the address has been entered, a window with its products opens as shown in Fig. 4.

Further two large makers of tools and hard-metal inserts for turning, milling and drilling are Iscar and Seco. They, too, present their products on the Internet (www.iscar.com, www.secotools.com).

Fig. 4. Sandvik Coromant's products

10. Expert system for optimization of cutting parameters

The OPTIS expert system selects the optimum cutting conditions from commercial data bases with respect to minimum manufacturing costs by taking into account the cutting process limitations.

The OPTIS selects the optimum cutting conditions (v_c, f, a) for one or more tool makers.

It is possible to enter into the OPTIS also the cutting conditions of some other tool maker that can be obtained in the book catalogs, on CDs or through Internet.

The program OPTIS was made by means of the program package Microsoft Visual Basic 6.0. The program uses the data base of type Microsoft Access.

10.1. Functioning of the OPTIS expert system

The cutting conditions are indicated over an interval from the smallest to the greatest ones.

The cutting speed increases over the interval with a certain step. Feeding increases over the interval with a certain step. Also the cutting depth increases over the interval with a certain step.

The OPTIS expert system selects from all possible combinations v_c, f, a the optimum cutting conditions that satisfy all limitations of the cutting process.

In case of several tool makers the program first selects for each of them the best cutting conditions and then from these obtained cutting conditions it determines those that are optimal for a given case.

The program is rather fast since the optimization process takes only a few minutes depending on the number of possible combinations v_c, f, a.

If a small step is selected for v_c, f, a, the results are more accurate and the computer will spend more time for optimization and inversely.

The OPTIS first calculates the manufacturing costs for all combinations of cutting conditions and then it classifies them into the smallest to the greatest ones.

Then successively (from lowest to highest manufacturing costs), it verifies also all limitations.

The first combination of cutting conditions, that satisfies the limitations, is the best one for the respective tool maker.

A similar procedure is repeated also for other tool maker. In the last step the OPTIS selects the optimum cutting conditions from all the best cutting conditions for the individual tool makers.

10.2. Structure of OPTIS expert system

Fig. 5 shows the modular diagram of the OPTIS expert system. The main menus and sub-menus are presented.
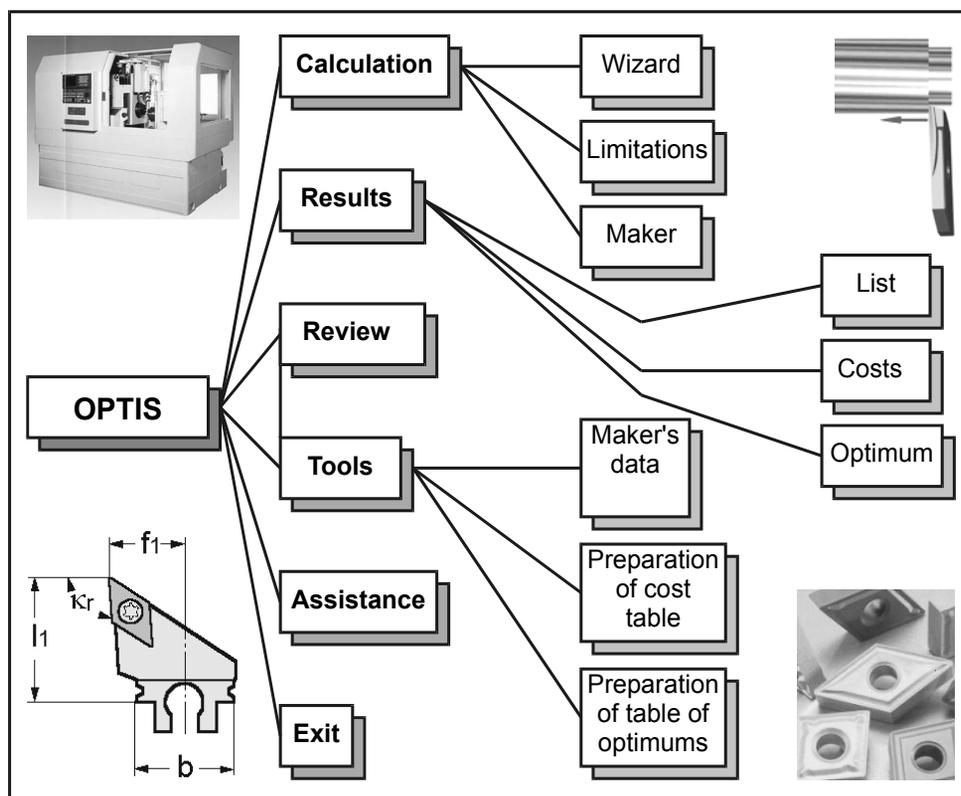

