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CLASSIFICATION OF MACHINED MATERIALS FOR COMPUTER AIDED MANUFACTURING PROCESS

Summary. The paper describes the idea of automated classification of machined materials based on the philosophy represented by a well known tool manufacturer Coromant. Thanks to this the classification can be realized on the basis of essential material data like chemical composition, structure and hardness. The proper classification of materials, tools and machine tools is important for building CAD/CAM systems including data bases.

1. Formalization of the task and basic assumptions

Classification is a process in which facts or objects are assigned to classes and sub classes according to the most important features possessed by these facts or objects. The features according to which the classification takes place is called the basis of division.
Classification should be performed in agreement with the following formal logic rules:

- the selection of classes should be done only according to the basis of division,
- sub classes, obtained as a result of classification, should exclude each other,
- sub classes division should be regular,
- sub classes division should be continuous, without skipping.

If we assume that K is a class which was divided to a number of sub classes k_1, k_2, ..., k_n according to a certain feature then the rules described above can be written in the following way:

$$k_1 \cup k_2 \cup k_3 \ldots\ldots \cup k_n = K \qquad [1]$$

$$k_1 \cap k_2 \cap k_3 \ldots\ldots \cap k_n = \emptyset \qquad [2]$$

$$k_i \cap k_j = \emptyset \quad \text{for each pair } i,j,\ i=j$$

Hierarchy (subordination) and interdependence are the basic relations between particular classified elements. Hierarchy is a relation in which a class is a sub class of another more general class. Hierarchy takes place between a class K and a sub class k_i ($k_i \subset K$, $i=1, 2, 3, \ldots n$), while interdependence takes place between sub classes k_1, k_2, k_3,.....k_n ; ($k_1 \subset K$, $k_2 \subset K$,....,$k_n \subset K$). Sometimes, two kinds of hierarchy are distinguished: strong and weak. As to the strong hierarchy each sub class has one and only one preceding class. As to the weak hierarchy each sub class has more then one preceding class. Classifications which have only strong hierarchy and interdependence are called hierarchy classifications. This kind of classification is widely used for construction materials and is a starting point for the classification of machined materials [1]. Taking into account existing classes it is necessary to systematize materials according to their machinability i.e. machining properties. It is assumed that machinability describes mainly machined material and only in a very limited way depends on the features of tool material, the status of a tool, kind of machining, the status of a machine tool and cutting conditions. Moreover, it is assumed that properties of machined materials depend mainly on the chemical composition, structure and hardness. Metallurgical process is less important. Cutting speed and the roughness of machined surface are basic practical indicators of machinability.

Good machinability should commensurate with high cutting speed under established tool life and small roughness of machined surface.

To make the result of classification independent from the necessity of getting data concerning cutting speed and roughness, only the first indicator has been taken into account using experimental dependence between hardness and cutting speed. Due to this the classification can be based on data taken from catalogues concerning properties of construction materials. On the ground of chemical composition and structure a specify class can be established while mechanical properties (hardness) of material serve as a base for establishing a sub class. When the mechanical properties of material are characterized only by its tensile strength it is recalculated to corresponding hardness.

The number of sub classes depend on an arbitrary adopted range of hardness [HB_{min}, HB_{max}] which decides about the

membership of material to a sub class. It has been decided to set 75 [HB] as the beginning of the first range and a step equal 50 [HB] has been chosen. The upper limit is 375 [HB]. The total number of sub classes depends mainly on the number of arbitrary chosen classes. Classifications proposed by Seco [3] and Coromant [2] can be thought to be extreme. For ferrous metals Seco applies three classes :

- steel with five sub classes,
- special steel with two sub classes,
- cast iron with three sub classes.

Coromant uses in its classification ten classes. The total number of sub classes is 26 in comparison with 10 sub classes proposed by Seco.
Notwithstanding the fact that Seco classification provides us with more compact set of data, for the computer program of automated classification the idea proposed by Coromant has been chosen. This classification is also adopted by Polish manufacturer of carbide inserts [4]. Data for this kind of classification has been collected and organized in a decision tree. The part of the tree presents fig. 1.

2. Computer program for automated classification of machined materials

A prototype computer program for automated material classification has been built by authors [5]. The program was written in language C and runs on IBM PC computers. The simplified algorithm of the program presents fig. 2.
The program has a classification procedure which acts on the basis of the knowledge organized in a set of rules. In this prototype version rules are part of the program. It is planned to separate the set of rules from the main body of the program so as to enable the user to modify the rules in an easy way. This would be in agreement with the principles of building expert systems. The program reads data from a text file from a disk. This file must be placed in a current catalogue. The file consists of materials which Coromant classification group and hardness had been establish during preceding sessions.
At the beginning the program asks the user to input the name of the material and its hardness if the material had been previously hardened. If data input format is incorrect, the program prompts the user to correct the input data. If the user input is blank i.e. the user presses ENTER without writing any name, the program tests if any new materials were introduced during the current session and if so, the text file is modified and new materials are added to the data base.
When the user writes the input data correctly, the program looks for the name of the material in the data base. If the material is in the data base the proper Coromant material classification number, and hardness of the material are presented to the user. If not, a classification procedure is called. Then, the user is asked a set of questions concerning

