DISAP
A DIALOGUE ORIENTATED PROCESS PLANNING SYSTEM

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Abstract

The EDP-system DISAP represents today an efficient, self contained software pakkage to plan manufacturing parts. It has been developed at the Laboratory for Machine Tools and Production Engineering, Aachen (WZL), in cooperation with the German aircraft industry. The high degree of requirements concerning the flexibility of planable parts, accuracy of planning and the ability to integrate the system into the existing EDP-environment were regarded during the system development. So, with less expense it is adaptable to minor demands of companies, too.

Thus, DISAP became an universal aid with a broad application for process planning. The present report gives an impression about the main system features and describes the philosophy of processing logic.

1. Introduction

In many companies today the reality of process planning is described by a lot of manual, repetitive work with only conventional aids. In some cases the support by computer is only dedicated to the administration of process plan data.

The need of computer systems to support the generation of process plans is doubtless evident and this support can lead to greater efficiency in the planning department and to higher accuracy of plan data. Different developments in the field of computer aided planning (CAP) underline this statement and show the state of art /1,2,3,4,5,6/.

Designing such process plan generation systems a close regard to the data exchange with other systems, like CAD- or CAM-systems must be kept to provide an optimum flow of information.

The process planning system DISAP fulfills all requirements mentioned above and is one of the most capable systems which are available. /7/

2. General system features

The DISAP system can be used just as a stand-alone-system or as a component integrated into a complex manufacturing system ranging from design to NC-programming. DISAP is dedicated to generate process plans for single part manufacturing of every fabrication technology whose relating different parameters - in completion with the demand that all calculation methods are applicable - need an interactive flexible system architecture which is explained as follows.

The operating principle is a rule based

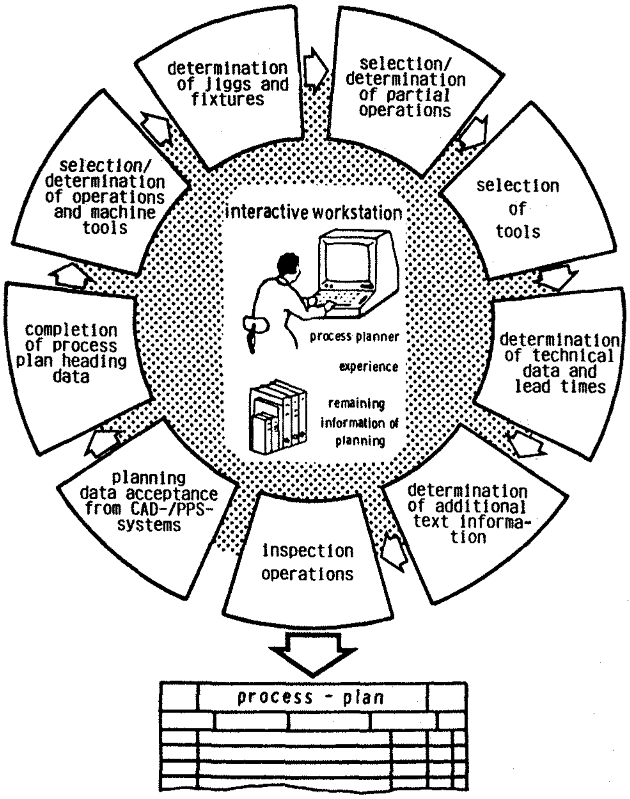


figure 1: functions of the system DISAP

data processing which builds up a process plan step by step, different from the often used group technology approach. The step by step generation devides the whole system into nine sequenced functions representing the usual way of planning (figure 1). Like on a red thread the user is lead through the generation from one function to the other. Only the system decides whether it is necessary to use the next or a foregoing function just in relation to the present planning task.

3. System functions

3.1 Planning data

The system initializing actuates the extraction of the relevant planning data from the interface to a CAD- or production-control-system if there is one. Usually the identification of these data is made by stating the identification number of the part to be planned.

3.2 Process plan heading data

Subsequently, in the next function, the remaining work is only to complete the header of the process plan, because many of the part describing, raw material defining, and organizational data are given by the designer. A formal and logic check of all planner input is done and if the planner changes a given data, e.g. the length of raw material, the system examines whether the relating data must also be changed, e.g. identification of the raw material.

