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A short note on an intelligent system for selection of materials for progressive die components

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Abstract

Selection of materials for die components is an important activity during progressive die design in stamping industries. This paper presents an intelligent system for selection of materials for progressive die components. The proposed system SMPDC comprises of two knowledge base modules, namely DIEMAT and SELHRD. The module DIEMAT is designed for selection of materials for both active and inactive components of progressive die. The module SELHRD is developed for determination of hardness range of materials for active components of progressive die. Knowledge for both the modules of the proposed system is acquired, analyzed, tabulated and incorporated into a set of production rules of IF-THEN variety. The system is coded in the AutoLISP language and loaded into the prompt area of AutoCAD. The system is designed to interact with the user through the user interface. The usefulness of the proposed system is demonstrated through a sample run using an example of an industrial component. The knowledge base of the system can be modified depending upon the availability of new materials and advancement in technology.

Keywords: Progressive die; Material selection; Knowledge base; Intelligent system

1. Introduction

Progressive die is widely used for mass production of sheet metal components due to its high productivity, high precision and relatively economic cost in terms of per piece of product. The design of die components and their material selection are major activities during progressive die design [1]. The selection of proper materials for progressive die components essentially increases the die life and hence reduces the cost of production of sheet metal parts. Traditional methods for carrying out this important activity are dependent on the vast experience and depth of knowledge of die design experts. Most of the times, material selection for progressive die components is carried out manually using die design handbooks, material handbooks, thumb-rules and heuristics. Existing computer-aided die design systems have still not fully dealt with the core die design issue of material selection for progressive die components. Some existing CAD/CAM systems for progressive dies [2–4] are able to generate bill of materials, however, these systems do not take in account the availability of other suitable materials for the choice of user for better performance of die components and hence the long life of progressive die. Further, these systems do not have even knowledge base consisting of experienced knowledge of domain experts in material selection for progressive die components. World-wide researchers [5,6] have stressed to apply research efforts for capturing and documenting the invaluable practical knowledge of experienced die designers and toolmakers through the applications of artificial intelligence (AI) techniques. The highly experience based progressive die design activities such as material selection of die components can be simplified by using knowledge-based system (KBS) or intelligent system approach Development of such system can prove a landmark to ease the complexities involved in the process of material selection for die components.

Although long life of all the components of progressive die is desirable, however special due attention is required to improve the life of active components (i.e. punch and die/inserts). For selecting the suitable material for a progressive die component, the die designer properly investigates the functional requirements of that component and then a critical study is carried out to identify the required mechanical properties and possible causes,

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which may result the failure of the component. The selection of material for a given application depends on which failure mechanisms dominate. The basic idea of a die designer is to select a suitable material such that all other failure mechanisms except wear are eliminated. The wear can then be optimized to match the required production quantity of sheet metal parts. To obtain longer die life and hence higher productivity, tool steels are being widely used as materials for die components. One of the most important advantages of using steels as cutting tool materials is that, they are originally soft and machinable, by applying suitable heat treatment, they become extremely hard and wear resistant. Selection of suitable hardness range of selected materials of die components depends on the geometry of the part to be manufactured on progressive die. The specific objective of the present work is the development of an intelligent system for selection of materials for progressive die components to assist the die designers and toolmakers working in small and medium size sheet metal industries. A brief description of the procedure