Fig. 5. Main menus and sub-menus of the OPTIS expert system

The OPTIS expert system for optimization of cutting conditions consists of five thematic areas:

- **Calculation** for calculating the optimal cutting conditions. In this area it is possible to calculate the optimal cutting condition for different tool makers (for one or more makers) with some limitation equations. It is also possible to determine the limitations of manufacturing costs for the individual tool maker and thus the cutting conditions are obtained that meet that limitation of the manufacturing costs,
- **Results** where the calculated values of cutting conditions and their optimal values are examined. The manufacturing costs for all combinations off cutting conditions are accessible,
- **Review** – in this area the data (vc, f, a, tensile strength, ...) of different tool makers for all types of machining (rough, intermediate, final, ...) are available,
- **Tools** for manual entering of the maker's data in case of different types of machining (vc, f, a), for preparation of the table of costs and for preparation of the table of optimums,
- **Assistance** for the description of functioning of the programme with diagrams and the basic information about the programme. The module **Assistance** contains the basic data on the programme OPTIS and general instructions for work with this programme.

The thematic area **Calculation** consists of three programme modules:

- **Wizard**,
- **Limitations**,
- **Maker**.

The **Wizard** serves for entering and processing the data of the calculation with limitations. The data entering takes place interactively and through the outside data base (book catalog, CD, Internet, ...). During processing of the computation module and limitation conditions the programme writes the calculation results into the data file of Microsoft Access format.

The **Wizard** for entering of data has the following steps:

- Selection of tool maker - it is possible to select from among different tool makers,
- Selection of workpiece material from table,
- Selection of type of machining (rough, intermediate, final) from the maker's table,
- Selection of machine - we have available the turning cell and the universal turning lathe, but it is possible to enter also the data from any other lathe,
- Selection of maker's parameters with respect to type of machining – table,
- Tool - the adjustable angle of the cutting insert radius and the tool resistance to wear are selected,
- Data on series - (price of work station, tool price, number of workpieces in series and time parameters),
- Selection of type of clamping - one of the three types of clamping can be selected (sketches of clamping are added),
- Workpiece geometry (initial diameter, final diameter, cutting length and surface roughness).

In the conclusion of the calculation the OPTIS expert system records the minimum manufacturing cost and cutting speed v_c, feeding f and cutting depth a in case of minimum manufacturing cost by taking into account all the limitations.

The module **Limitations** serves for the limitation of the manufacturing costs. It is used only in case when the cutting conditions for one tool maker are calculated. The manufacturing costs are limited by a certain value (how much the manufacture can maximally cost). Then the programme writes the cutting conditions when the manufacturing costs are just below the permissible limit. This limitation of the manufacturing costs is very useful in case when the buyer tells what maximum price he is ready to pay for one piece.

The module **Maker** serves to calculate the optimum cutting conditions in case the cutting conditions of several different tool makers are available. That module selects the optimum cutting conditions from among different tool makers.

The calculation **Results** are examined in three ways:

- The **List** for the review of the calculated best cutting conditions and the lowest manufacturing costs of different makers (the maker, v_c, f, a, manufacturing costs),
- The **Costs** for tabulated presentation of all results of the optimization of cutting conditions (all v_c, f, a and all manufacturing costs) for some maker,
- The **Optimum** showing the best tool maker, minimum manufacturing cost and related cutting conditions.

In the **Review** the insight into the tables of parameters (recommended, minimal and maximal cutting conditions v_c, f, a) of the individual tool makers for different types off machining (rough, intermediate, final) is ensured.

The **Tools** used for work with the data in the OPTIS data base are as follows:

- The **Maker's data** for entering the cutting conditions of any tool maker (cutting, conditions obtained from book catalogs, pamphlets, CDs, Internet etc.),
- **Preparation of cost table**. This command deletes from the table all the manufacturing costs and all related optimum cutting conditions,
- **Preparation of table of optimums** serves to delete the manufacturing costs and related optimum cutting conditions. This command deletes from the table all manufacturing costs and the best cutting conditions for the individual tool makers.