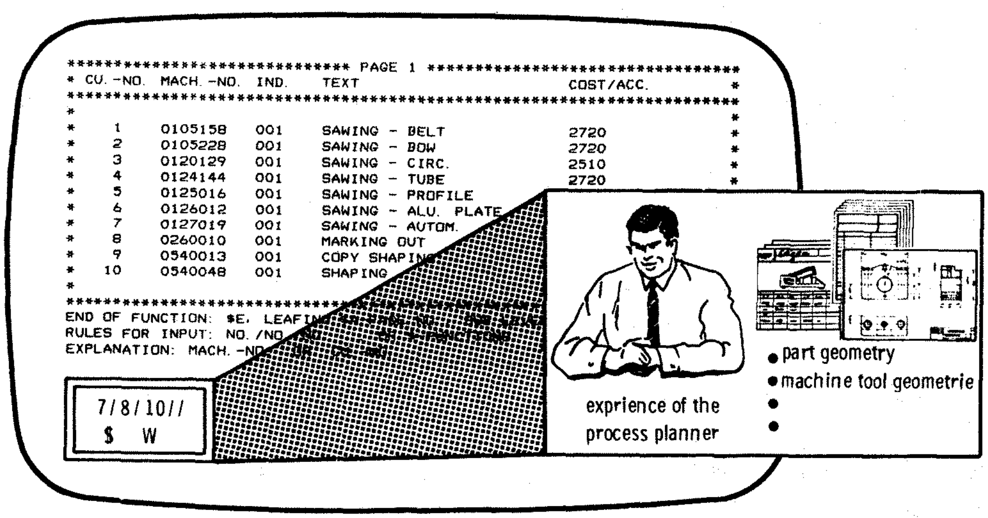


figure 2: procedure to select processes and machines

3.3 Operations and machine tools

For a maximum flexibility the selection of operations is supported by menu technique (figure 2). Standardized sequences of operations may be linked to one operation to get a complete work cycle of several operations.

So the result is a change of the number and the kind of decisions the process planner has to make. In case of an extremely reduced menu the planner only has to check the suitability of a machine. But if he misses a special machine he

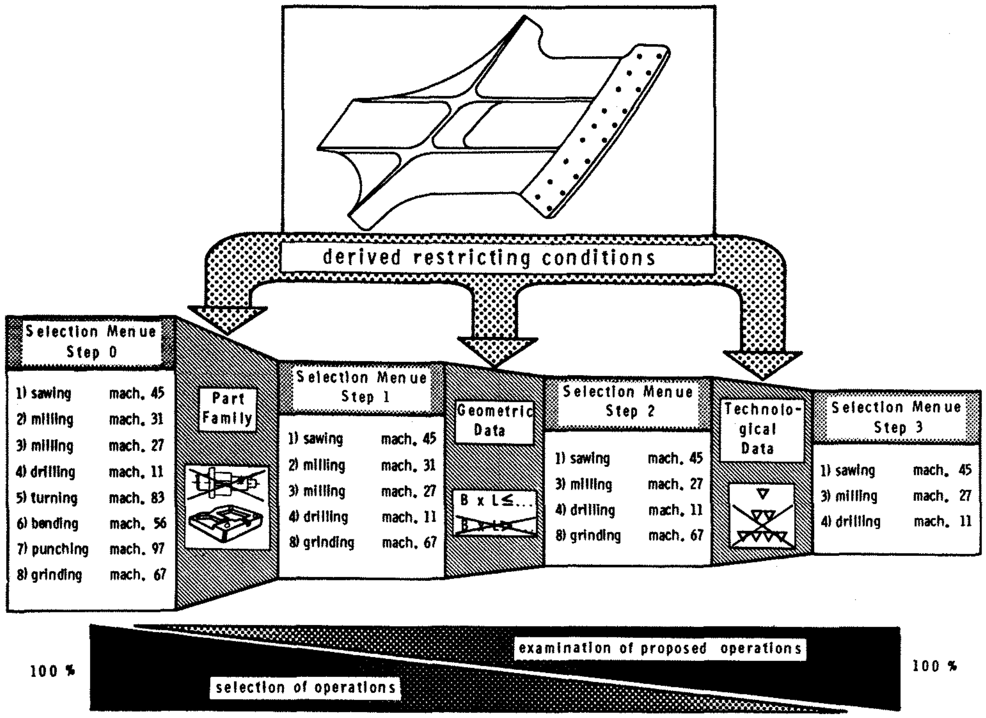


figure 3: part features to reduce number of selectable processes in DISAP

The current number or the machine-number identifies the selected operation and - in one step - the accessory machine. To help the planner to find the adequate machines the operations are roughly sorted in the right technological order, deduced from the analysis of existing process plans.

