https://doi.org/10.26552/com.C.2000.1.45-50

KOMUNIKÁCIE
COMMUNICATIONS

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KÓDOVANIE A KLASIFIKÁCIA AKO ASPEKT PRUŽNOSTI SYSTÉMU PRE TECHNOLÓGIU PLOŠNÉHO TVÁRNENIA

A CODING AND CLASSIFICATION AS AN ASPECT OF SYSTEM FLEXIBILITY IN SHEET METAL MANUFACTURING

Priemysel vo zvýšenej miere čelí potrebe rýchlo a účinne odpovedať na stále sa meniace požiadavky trhu. Táto potreba je čiastočne spôsobená uvedením vysokého stupňa pružnosti do všetkých priemyselných fáz, hlavne do spracovania. Myšlienka skupinovej technológie(GT) sa vo veľkej miere aplikovala do oblasti rezania kovov. V mnohých prípadoch sa dosiahli, čo sa týka produktivity, značné výsledky. Avšak doteraz je len málo správ o práci s použitím GT pri technológii plošného tvárnenia. Na vzostupe sú plošné kovové časti vyrobené v procese plošného tvárnenia s/bez plastickej deformácie (stláčanie, perforovanie, ohýbanie atď.) Tento sa stáva jedným z hlavných výrobných procesov. Jeden z možných dôvodov obmedzenej aplikácie GT pri technológii plošného tvárnenia by mohol byť chýbajúci vhodný systém kódovania a klasifikácie. Z uvedených výsledkov vyplýva, že navrhovaný koncept GT by zvýšil flexibilitu systému výroby.

Industry increasingly faces the need to respond rapidly and effectively to ever changing market demand. This need is partially met by introducing a high degree of flexibility into all industry phases, especially manufacturing. Group technology idea has been widely applied to the metal cutting area. In many instances, significant productivity gains have been achieved. However, very little work has been reported in applying GT in the sheet metal manufacturing. Sheet metal parts produced in sheet metal process with/without plastic deformation (pressing, punching, bending, etc) are on the increase. These processes are becoming one of the major manufacturing processes. One possible reason for the limited GT application in sheet metal manufacturing could be the lack of a suitable coding and classification system. Results indicated here say that the proposed GT concept would increase production system flexibility.

1. Introduction

In today's competitive environment market computer integrated manufacturing and computer integrated systems must be flexible. In these systems we use computer technology to integrate manufacturing activities such as design, production and process planning and control, programming, production automation, etc. The flexibility of manufacturing system is one measure of its ability to adapt to market demand, technology changing and production process conditions. Zelenovic has described flexibility as the probability that a given production system structure will adapt itself to changing environmental conditions within a specified time and within the limits of given design parameters. Flexibility has value only when there is uncertainty in these changing conditions [8].

In GT-concept, workpieces with similar characteristics are grouped into families in order to facilitate design and manufacturing processes, quality control and assembly. For design applications, a part family would involve a group of workpieces with similar shape or with some other similar design attributes. If such part families are available, the effort in designing a new part can be greatly reduced if the part is similar to the existing one. Also, the same principle is valid in activities as manufacturing process, assembly, quality control, etc.

There is no detailed explanation here about other advantages for using group technology concept. Also, in this article will be elaborated no other developed classification system based on GT concept which are well known in scientific circles.

The system classifies the sheet metal part spectrum into groups with defined similarities and/or features with the aid of a computer system in order that information and knowledge regarding the search for similarity features can be retrieved if required. This is the only chance to avoid that one known construction is permanently newly invented with an exploding multitude of variations. Falling back on the existing know-how leads to a standardization of the sheet metal part spectrum and thus to a reduction of the part variety. The period of the product development is shortened by the use of available data in the technically planning areas and the costs for the data administration and maintenance are reduced. And, not at the end, the system flexibility was significantly increased [1], [2].

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2. SMA-COD-SHEET metal alphanumerical coding system

The system developed in this chapter, SMA-COD system is basically alphanumerical system but the code structure is based on the hybrid code. In the first design stage (genuine design) it is an alphanumerical code; in the second design stage (detailed design) it becomes a hybrid code. Its code structure is shown in Fig. 1. It uses integer values to define various attributes and is composed of 11 digits. Digits 1, 2 and 3 represent the part shape.