Table 1
A sample of production rules incorporated in module DIEMAT

S. no.	IF	THEN
1	Sheet material = Al or Cu or brass or Pb or beryllium copper 5 < Shear strength of sheet material (kgf/mm^2) ≤ 20 Type of operations = shearing Production quantity ≤ 100,000	Select an easily available material for punch and die/inserts from the following: EN-31 (56–60 HRC) (AISI 52100) ‘OR’ UHB-ARNE (54–62 HRC) (AISI O1, W.-Nr. 1.2510)
2	Sheet material = mild steel or stainless steel or austenitic stainless steel or hardened steel or CRCA or spring steel 30 < Shear strength of sheet material (kgf/mm^2) ≤70 Type of operations = shearing Production quantity >1,000,000	Select an easily available material for punch and die/inserts from the following: SEVERKER 3 (60–64 HRC) (AISI D6 (D3), W.-Nr. 1.2436, JIS-SKD2) ‘OR’ UHB-VANADIS 6 (62–64 HRC) ‘OR’ UHB-VANADIS 10 (60–64 HRC)
3	Sheet material = Al or Cu or brass or Pb or beryllium copper 5 < Shear strength of sheet material (kgf/mm^2) ≤ 20 Type of operations = forming or forming and shearing both Production quantity ≤100,000	Select an easily available material for punch and die/inserts from the following: EN-31 (56–60 HRC) (AISI 52100) ‘OR’ UHB-ARNE (54–62 HRC) (AISI O1, W.-Nr. 1.2510) ‘OR’ UHB-CALMAX (56–59 HRC)
4	Sheet material = mild steel or stainless steel or austenitic stainless steel or hardened steel or CRCA or spring steel 30 < Shear strength of sheet material (kgf/mm^2) ≤ 70 Type of operations = forming or forming and shearing both 100,000 < production quantity ≤ 1,000,000	Select an easily available material for punch and die/inserts from the following: SEVERKER 21 (58–62 HRC) (AISI D2, W.-Nr. 1.2379, JIS-SKD11) ‘OR’ AISI A2 (58–62 HRC) (UHB-RIGOR, W.-Nr. 1.2363)
5	Category of inactive elements = plate elements	Select an easily available material for plate elements from the following: • Top plate and bottom plate: Mild steel ‘OR’ UHB-11 (AISI 1148) ‘OR’ EN-31 (AISI 52100) ‘OR’ UHB- FORMAX (W.-Nr.-10050, SS-2172) ‘OR’ EN-8 (AISI 1040) • Punch plate: Mild steel ‘OR’ EN-8 (AISI 1040) ‘OR’ UHB-ARNE (AISI O1, W.-Nr. 1.2510) • Punch back plate: EN-31 (AISI 52100) ‘OR’ UHB-ARNE (AISI O1, W.-Nr. 1.2510) • Stripper plate: EN-31 (AISI 52100) ‘OR’ UHB-11 (AISI 1148) • Die support plate: EN-31 (AISI 52100)
6	Category of inactive elements = guiding and locating elements	Please select an easily available material for guiding and locating elements from the following: • Die gages (R_a* = 0.1–0.4 μm) (48–50 HRC): EN-31 (AISI 52100) ‘OR’ UHB-11 (AISI 1148) • Die stops (R_a = 0.1–0.4 μm) (42–46 HRC): EN-31 (AISI 52100) ‘OR’ EN-47 (AISI 6150) • Lifter (R_a = 0.1–0.4 μm) (52–55 HRC): HCHCr ‘OR’ SEVERKER-21 (AISI D2, W.-Nr. 1.2379, JIS-SKD11) ‘OR’ H.S.S. • Guide pin and guide piller pin (R_a = 0.1–0.4 μm) (50–52 HRC): EN-353 • Ball cage (R_a = 0.025–0.05 μm): Aluminium ‘OR’ Brass ‘OR’ plastics • Sleeve (R_a = 0.1–0.4 μm): EN-31 (AISI 52100) • Shank (R_a = 0.8–3.2 μm): Mild steel • Dowel pins (R_a = 0.8–3.2 μm) (50–52 HRC): C-40 ‘OR’ EN-8(AISI 1040) ‘OR’ EN-9 (AISI 1055) ‘OR’ silver steel

* R_a: surface roughness.

[7] of development of the proposed intelligent system SMPDC is given as under.

2. Development of proposed intelligent system SMPDC

The proposed intelligent system SMPDC comprises of two modules, namely DIEMAT and SELHRD. The module DIEMAT is designed for selection of materials for progressive die components. The module SELHRD is developed for determination of hardness range of materials selected for active components of progressive die. The proposed system supports mainly tool steels. The procedural steps utilized in constructing the system include acquisition of the domain knowledge, preparation and verification of production rules, and coding of production rules and preparation of user interface. Each step of the procedure is discussed as under.

2.1. Acquisition of the domain knowledge

The technical knowledge for the development of proposed system was collected through die design handbooks, industrial brochures, technical reports, and experienced progressive die designers and tool manufacturers. The knowledge of selection of materials for progressive die components was obtained from experienced progressive die designers and tool manufacturers by holding discussions on typical problems and letting them talk about the approach and rules of thumb relied upon by them. During the verbal analysis, they were questioned to explain why a particular material was selected for specific die component. This was accomplished to identify the factors influencing the selection of materials of progressive die components.

2.2. Preparation and verification of production rules

The knowledge acquired for both the modules of proposed intelligent system was analyzed and tabulated in form of production rules of 'IF-THEN' variety. The production rules so framed were verified from a team of progressive die design experts and tool manufacturers. A sample of production rules so framed and verified, and then incorporated in the module DIEMAT is given in Table 1 and a sample of production rules included in the module SELHRD is given in Table 2.