The next higher level of computer support is to reduce the number of selectable machines and operations by interpreting the part data or other relevant data (figure 3). For example, this may be the number of a special group of parts, i.e. a special group of machines. But these may also be part features which only have roughly to define the part in order to get a markable reduction in selectable machines.

needs, which is withdrawn by the reducing function, the system offers all facilities to modify an operation sequence interactively.

3.4 Jiggs and fixtures, partial operaions, operation data and text information

After operation and machine selection the system starts automatically to determine the data belonging to each operation which range from jigs and fixtures to additional text information. The principle here is that only those parameters must be determined by the process planner which cannot be derived from system-known-data (figure 4). The size and number of system-known-data grow during

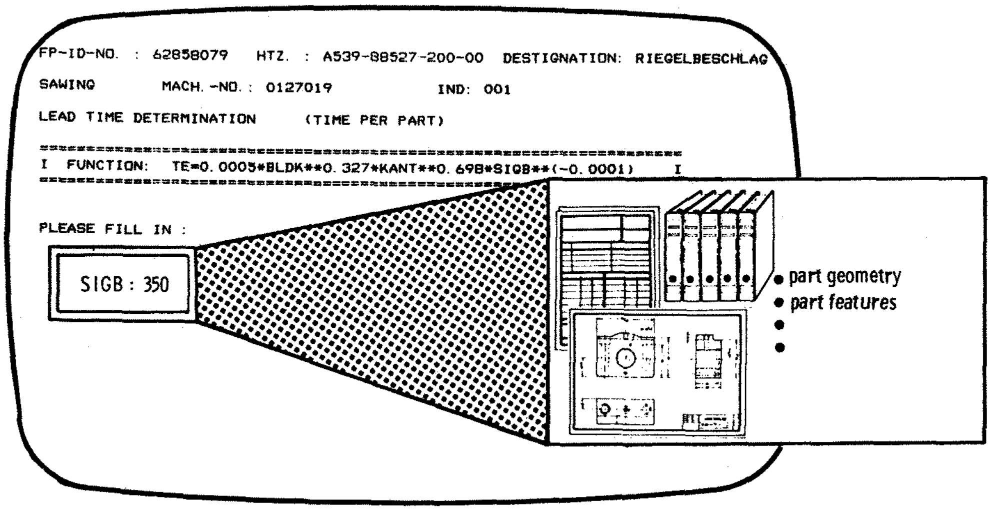


figure 4: interactive lead time determination in defining relevant formular parameter

the planning session so that interactive operations between man and system become less frequent.

The determination of operation data is practical on two levels: on the rough level of one operation and on the detailed level of several partial operations of one operation. In this way, any demand on the exactness of process data can be fulfilled.

The use of the detailed level is appropriate to plan complex machining operations like turning, milling and s.o. by deviding them into the necessary partial operations (clamping, face milling, boring...). The lead time for a milling for example, is in consequence the result of the summation of the operation lead times.

3.5 Inspection Operations

Inspection instructions are often an integral part of process plans for complex workpieces. By means of integration it is planned to find out defects already during the production to reduce the defect costs. A comparison of the generation of process plans and inspection plans shows a large similarity to the contents of planning (figure 5):

- the number of planning functions is comparable
- the planning functions are similar
- fixed sequence relations partly exist between the single planning functions