Part shape is considered to be the main attribute of a coding system. First digit defines the basic shape (primary shape) and is used in genuine design and primary productibility estimation. Second and third digits are dependent on the first digit. These two digits posses 99 combination (01. 02. 99) and define all features in every basic class. These digits are only used in detailed design level and finally productibility estimation [6], [10].

Digit	1 ÷ 3	4	5	6	7	8	9	10	11
Attributes	Shape	Thickness of sheet	Length	Relation value	Process	Tools	Materials	Tolerances	Heat treatment

Figure 1. Structure of SMA-COD System

Since the primary factor in the sheet metal manufacturing is part geometry, part classification based on shape is a key attribute in SMA-COD system. Tool cost, one of the major costs in sheet metalworking, is mainly dependent on part geometry. In addition, most defects are caused by inappropriate die design. In SMA-COD system one attempt is mode to group all possible geometry shapes that can be produced by sheet metal working.

The basic shapes defined by first digit are classified in ten categories as follows:

Code	Attribute: **Basic Shape (description)**
0	Flat surfaces
1	Simple bending
2	Complex bending (multiple bends)
3	One and more punched simplest holed
4	Shallow formed and embossed regions
5	One and more punched complex holed
6	Lanced and formed louver
7	Simple bending and punched simplest holed
8	Simple bending, shallow formed and embossed regions
9	Simple bending, lanced and formed louver

All of these classes have possibilities to form new subclasses (minimum 0, maximum 99) defined by second and third digit. These two classes definitely defined geometry shape of workpieces and were built by experts for sheet metal designer and manufacturer for concrete production program and kind of workshops, or kind of using computer aided design system.

The fourth digit shows the range of gauge thickness available for the four alloy types, which represent almost all the materials used in sheet metalworking (defined on the ninth position). This digit is the most important factor for manufacturibility of workpiece. The thickness of sheet are classified as follows:

Attribute: **Thickness of sheet metal (4 th Digit)**

Code	Value
0	0.13 mm $<$
1	$0.13 \leq \delta < 0.28$ mm
2	$0.28 \leq \delta < 0.76$ mm
3	$0.76 \leq \delta < 1.07$ mm
4	$1.07 \leq \delta < 1.52$ mm
5	$1.52 \leq \delta < 3.05$ mm
6	$3.05 \leq \delta < 5.08$ mm
7	$5.08 \leq \delta < 10$ mm
8	$\delta \geq 10$ mm

The fifth and sixth digits are supplementary codes for shape. The size of part length and part width expressed as relational value (relation between length and width), are important factors for manufacturing costs. A large size increases production cost exponentially, especially the costs of dies and manufacturing equipment. The sizes are classified as shown in Fig.2.

The seventh digit defined the main manufacturing process need to obtain for requirement geometry of workpieces. There are two basic sheet metal processes. One is the passage operation that involves cutting or tearing the sheet metal by methods such as punching, notching or blanking. The other is the nonpassage operation that involves plastic deformation of the metal by methods such as bending, hemming or curling. Based on this consideration the processes are classified as follows [1]:

Attribute: **Processes of sheet metalworking (7 th Digit)**

Code	Definition (description)
0	Bending
1	Hemming
2	Curling
3	Punching
4	Notching
5	Blanking
6	Miscellaneous
7	Press brake operations
8	Bending and Punching

With these seven attributes conditions for definition of all processes in sheet metalworking are obtained. This attribute is a main difference of the coding system in machining removal processes.

The eighth digit defines the kind of tools. This factor is one of the most important values for cost and flexibility of process and