10.3. Definition of programme steps in OPTIS expert system

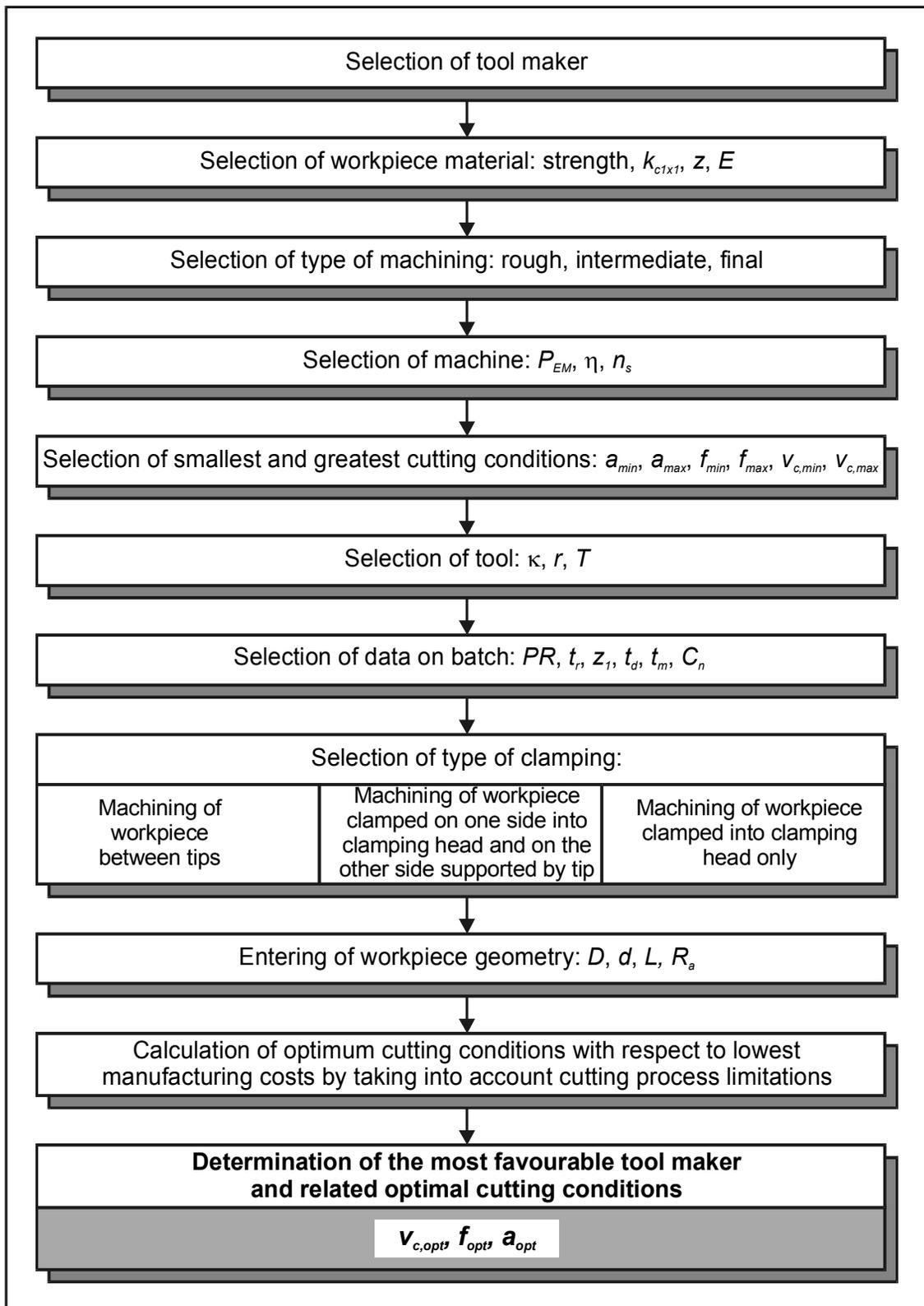Fig. 6 defines the programme steps in the OPTIS expert system.