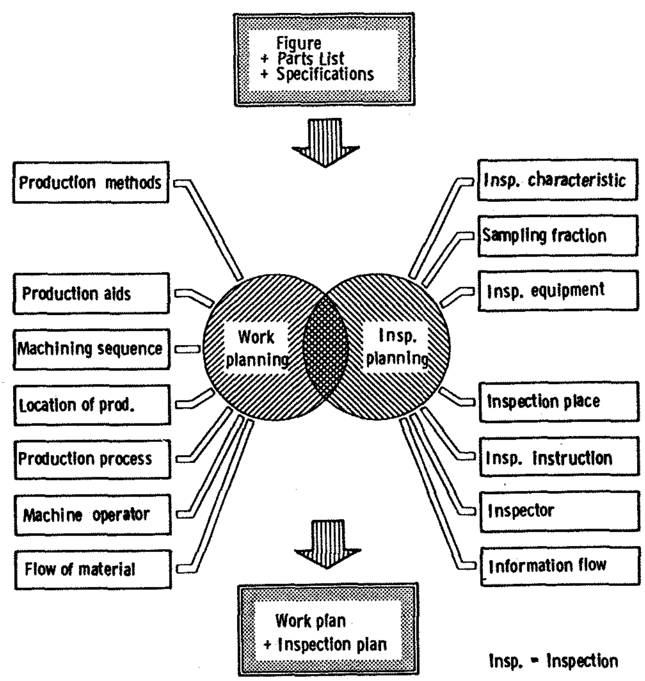


figure 5: Contents of process plan and inspection plan generation

An analysis of inspection plans containing inspection instructions assigned to each operation revealed that 90 % of all operations had to be provided with up to five inspection characteristics. To a large extend it is even possible to assign one inspection characteristic to one operation.

Therefore with each process operation there should be planned a (necessary) inspection simultaneously. In addition the similarity between the contents of process planning and inspection planning makes it possible to use the system functions of process planning in order to generate inspection instructions.

At the moment, inspection instructions can only be planned as independant operations in the DISAP system. The inspection instruction as a part of an operation with the corresponding assignment of inspection characteristics is planned for further development. For generating the inspection instruction, a similar planning sequence as for the determination of the operation data becomes necessary.

First of all, the needed inspection characteristic is selected on the basis of the operation related inspection characteristic menu. By selecting an inspection characteristic the related code number is defined. This code number serves the assignment of suitable inspection devices.

A detailed classification and description of the test devices is necessary to an automated selection of test devices. The most significant describing elements are the inspection characteristic related coding, the measuring range, and the uncertainty of measurement (figure 6).

By comparing the inspection characteristic coding with the code numbers of the data block of an inspection device a

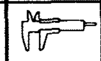
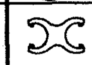
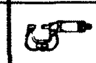
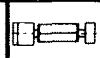
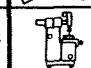
catalogue of inspection devices	attribute related coding	unit of measure	test method	measuring range	uncertainty in measurement	symbols
steal measuring tape	G10	mm	V	0 - 100	0,25	
caliper rule	G10	mm	V	0 - 200	0,04	
measuring instrument for thickness	G11	mm	V	0 - 10	0,01	
limit snap gauge	G11	mm	A	300 - 300,05	0,02	
micrometer screw	G11	mm	V	0 - 50	0,01	
tolerance plug gauge	G12	mm	A	299,5 - 300	0,02	
all purpose bevel protractor	G20	Grad	V	0 - 360	0,03	
coordinate measuring machine	G10 G20 G42	mm	V	0 - 650	0,05	
radius gauge	G33	mm	A	50	0,1	

figure 6: catalogue of test devices for computer aided test device selection

specified inspection device can be investigated with regard to its technical suitability. The next step contains an investigation of the measuring range with the upper and lower limit of the inspection characteristic. Subsequently the inspection characteristic tolerance is compared with the uncertainty of measurement of the test divice.

If there is more than one test device available for the fulfillment of the task after having finished this comparison, the final selection can be determined by economic criteria or even be executed interactivly.

By use of integrated inspection instructions in the process plan, a constant sampling fraction of inspection should be present due to the following reasons:
A process plan containing optimal conditions for a given operation should be applied unchanged. Using an inspection

plan the intention is to reduce the sampling frange of inspection whenever adequate inspection results are achieved.

The necessary data for the completion of inspection instructions are for example inspection place and inspector. These data are mainly determined interactively.

4. Conceptual Design

The conceptual design of the DISAP system, regarding the process data determination, is based on a control matrix which includes the determination procedure for each operation (figure 7). These rules consist of two numbers:

- the processing indicator to define the way for the determination (function, table, direct-planner-input...)