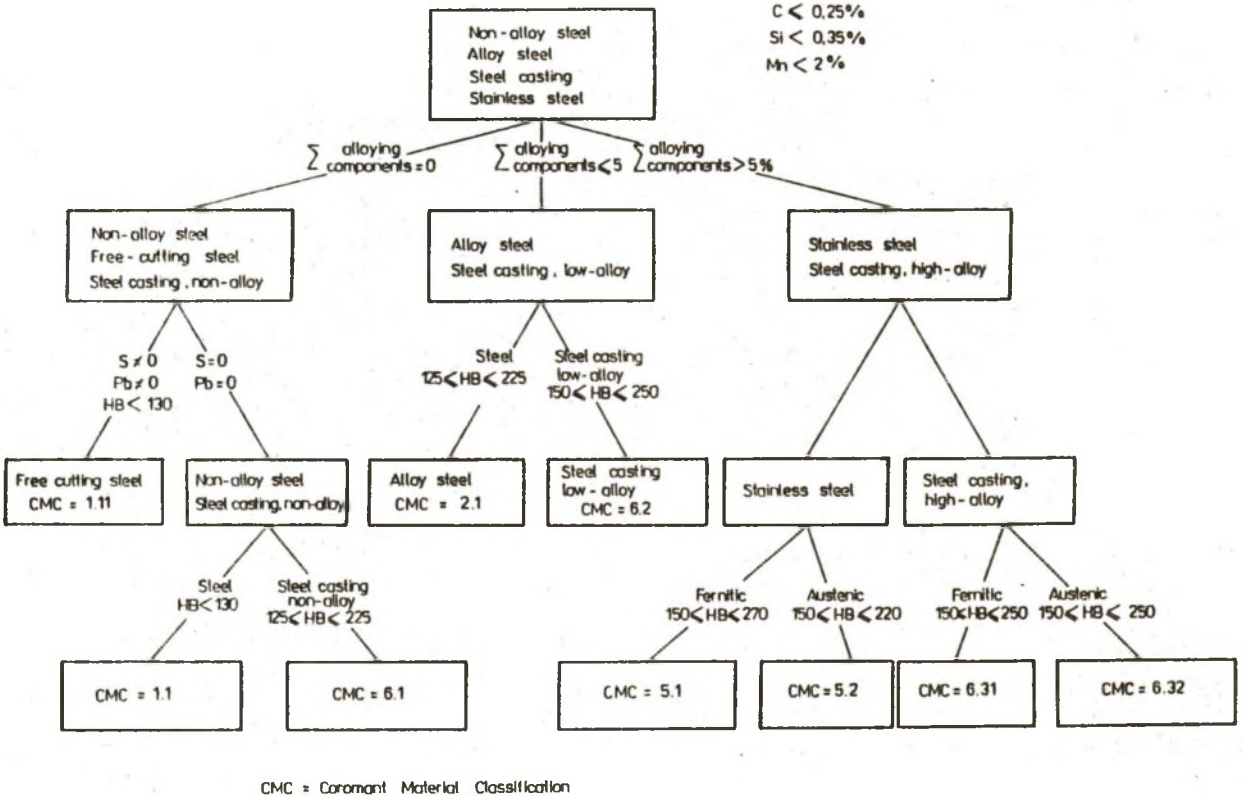

Fig.1.A part of a classification decision tree

chemical composition and hardness of the material. Some rules concerning the classification of steel are presented below.

```
if(       carbon(&s)<=0.25     &&
          alloy_comp(&s)==0.0     &&
          !Pb_S(&s)            &&
          steel(&s)             )
     strcpy(group_cor,"1.1");

else
if(       carbon(&s)<=0.25     &&
          alloy_comp(&s)==0.0     &&
          !Pb_S(&s)            &&
          cast_steel(&s)          )
     strcpy(group_cor,"6.1");

else
if(       carbon(&s)<=0.25     &&
          alloy_comp(&s)==0.0     &&
          Pb_S(&s)              )
     strcpy(group_cor,"1.11");

else
if(       carbon(&s)<=0.25     &&
          alloy_comp(&s)>0.0      &&
          alloy_comp(&s)<=5.0     &&
          steel(&s)             )
     strcpy(group_cor,"2.1");

else
if(       carbon(&s)<=0.25     &&
          alloy_comp(&s)>0.0      &&
          alloy_comp(&s)<=5.0     &&
          cast_steel(&s)          )
     strcpy(group_cor,"6.2");
```

It can be seen that the rules are understandable for a non professional in C programming. The classification procedure matches IF part of the rule with data provided by the user. If they agree the classification number is established. If not the next rule is tested. Data entered by the user fill the working memory of the system. Due to this solution the user is asked only the questions which are necessary for testing the current rule and the user had not answered them yet. When the classification group is established (taking into account chemical composition of the material) the correction of the group takes place taking into account the hardness of the material. To do this the user can enter the hardness of the material or its tensile strength R_m. The classification group may change when, for example, it turns out that the material was hardened. Next the classification number and hardness together with the name of the material are displayed and when ENTER key is pressed the data base is complemented. These data are sufficient for further calculations of cutting data.
The program described above is to be the first module of a

program for the selection of machining parameters using the idea of expert systems [6].