2.3. Coding of production rules and preparation of user interface

The production rules incorporated in both modules of the proposed intelligent system have been coded in AutoLISP language. The production rules and the knowledge base of the system are linked together by an inference mechanism, which makes use of forward chaining. The system works with input information supplied by the user on the problem of material selection, coupled with knowledge stored in the knowledge base, to draw conclusions or recommendations. The knowledge base of the

Table 2
A sample of production rules included in module SELHRD

S. no.	IF	THEN
1	Sheet thickness ≤2 mm Geometry of blanked part = simple	Use upper limit of hardness range of selected material
2	Sheet thickness ≤2 mm Geometry of blanked part = normal	Use lower limit of hardness = upper limit of hardness of selected material-2.0 Use upper limit of hardness = upper limit of hardness of selected material
3	Sheet thickness ≤2 mm Geometry of blanked part = complicated Hardness range of selected material in HRC ≤ 4	Use same range of hardness as mentioned with the selected material
4	Sheet thickness > 2 mm Sheet thickness ≤ 5 mm Geometry of blanked part = normal Hardness range of selected material in HRC > 4	Use lower limit of hardness = upper limit of hardness of selected material-4.0 Use upper limit of hardness = upper limit of hardness of selected material
5	Sheet thickness > 2 mm Sheet thickness ≤ 5 mm Geometry of blanked part = complicated Hardness range of selected material in HRC ≤ 6	Use same range of hardness as mentioned with the selected material
6	Sheet thickness > 2 mm Sheet thickness ≤ 5 mm Geometry of blanked part = complicated Hardness range of selected material in HRC > 6	Use lower limit of hardness = upper limit of hardness of selected material-6.0 Use upper limit of hardness = upper limit of hardness of selected material
7	Sheet thickness > 5 mm Sheet thickness ≤8 mm Geometry of blanked part = complicated Hardness range of selected material in HRC > 8	Use lower limit of hardness = upper limit of hardness of selected material-8.0 Use upper limit of hardness = upper limit of hardness of selected material
8	Sheet thickness > 8 mm Geometry of blanked part = simple or normal or complicated	Use same range of hardness as mentioned with the selected material