- the rule number to identify the function, table etc. in the relating data base

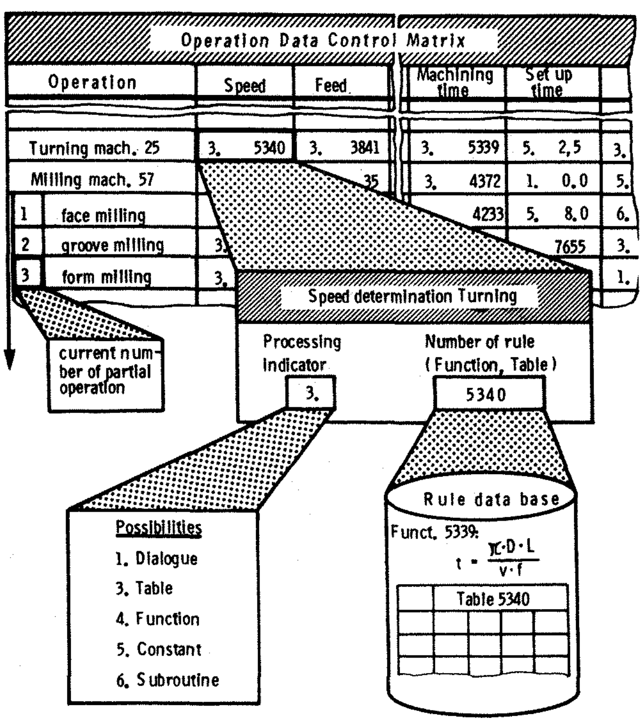


figure 7: principal technique to determine operation data in DISAP

The rule matrix contents all relevant planning parameters of an operation or partial operation, and the accessory rules which may include further parameters for its determination.

Decision tables offer the possibility to select automatically the determinative function/table in relation to defined decision parameters. This technique permits to build up a branched out, complex planning logic without special knowledge of a programming language, because any basic planning data, like tools, machine performance, material characteristics, and any planning logic is installed in data bases with a structure which is easy to maintain.

In addition, some other facilities support the following action (extract):

- *reproducing of a completed calculation*

- restart of an interrupted planning session without loss of information

- manipulation of the operation sequence in a finished plan

- data securing during the planning session to avoid loss of information of the operating system

5. Interface to other systems

As a stand-alone-system the generated process plan data can be used for direct printing, as integrated into a management system environment, the information are transfered by a direct interface.

Not only the complete process plan depicts the output of DISAP, but all information necessary to generate the plan (figure 8). The big advantage of this generation record is the possibility to use it for documentation to changed con-

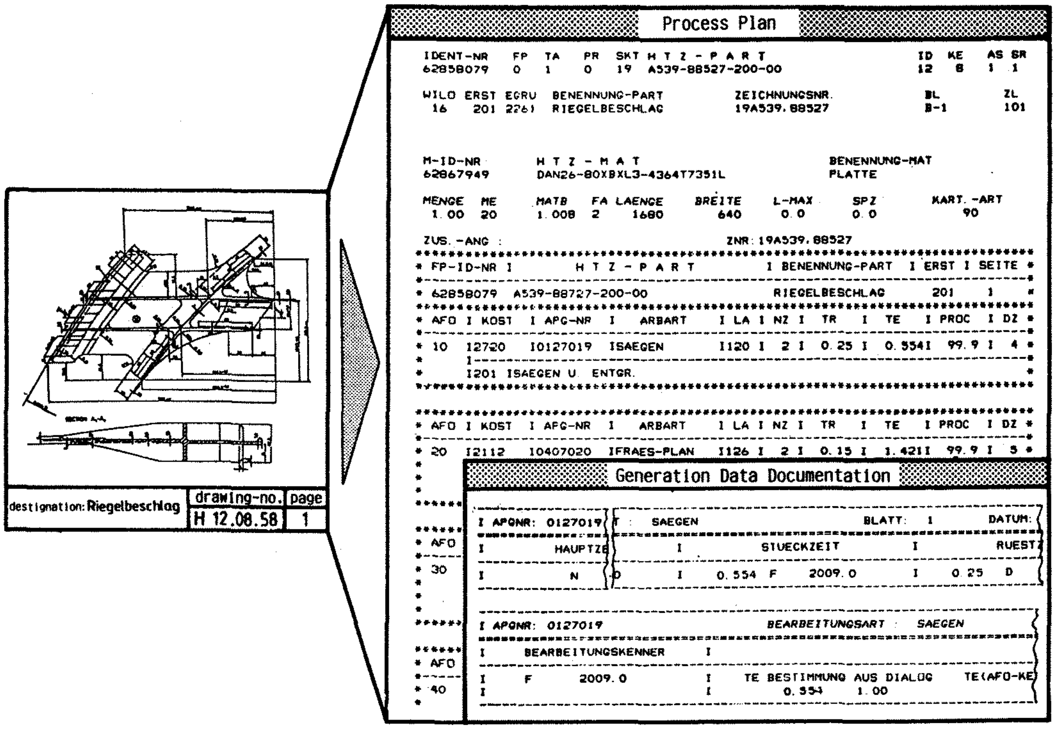


figure 8: DISAP-generated process plan with recored generation data

ditions or for a similar part is much easier than without this information, because the planner can reproduce the old calculation and then can go ahead with selective interventions.