Selection of tool maker

Selection of workpiece material: strength, k_{c1x1}, z, E

Selection of type of machining: rough, intermediate, final

Selection of machine: P_{EM}, η, n_s

Selection of smallest and greatest cutting conditions: a_{min}, a_{max}, f_{min}, f_{max}, $v_{c,min}$, $v_{c,max}$

Selection of tool: κ, r, T

Selection of data on batch: PR, t_r, z_1, t_d, t_m, C_n

Selection of type of clamping:		
Machining of workpiece between tips	Machining of workpiece clamped on one side into clamping head and on the other side supported by tip	Machining of workpiece clamped into clamping head only

Entering of workpiece geometry: D, d, L, R_a

Calculation of optimum cutting conditions with respect to lowest manufacturing costs by taking into account cutting process limitations

Determination of the most favourable tool maker and related optimal cutting conditions

$v_{c,opt}$, f_{opt}, a_{opt}

Fig. 6. Definition of programme steps in OPTIS expert system

Symbols used in the OPTIS expert system:

k_{clxl} … coefficient for calculation of the main force
z … exponent for calculation of the main force
E ... modulus of elasticity
P_{EM} … electric motor output
η … efficiency of the machine
n_s … maximum number of revolutions of the machine
a_{min} …minimum cutting depth
a_{max} … maximum cutting depth
f_{min} … minimum feeding
f_{max} … maximum feeding
$v_{c,min}$ … minimum cutting speed
$v_{c,max}$ … maximum cutting speed
κ … adjustment angle
r … cutting insert radius
T … tool resistance of wear
PR … price of work station
t_r … time of non-production work
z_1 … number of workpieces in batch
t_d … additional time
t_m … time of tool replacement
C_n … tool price
D … initial diameter of workpiece
d ... final diameter of worpiece
L ... cutting length
R_a … average deviation of profile

10.4. Savings in selection of optimum cutting conditions

By selecting optimum cutting conditions and accurate planning of the machining process it is possible to reduce significantly the workpiece manufacturing costs [14]. To this end the data (cutting conditions) are available from the World Web (Internet) where the web pages of the tool makers can be found. The cutting conditions can also be selected from the tool makers' CDs [15]. Large batches of products imply the possibility of great savings. The concept of the manufacturing process includes the Internet as a means of assistance in planning of the technology. The OPTIS expert system needs some minutes for calculating the minimum manufacturing costs and the related cutting conditions. The manual process would need several months and is practically not feasible without the use of computer applications.

The OPTIS expert system is a great acquisition for all makers producing the products by turning. It is a great acquisition for the production. The results calculated by the OPTIS expert system clearly show that the value of the manufacturing costs changes very much depending on the selected cutting conditions already on one product. In cases of large batches of products the manufacturing costs change still much more. The OPTIS ensures careful control of the manufacturing costs.

By using the cutting conditions calculated by the OPTIS expert system it is possible to reach very low manufacturing costs increasing the profit. It is very much recommendable to use the OPTIS expert system in cases of large batches of products, since then the saving are much higher.

The OPTIS enables us to record how much the manufacture of some product can maximally cost. From this limitation of the

manufacturing costs the OPTIS calculates the related cutting conditions. So far, this has not been ensured by the programmes.

10.5. Accuracy of optimization in the OPTIS expert system

Accuracy of the optimization process depends on the steps in which v_c, f and a increase within the interval between the minimum and maximum value for the individual tool maker.

In the OPTIS expert system the step of increasing was determined with respect to the size of the interval so that too many mutual, combinations of cutting conditions are not obtained and that the desired accuracy of the optimization process is reached.

The OPTIS expert system is so conceived that the optimization accuracy is good and that it spends only a few minutes for the calculation. It pays to devote a few those minutes to optimization of the cutting conditions, since the manufacturing costs will be much lower.

The use of expert systems in agriculture is also described [16-18].

11. Conclusions

The integration of technological data bases and management systems is urgently necessary. There are very many different tool makers over the world and often one finds it difficult to select suitable tools. The integration in this area establishes order. The use of computers in production offers a possibility of using the media which can replace the book catalogs used so far. Some tool makers already offer technological data on compact discs. We expect that in the near future the users will obtain all necessary information on tools through Internet.

Nowadays many electronic catalogs for selection of tools and cutting conditions, in different forms, are accessible through Internet. The electronic catalogs have their advantages and disadvantages. The best are the catalogs in the FTP form because they ensure fastest and clearest determination of cutting tools.