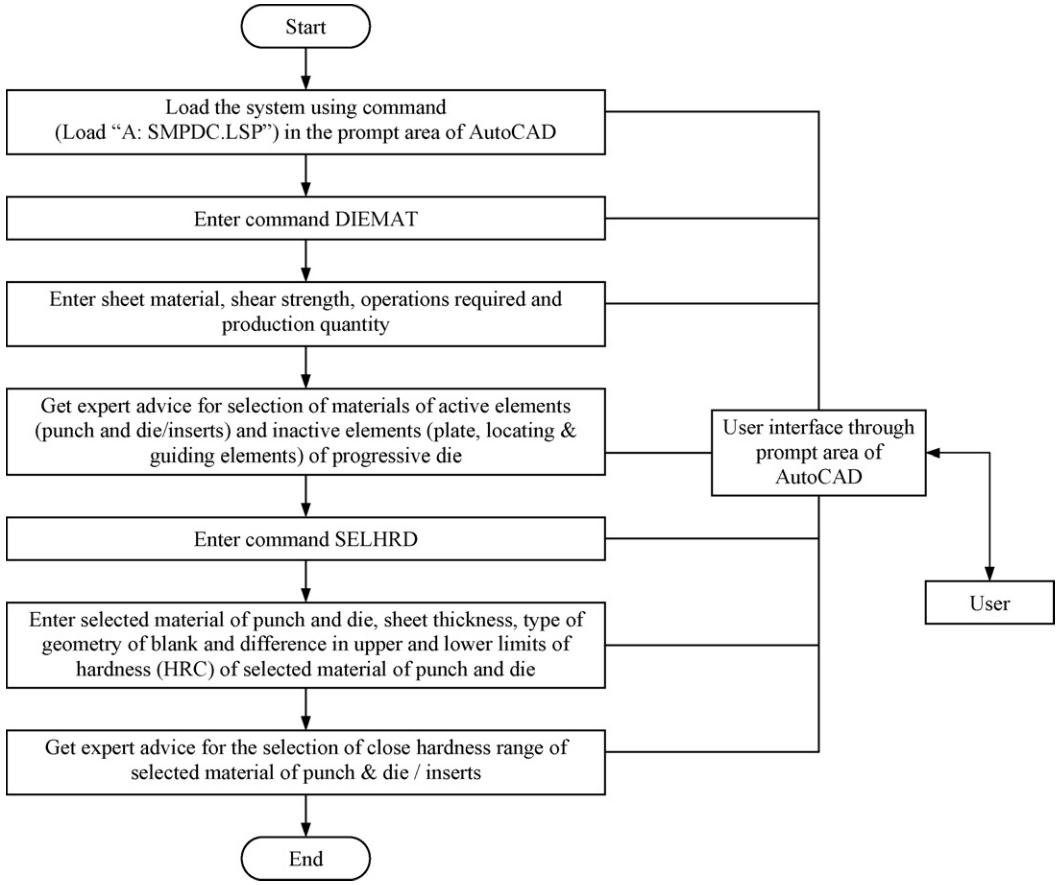

Fig. 1. Execution of proposed intelligent system SMPDC.

system SMPDC comprises of more than 60 production rules. However, the system is flexible enough as its knowledge base can be updated and modified, if necessary, on the advancement in technology and availability of new materials in future having better performance than recommended by the proposed system. Both the modules of the proposed system are designed to be interactive in nature to enable the user to input the essential sheet metal component data; and to displays the optimal decision choices for the user's benefit. The former is accomplished by flashing AutoCAD prompts to the user at appropriate stages during a consultation to feed data items. Messages or items of advices are likewise flashed into the computer screen whenever relevant production rules are fired. The system can be loaded by entering the command (load "A: SMPDC.LSP") in the prompt area of AutoCAD. The execution of the system is demonstrated through a flow chart as shown in Fig. 1. The output of the program includes the intelligent advices for selection of materials for active elements (i.e. punch and die/inserts) and inactive elements (i.e. plate elements, guiding and locating elements) and close hardness range of the material selected for active elements of progressive die.

3. Sample run of the proposed system

The proposed system is implemented on PC (Pentium 4 CPU, 2.4 GHz, 256 MB of RAM) with Autodesk AutoCAD 2004. The system has been tested for different types of sheet metal parts for the problem of material selection for progressive die components. Typical prompts, user responses and the recommendations obtained by the user during the execution of the proposed intelligent system SMPDC for an example component (Fig. 2) are given in Table 3. The recommended materials by the system were found to be reasonably close to those actually used in industry (Indo-Asian Fuse Gear Private Limited, Murthal, Haryana, India) for the example component.

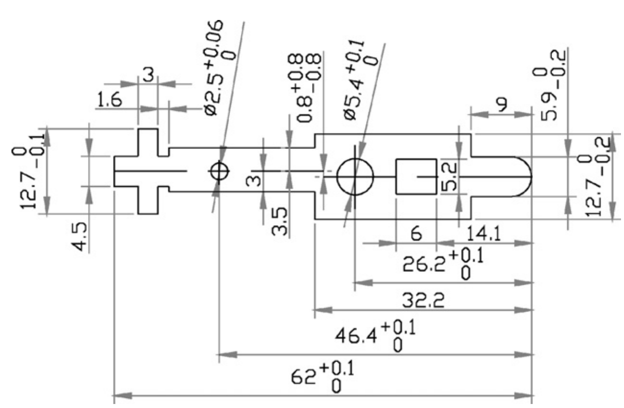

Fig. 2. Example component (all dimensions in mm): Brass, sheet thickness = 0.6 mm.

Table 3
Typical prompts, user responses and expert advice generated during execution of the proposed intelligent system SMPDC for example component