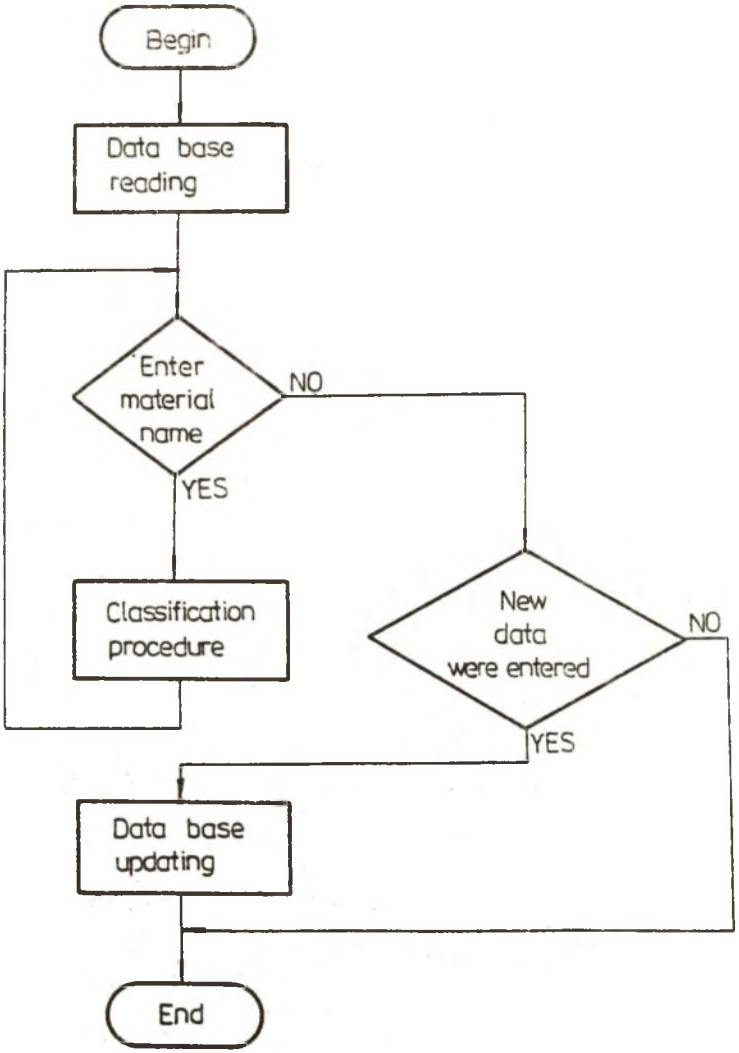

Fig. 2. Algorithm of the classification program

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KLASSIFIZIERUNG VON BEARBERTENDEN MATERIALEN FÜR DIE RECHNERUNTERSTÜTZTEN FERTIGUNGSPROZESSEN

Zusammenfassung

Im Referat wurden die Methode und das Programm der automa-tischen Klassifizierung von Konstruktionsmaterialen in Hinsicht auf die Zerspanfähigkeit dargestellt. Die angewandte Grundlage der Gliederung von Materialen ist mit den von Firma Coromant angenmmenen Prinzipen vereinbart, so daß die maschinelle Mate-rialklassifizierung auf dem Grund der Daten über grundlegende Eigenschaften, zum Beispiel die chemische Zusammenzetzung, die Struktur und die Härte, durchgeführt werden kann. Das Systematisieren der Konstruktionsmaterialen von Werk-zeugen und Werkzeugmaschinen ist der Schlüßel von den, auf den integrierten Datenbanken gestützten CAD/CAM-Systemen.

KLASYFIKACJA MATERIAŁÓW OBRABIANYCH DLA KOMPUTEROWO WSPOMAGANYCH PROCESÓW WYTWARZANIA

Streszczenie

Referat opisuje metodę i program automatycznej klasyfikacji materiałów konstrukcyjnych ze względu na ich podatność na obróbkę skrawaniem. Przyjęta podstawa podziału materiałów jest zgodna z zasadami przyjętymi przez firmę Coromant. Dzięki temu maszynowe klasyfikowanie materiałów może być przeprowadzone już na podstawie danych o podstawowych własnościach materiałów, takich jak skład chemiczny, struktura i twardość. Systematyzowanie materiałów obrabianych, narzędzi i obrabiarek jest kluczem do systemów CAD/CAM opartych na zintegrowanych bazach danych.

Wpłynęło do redakcji w styczniu 1992 r. Recenzent: Jan Darlewski