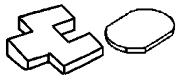
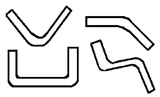
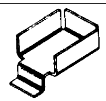
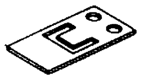
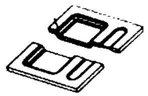
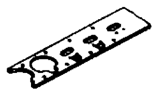
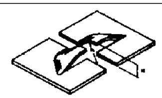
C/F	Basic Shape		Thickness of sheet (mm)	Basic dimension between basic A-lenght (mm)	The relation Process dimensions A/B	Tools	Materials	Tolerances (mm)	Heat treatment	
	Form, shapes, features									
0	1	1.1	4	5	6	7	8	9	10	11
0	Flat surfaces		0.13 mm ≤	A < 20	A/B = 1 ... < 2	Bending	Cutt-off dies	Steel, low carbon, commercial quality	T < ± 0.10	Not required
1	Simple bending		0.13 ≤ δ < 0.28	20 ≤ A < 50	2 ≤ A/B < 4	Hemming	Part-off dies	Steel, low carbon, drawing quality	±0.10 ≤ T < 0.25	Normalizing
2	Complex bending (multiple bends)		0.28 ≤ δ < 0.76	50 ≤ A < 150	4 ≤ A/B < 8	Curling	Blanking dies	Stainless steel T 304	±0.25 ≤ T < 0.50	Annealing
3	One and more punched simpliest hole		0.76 ≤ δ < 1.07	150 ≤ A < 250	A/B ≥ 8	Punching	Drop-through dies	Aluminium 1100 soft	0.50 ≤ T < 0.75	Quenching
4	Shallow formed and embossed regions		1.07 ≤ δ < 1.52	250 ≤ A < 500		Notching	Piercing dies	Aluminium 1100 half hard	0.75 ≤ T < 1.00	Martempering
5	One and more punched complex holed		1.52 ≤ δ < 3.05	500 ≤ A < 1 000		Blanking	V, U, W, and Z double Wiper double V-die	Aluminium 3003 hard	1.00 ≤ T < 1.25	Tempering
6	Lanced and formed louver		3.05 ≤ δ < 5.08	1 000 ≤ A < 5 000		Miscellaneous	Progressive dies	Copper soft	1.25 ≤ T < 1.50	Austempering
7	1 + 3	1 + 3	5.08 ≤ δ < 10	5 000 ≤ A < 15 000		Press brake operations	Others	Copper 1/4 hard	1.50 ≤ T < 2.25	Case hardening
8	1 + 4	1 + 4	δ ≥ 10	A ≥ 15 000		0 + 3		Titanium Grade 2	2.25 ≤ T < 5.00	Others
9	1 + 6	1 + 6				Other		Titanium Grade 4	T ≥ 5.00 mm	

Figure 2. Alphanumerical coding scheme for sheet metal parts

estimation of productibility. The codes for tools are assigned as follows:

Attribute: **Tools for sheet metalworking (8 th Digit)**

Code	Type of tool
0	Cut-off dies
1	Part-off dies
2	Blanking dies
3	Drop-through dies
4	Piercing dies
5	V, U, W, Z, double dies
6	Progressive dies
7	Others

Formability depends on various materials as well as part geometry. The ninth digit represents material. These four alloy types represent almost all the materials used in sheet metalworking. In the stage of detail production and process design the exact material definition is feasible with supplement digit on a tenth position which is connected with the ninth digit and depends on them. In that case system SMA-COD has 12 digits. Material classification is in the order of manufacturability and use in industry.

Attribute: **Material (9 th Digit)**

Code:	Characteristic:
0	Steel, low carbon, commercial quality
1	Steel, low carbon, drawing quality
2	Stainless steel, T 304
3	Aluminium 1100, soft
4	Aluminium 1100, half hard
5	Aluminium 3003, hard
6	Copper, soft
7	Copper, 1/4 hard
8	Titanium, Grade 2
9	Titanium, Grade 4

The tenth digit represents the tolerance level. Clearly, close tolerances require more accurate manufacturing processes. To present a sheet metal part design that is ready for processing, assembly and inspection, the dimensional tolerance information is added to the feature definition. On the eleventh digit SMA-COD System provides a code for heat treatment. (See Fig. 2)

3. The design efective manufacturing structure on the base GT-Concept

After the design of the sheet metal products start three steps in building effective manufacturing structure as follows:

Step 1. The designing operational groups

- *Phase 1.* Classification of workpieces/products (award code number for every parts)
- *Phase 2.* Forming module elements (all products with the same code number)
- *Phase 3.* Defining operational manufacturing group (all elements with similar characteristics- part family group)

Step 2. Development of group technology process

- *Phase 1.* The design, forming or choosing complex part (all relevant technological data are incorporated in this part)
- *Phase 2.* Defining the group technology process (the same or similar technology process and other technological aspects)

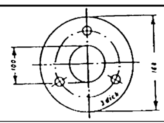
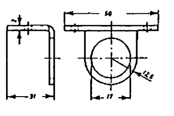
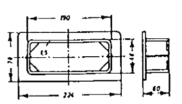
Step 3. Forming autonomous working cells

That is an independent part of the whole production system with ability that in a defining space, with technology equipment and skill workers, produces complete one or more family groups [7].