A home page has been made, which contains connections to web pages of cutting tool makers and to some catalogs for selection of cutting tools that are accessible through Internet. It is accessible on the server of the Laboratory for cutting at the Faculty of Mechanical Engineering in Maribor under the URL address: http://www.fs.uni-mb.si/si/inst/ips/labod/start.htm

By selecting optimal cutting conditions it is possible to reduce significantly the workpiece manufacturing costs. To this end the cutting conditions are available from the global information network (Internet) where the web pages of the tool makers can be found. The cutting conditions can also be selected from the CDs of the tool makers. The OPTIS spends only a few minutes to calculate the minimum manufacturing costs and the relevant cutting conditions. The manual procedure would take a long time and is practically not feasible without the use of computer applications. The OPTIS expert system is a very useful aid for optimization of cutting conditions in turning. The program tends to select cutting conditions with lowest manufacturing costs. As the cutting conditions must satisfy also all the limitation

equations, the value of the manufacturing costs slightly increases. Thus the OPTIS selects the cutting conditions with lowest manufacturing costs so that they satisfy all the limitation equations of the cutting process.

References

[1] J. Kopac, M. Bahor, M. Sokovic, Optimal machining parameters for achieving the desired surface roughness in fine turning of cold pre-formed steel workpieces, International Journal of Machine Tools and Manufacture, vol. 42, no. 6 (2002) 707-716.

[2] F. Cus, J. Balic, Selection of cutting conditions and tool flow in flexible manufacturing system, Journal of Materials Processing Technology, vol. 118 (2001) 485-489.

[3] B. Mursec, F. Cus, Integral model of selection of optimal cutting conditions from different databases of tool makers, Journal of Materials Processing Technology, vol. 133 (2003) 158-165.

[4] M. Kovacic, J. Balic, Evolutionary programming of a CNC cutting machine, The International Journal of Advanced Manufacturing Technology, September 2003, vol. 22, no. 1/2, 118-124.

[5] B. Katalinic, V. Kordic, Integration of subordination and self organisation in working scenarios of bionic assembly system, DAAAM International Scientific Book 2003, DAAAM International Vienna, 2003, 319-330.

[6] B. Mursec, F. Cus, J. Balic, Organization of tool supply and determination of cutting conditions, Journal of Materials Processing Technology, 3 April 2000, vol. 100, no. 1/3, 241-249, Elsevier.

[7] Z. Adamczyk, D. Jonczyk, K. Kociolek, A new approach to a CAD/CAM system as a part of distributed environment: Intranet database, Journal of Materials Processing Technology, vol. 133 (2003) 7-12.

[8] S. Adamczak, Computer-aided systems for manufacture and measurement of machine elements, Science report, Project PL-1, Kielce, 2003, 301-310.

[9] B. Mursec: Integral model for the selection of optimal cutting conditions in the computer aided tool management system, doctor's thesis, University of Maribor, Faculty of Mechanical Engineering, 2000, Maribor.

[10] B. Mursec, A. Ploj, Expert system OPTIS for optimization of cutting conditions and modern information systems of selection of tools and cutting conditions in cutting processes, Strojarstvo, 2001, 43, no. 4/6, 169-175.

[11] M. Debevec, T. Perme, D. Noe, Simulation-aided management of cutting tools in a tool-making company, Journal of Mechanical Engineering, 49, no. 1 (2003) 16-27.

[12] U. Zuperl, F. Cus, Optimization of cutting conditions during cutting by using neural networks, Robotics and Computer-Integrated Manufacturing, 2003, vol. 19, iss. 1/2, 189-199.

[13] F. Cus, B. Mursec, Databases for technological information systems, Journal of Materials Processing Technology, vol. 157/158 (2004) 75-81.

[14] R. Bernik, J. Benedicic, J. Duhovnik, Conceptual design of a stable-manure spreader using a mathematical model, Journal of Mechanical Engineering, vol. 49, no. 11 (2003) 538-548.

[15] A. Ploj, B. Mursec, F. Cus, U. Zuperl, Characterization of machines for processing of waste materials, Journal of Materials Processing Technology, vol. 175, iss. 1/3, (2006) 338-343.

[16] M. Janzekovic, B. Mursec, F. Cus, A. Ploj, I. Janzekovic, U. Zuperl, Use of machines for liquid manure aerating and mixing, Journal of Materials Processing Technology, vol. 162-163, no. 1 (2005) 744-750.

[17] C. Rozman, K. Pazek, M. Bavec, F. Bavec, J. Turk, D. Majkovic, The Multi-criteria analysis of spelt food processing alternatives on small organic farms, Journal of sustainable agriculture, vol. 28, no. 2, (2006) 159-179.

[18] B. Mursec, M. Janzekovic, F. Cus, U. Zuperl, Comparison of rollers after sowing of buckwheat, Journal of Achievements in Materials and Manufacturing Engineering, Jul.-Aug., vol. 17, iss. 1/2, (2006) 269-272.