The data interface is created as a structured data file and it is capable to contain not only input data from linked systems but all data DISAP produces (figure 9). The DISAP operates independently from the size of the file and its degree of completion.

This means that the completion of the DISAP output is not influenced by the input for a generation. Only the degree of automation and the number of interactive steps depend on the size of the file. In a borderline case the interface data file contents complete process plans with all belonging information.

The universal file structure is only orientated to the needs of the process plan generation in DISAP and not dedicated to a special CAD- or production control system, so it can be used for all

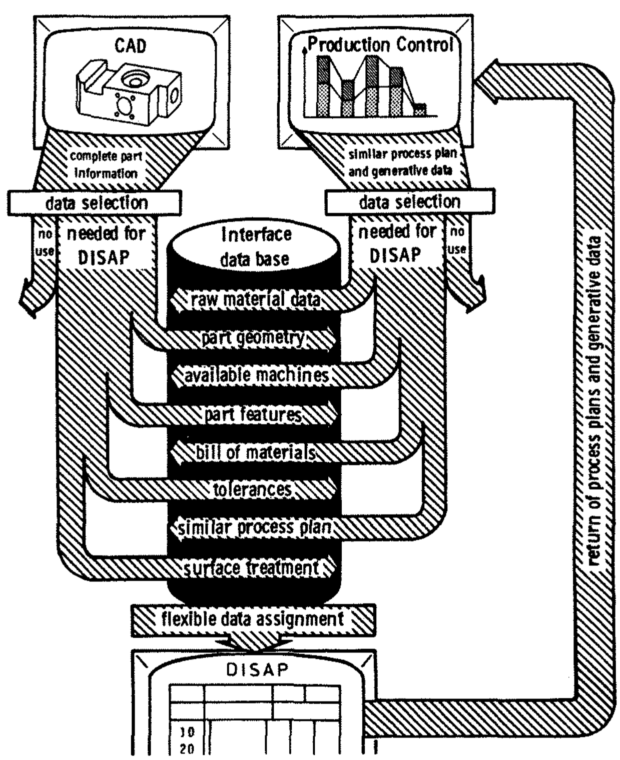


figure 9: DISAP interface to CAD- and Production Control-systems

kinds of linkage to other systems.

6. Example of a linkage system

The described data interface is used by the DISAP-system to generate process plans. To link it with CAM-systems, information on DISAP can be used for the completion of a CAD-workpiece description. Additional information about intermediate manufacturing stages and about inspection characteristics, are necessary for an automatic generation of NC-programs for machine tools and, especially,

coordinated measuring machines (figure 10). The linkage of CNC-coordinate measuring machines have hardly been realized yet in contrast to the linkage of CNC-tools. The preconditions and possibilities for the linkage of CNC-coordinate measuring machines are discribed as follows /8/.

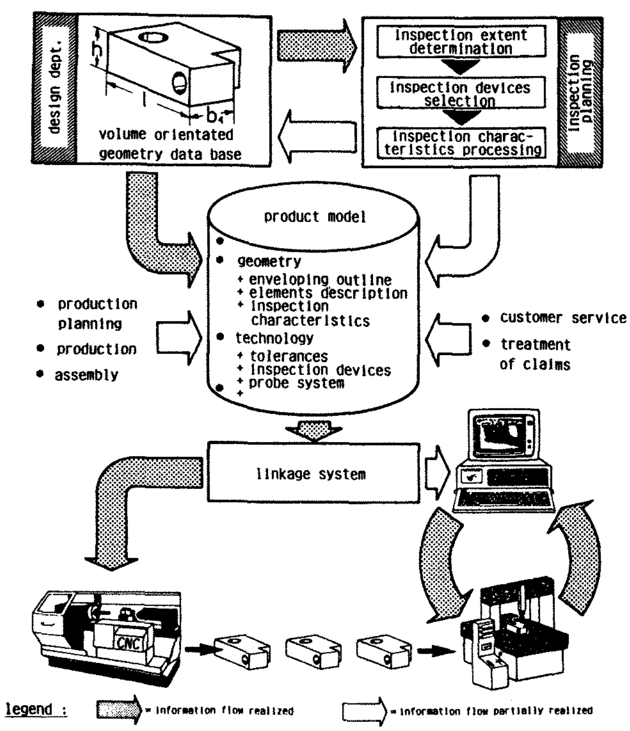


figure 10: "product model" as an extended workpiece description

An extended workpiece description is absolutly necessary for a completely automated generation of part programs for CNC-coordinate measuring machines. Additionally needed information as e.g. about selected inspection characteristics and tolerances must be put together out of all planning departments being concerned with the product generation (figure 10).