Prompt	Example data entry	Advice to the user
(Load "A: SMPDC.LSP")		Please enter command SMPDC
SMPDC		Welcome to the module SMPDC. Please enter command DIEMAT
DIEMAT		
Please enter sheet material	Brass	
Please enter the type of operations	Shearing	
Please enter shear strength of sheet material	15 kgf/mm^2	
Please enter required production quantity of sheet metal parts	90,000	Please select an easily available material for punch and die/inserts from the following: EN-31 (56–60 HRC) (AISI 52100) 'OR' UHB-ARNE (54–62 HRC) (AISI O1, W.-Nr. 1.2510)
Please enter the category of inactive elements (i.e. plate elements, locating and guiding elements)	Plate elements	Please select an easily available material for plate elements from the following: • Top plate and bottom plate: Mild steel 'OR' UHB-11 (AISI 1148) 'OR' EN-31 (AISI 52100) 'OR' UHB-FORMAX (W. Nr.-10050, SS-2172) 'OR' EN-8 (AISI 1040) • Punch plate: Mild steel 'OR' EN-8 (AISI 1040) 'OR' UHB-ARNE (AISI O1, W.-Nr. 1.2510) • Punch back plate: EN-31 (AISI 52100) 'OR' UHB-ARNE (AISI O1, W.-Nr. 1.2510) • Stripper plate: EN-31 (AISI 52100) 'OR' UHB-11 (AISI 1148) • Die support plate: EN-31 (AISI 52100)
Please enter the category of inactive elements	Guiding and locating elements	Please select an easily available material for guiding and locating elements from the following: • Die gages (R_a = 0.1–0.4 μm) (48–50 HRC): EN-31 (AISI 52100) 'OR' UHB-11 (AISI 1148) • Die stops (R_a = 0.1–0.4 μm) (42–46 HRC): EN-31 (AISI 52100) 'OR' EN-47 (AISI 6150) • Lifter (R_a = 0.1–0.4 μm) (52–55 HRC): HCHCr 'OR' SEVERKER-21 (AISI D2, W.-Nr.1.2379, JIS-SKD11) 'OR' H.S.S. • Guide pin and guide piller pin (R_a = 0.1–0.4 μm) (50–52 HRC): EN-353 • Ball cage (R_a = 0.025–0.05 μm): Aluminium 'OR' Brass 'OR' plastics • Sleeve (R_a = 0.1–0.4 μm): EN-31 (AISI 52100) • Shank (R_a = 0.8–3.2 μm): Mild steel • Dowel pins (R_a = 0.8–3.2 μm) (50–52 HRC): C-40 'OR' EN-8 (AISI 1040) 'OR' EN-9 (AISI 1055) 'OR' Silver steel Please enter command SELHRD
SELHRD		
Please enter the selected material of punch and die/inserts	EN-31 (56–60 HRC)	Typical analysis of EN-31: C = 0.90/1.2, Si = 0.10/0.35, Mn = 0.30/0.75, Cr = 1.0/1.6, S and P each = 0.025 (maximum)
Please enter sheet thickness (mm)	0.6	
Please enter the geometry of blanked part (i.e. simple/normal/complicated)	Normal	
Please enter the difference of upper limit and lower limit of hardness (HRC) of selected material	4.0	Use lower limit of hardness = upper limit of hardness of selected material-2.0, and Use upper limit of hardness same as the upper limit of hardness of selected material

4. Conclusion

The proposed system is capable of giving expert advice on selection of materials for progressive die components and selection of close hardness range of materials during the design stage of progressive dies. The user has been provided an option to select easily available materials from the advice received by the proposed system and then a bill of materials can be prepared suitably. The system has been tested for variety of sheet metal components and proved to be powerful and easy to handle because of its rich knowledge base and highly interactive nature. The sample run of the system using an industrial example component has demonstrated the usefulness of the system. The system supports mainly tool steels, however, its knowledge base can be modified and updated depending upon the availability of new materials and advancement in technology. The cost of implementation of the system is low as it can be run on a PC with AutoCAD software and hence it is within the easy reach of small and medium size sheet metal industries.

References

[1] L. Caiyuan, L. Jianjun, W. Jianyong, X. Xiangzhi, HPRODIE: using feature modeling and feature mapping to speed up progressive die design, Int. J. Prod. Res. 39 (2001) 4133–4151.

[2] K. Shirai, H. Murakami, Development of a CAD/CAM system for progressive dies, Ann. CIRP 34 (1) (1985) 187–190.
[3] Y.K.D.V. Prasad, S. Somasundaram, CADDS: an automated die design system for sheet metal blanking, Comput. Control Eng. J. 3 (1992) 185–191.
[4] K. Huang, H.S. Ismail, K.K.B. Hon, Automated design of progressive dies, Proc. Inst. Mech. Eng., Part B, J. Eng. Manuf. 210 (1996) 367–376.
[5] H.S. Ismail, K.K.B. Hon, K. Huang, CAPTD: a low-cost integrated computer aided design system for press tool design, Proc. Inst. Mech. Eng., Part B, J. Eng. Manuf. 207 (1993) 117–127.
[6] B.T. Cheok, K.Y. Foong, A.Y.C. Nee, C.H. Teng, Some aspects of a knowledge-based approach for automating progressive metal stamping die design, Comput. Ind. 24 (1994) 81–96.
[7] S. Kumar, R. Singh, Developmental framework of knowledge-based system for engineering problems, in: Proceedings All India Seminar on Power and Energy for Sustainable Growth, Institute Engrineers (India), Haryana State Centre, CRSCE Murthal, Haryana, India, February 20–21, 2003, pp. 290–295.