4. Factory application

In one factory test 32 sheet metal parts were casually chosen and used in the methodology developed and explained in main

The final characteristics for forming operational groups — Table 1.

No	Parts	Sign	Code number of complex part	Number of parts in one group	Figure of complex part
1.	Flat parts with simplest hole	OG 1	752184151	16	
2.	Simple bending parts with hole	OG 2	152181251	13	
3.	Complex bending sheet metal parts with hole	OG 3	243101261	3	

aspect in chapters 2 and 3. After using the three explained steps three operational manufacturing groups (OG) with the characteristics shown in Table 1 will be formed.

From Table 1 we may see that using the developed GT approach great simplifications in process planning (design, technology, tools, etc.) were obtained because, now, instead of developing manufacturing process for 32 products we may use only 3 operational groups with 3 complex parts.

In the results of flexibility improvement in the new concept of testing system (Re-Engineering of existing system) was achieved

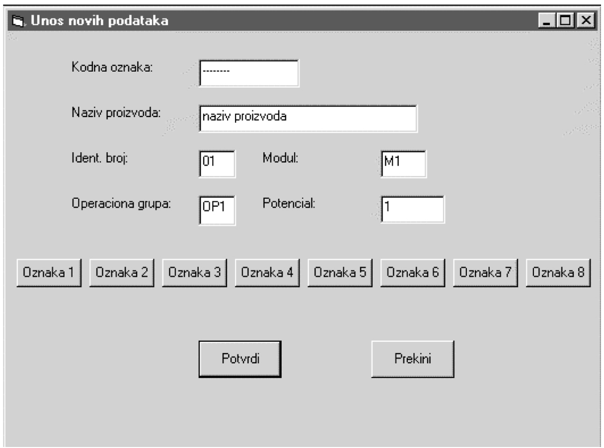


Figure 3. The screen layout for data entrance

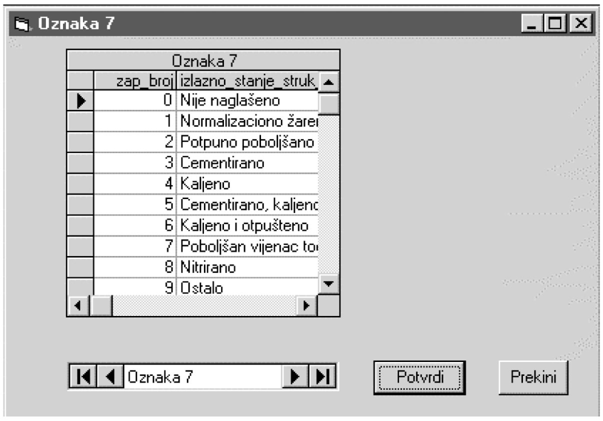


Figure 4. The screen layout of main material division

FS1=0,062 in comparison of FS=0,034 for the real existing production system. The measurement of flexibility was calculated on the base equation:

$$Fs = 1-(1-f_{ts}\ (f_{ks}\ (f_p)\ (1-f_{pr})$$

where: f_{ts} - technology component of system flexibility
f_{ks} -capacity component of system flexibility
f_p - flexibility of space structure,
f_{pr} - flexibility of technology process.

5. Computer application

For practical implementation the developed and presented models in factories and laboratories were built. Software, called CODI was written in computer language Visual Basic 5,0. For creating data base MS Access 97 were used. This program allows for technology coding of parts in designing phases, forming module and operational groups and calculations of potential level similarities with complex part in every technology groups. Also, there is no problem for adaptation of this program for different coding digits in different cases as some special characteristics in different factories or different technologies. For installation of this program configuration of WIN 95 or WIN NT were needed and for memory request personal computer type Pentium with 32 MB RAM suffices. The developed software can be installed as one sub-program of the well known software as I-DEAS, CATIA, Auto-CAD etc. It is also possible to connect this software with technology solutions of data bank, tools, machine tools, clamping devices, program instructions with CNC, etc. In the Fig. 3 and 4 are presented two computer screens of developed software for automatically (computer) coding and classification [11], [12].

6. Conclusion

A designer needs computer-assisted tools to design products that can be readily manufactured without costly and time-consuming redesign to improve manufacturability. Therefore, a CAD-CAPP-CAM system for sheet metal design, planning and manufacturing is developed under these considerations. To be successful, manufacturing strategies increasingly rely on flexibility, which is presently considered as an important attribute of any modern technology.

Reviewed by: J. Duda, A. Sladek

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