A volume oriented geometry data base is a precondition for the usage of CAD-data which enables to link single elements computer internal, and to determine their common bounderies. By this a definite statement on which side of each surface the material is to be found can be made. This is the only way how path direction can be derived automatically. The completely different demands of the coordinate measuring machines programming, and the NC-machine tool programming do not allow a uniform structure of linking mechanisims. In contrast to NC-machine tools a data backflow takes places in form of measuring point coordinates being used for further processing in the controlling/ evaluating computer.

These evaluations, usually a comparison between measuring results and desired data, have to be regarded in the inspection program and lead to a complex program structure.

The complete inspection routine on the basis of the workpiece description requires all information necessary for the generation of control sequences. As far as the geometry is concerned, this requires a description of all workpiece elements. A precise description of the elements belonging to the inspection characteristics are necessary. A rough description of the remaining shell is sufficient for the automatic path generation (figure 11).

Tolerance indicators and parameters are

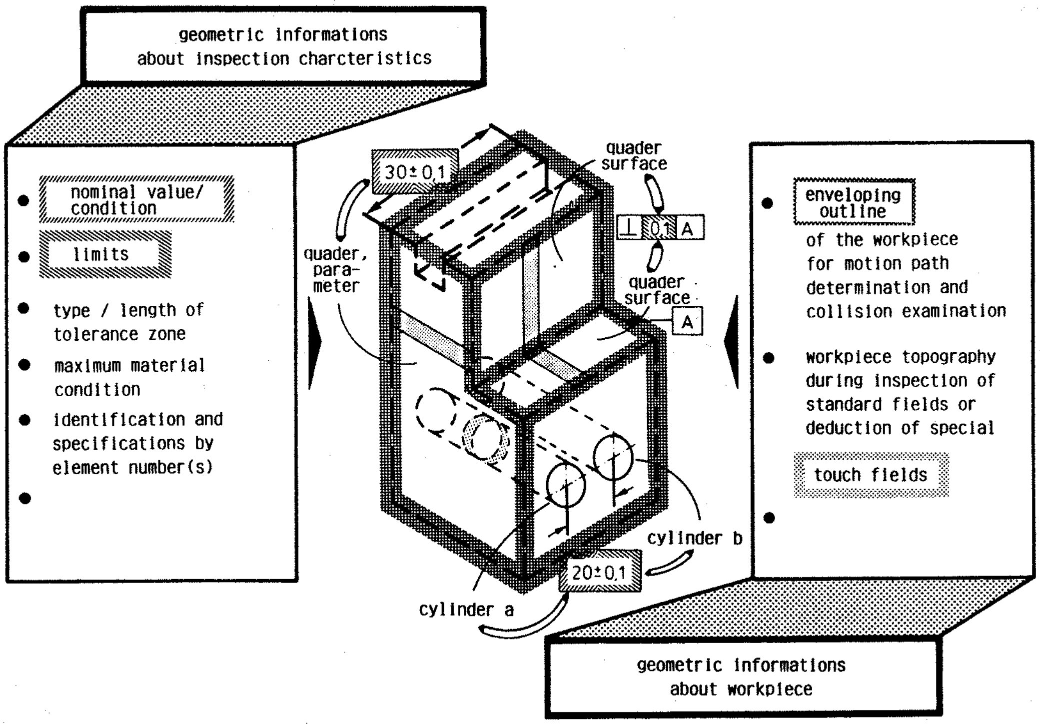


figure 11: Demands on the geometry description

necessary for the generation of measuring and evaluaion orders and for the comparison of the desired and real values. Indicators for identification and relation guaranteeing a linkage between the desired data and the geometry elements have a special significance in this context.

The remaining geometry information to the workpiece, i.e. to the shell, must be known to determine the probe path between two inspection characteristic measurings. The indication of one or more elements is not sufficient for some measuring tasks. The definition of the rectangularity shown in figure 11 can also require indications in which range the surfaces formed by the angles can be touched./9/

In analogy to the geometry additional demands on the technology input result from the automatic generation of part programs. Technological instructions are normally specified for particular part programs. The automated generation can only be achieved with great effort. Thus, for each part programm it has for example to be defined in advance what kind of probe is used.

The most important tasks of the desired and partly realized linkage system on the basis of the described preconditions are:

- issue of test relevant information out of the CAD system

- Completion of this information by the operation planning (e.g. with information from the DISAP system)

- generation of control data for a CNC-coordinate measuring machine

For first development activities, the volume orientated and therefore well appropriate CAD-system DETAIL 3 was used. It was developed at the Laboratory for Machine Tools and Production Engineering, Aachen (WZL). The off-line programming system NCMES (Numerically Controlled Mea-

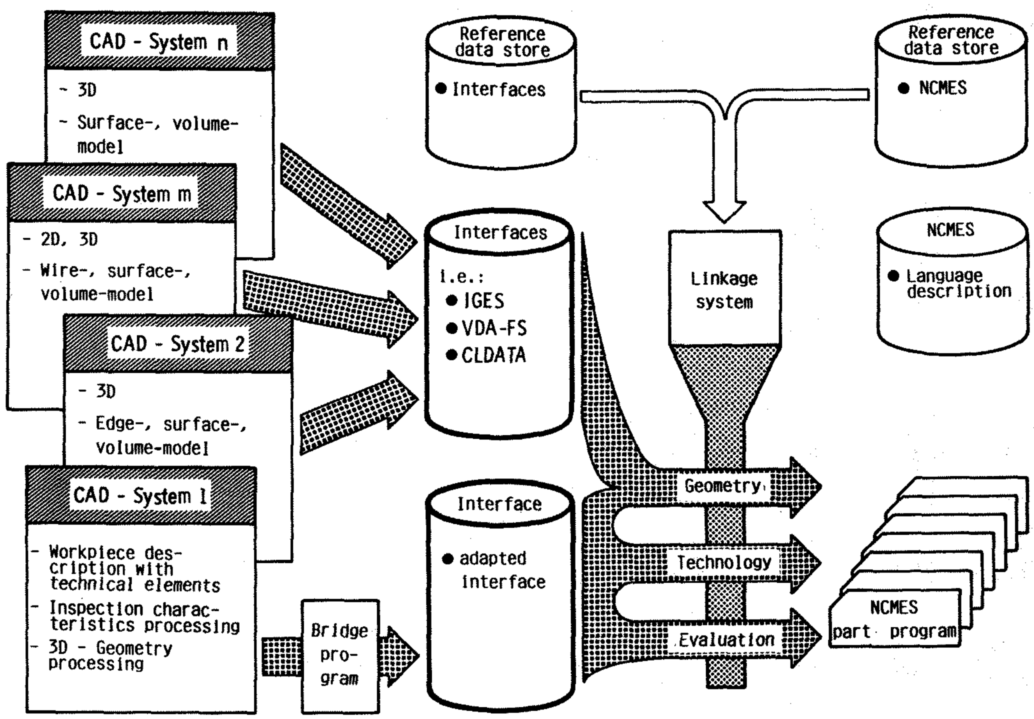


figure 12: linkage of the system NCMES with different CAD-systems

suring and Evaluation System) is used as an interface for CNC-coordinate measuring machines.

To acquire various possibilities of linkage it is planned to analyse and select various CAD-systems (figure 12). In this context interfaces being appropriate for a linkage of the automated inspection should also be investigated.

7. Conclusion

In this paper an interactive process plan generation system (DISAP) is presented as a high efficient and flexible aid to support conventional process planning.

This is an existing system which application will soon be completed in a factory of the aircraft industry for single part manufacturing of all kinds of parts. The free selectable degree of automation gives no restriction to the use in every stage of system introduction. The company specicific adaption is only to be made by changing the contents of the permanent data bases and not changing the program.

The procession of the planning functions represents the natural way of planning and in connection with a user friendly designed screen layout supports the acceptance of this new technology.

For further development, especially the operation related generation of inspection instructions is planned. For the realization of CAD/CAM-systems, necessary data can be made available for an automatic generation of part programs for CNC machine tools as well as for CNC-coordinate measuring machines.

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