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Decision Support System for Grinding Wheel Selection Using Data-Mining

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Abstract
In the grinding wheel catalog data-set, the recommended grinding conditions are shown in reference to five factors (abrasive grain, grain size, grade, structure, and bonding material) of the three main elements (abrasive grain, bonding material, and pore). Since systematic arrangement is not made, grinding conditions (cutting speed, table feed, depth of cut) have to be decided on the basis of an experienced engineer's information or experience. Moreover, although the setting of the five factors of the three elements of a grinding wheel is important parameter that affects the surface quality and grinding efficiency, it is difficult to determine the optimal combination of workpiece materials and grinding conditions. In this research, a support system for effectively deciding the desired grinding wheel was built by using a decision tree technique, which is one of the data-mining techniques. This system extracts a significant tendency of grinding wheel conditions from catalog data. As a result, a visualization process was proposed in correspondence to the action of the grinding wheel elements and their factors to the material characteristics of the workpiece material.

Keywords: Data-mining, Decision tree, Grinding wheel, cylindrical grinding

1. Introduction

A grinding wheel has three main constituents (abrasive grain, bonding material, and pores), and five principal factors that affect the performance of each constituent (grain type, grain size of the abrasive grain, strength of the bonding material (bonding strength A–Z), degree of porosity (structure 1–14) and type of bonding material). When using a grinding wheel, the results are affected by interactions between multiple factors, so it is necessary to determine the grinding wheel shape and grinding conditions and the most appropriate specification of the above three elements and five factors after considering the material and finish precision of the workpiece. If these conditions are set incorrectly, it can cause loading, shedding, dulling, leaving burn marks, rough finish on the workpiece, resulting in unacceptable end finish and reduced productivity [1]. The setting of grinding wheel parameters is currently a difficult and important issue. In the precedence research, some of the research about decision making of grinding wheel were conducted and promoted automated-decision mechanism of five factors [2]. In this study, we used the catalogs of grinding wheel manufacturers to perform catalog data mining [3] in order to develop an optimal grinding wheel selection support system. To conduct so, data mining method called "decision trees" was focused on to construct a system that visualizes the grinding wheel selection decision process and produces patterns to support the selection of grinding wheels for cylindrical grinding.

2. Catalog data mining method

2.1. Decision tree algorism used in this study

The decision trees used in this study are trees for determining conditions. To explain this decision tree algorithm, indicators of entropy and gain were used. First, in the state where *i* different factors are included among the attributes, if *pi* is the ratio of the total number in an attribute to the total number of each factor, then the entropy (*H*) can be expressed as follows:

Table 1 Data ranges for each predictor and criterion variables

Data set	JIS (B4051)
Outside diameter *D* [mm]	≦355, 355~610, 610~915
Abrasive grain type	WA, A+WA, PA, HA, GC
Grain size	46, 54, 60, 80
Bonding strength	F, I, J, K, L, M
Vickers hardness *HV*	12~1900
Elongation φ [%]	0.5~60
Tensile strength σ [MPa]	30~2400
Thermal conductivity ε [W/(m·K)]	4~230
Workpiece	Carbon steel, Alloy steel, Tool steel, Malleable cast iron, Martensitic stainless steel, Austenitic stainless steel, Gray cast iron, Nodular graphite cast iron, Aluminum alloy, Cemented carbide Brass, Bronze casting, Permanent magnet material

$$H = -\sum_{i=1}^{c} p(i|t)\log_2 p(i|t_i) \quad (1)$$

t is node of decision tree. When this attribute branches into *k* classes under certain conditions, *GI* (Gini index) is calculated as eq. (2).

$$GI = 1 - \sum_{i=1}^{c} [p(i|t)]^2 \quad (2)$$

In the decision tree algorithm, factors for which *GI* has a large value are used for branching. By repeating this step, we arrive at a simpler decision tree with greater branching accuracy. R (CART) as the analysis software for deriving decision trees was used in this study.

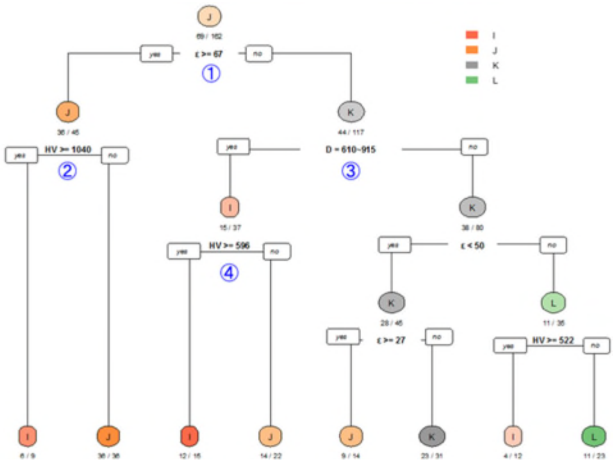

Figure 1. Example result of decision tree for bonding strength decision

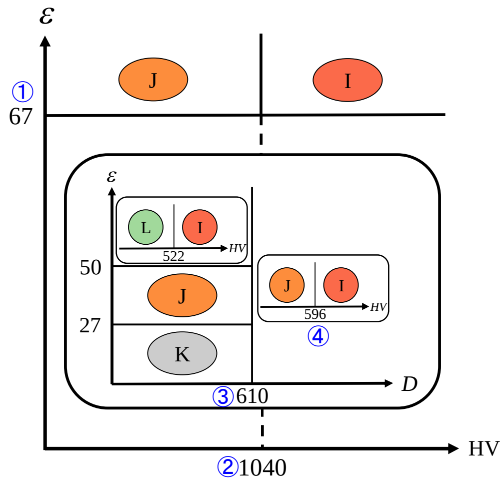

Figure 2. Visualization map of bonding strength selection

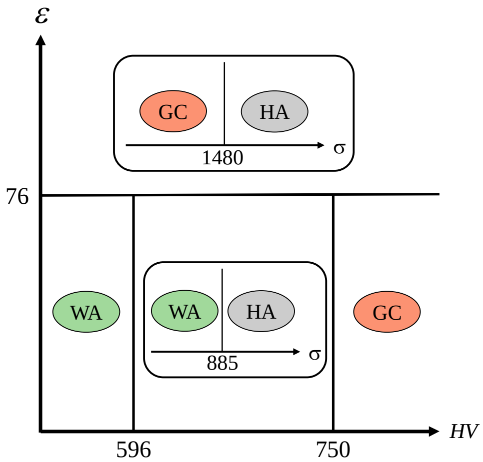

Figure 3. Visualization map of abrasive grain type selection

2.2. Target data for making decision tree

In inputting data, it is important to have target factors and explanatory factors as parameters for branching the conditions. In this study, as shown in Table 1, we selected abrasive grain, grain size, bonding strength and structure out of the three factors and five elements of grinding wheels, and for the latter, as the workpiece material and grinding wheel shape, we input the Vickers hardness *HV*, elongation φ [%], tensile strength σ [N/mm²], thermal conductivity ε [W/(m·K)], grinding wheel outer diameter *D* [mm]. JIS standard (JIS B 4051) to general-purpose grinding wheels for cylindrical grinding was as target data. For inputting the value of workpiece material characteristic, material data book edited by The Japan Institute of Metals and Materials was referenced.

3. Visualization method of extracted knowledge

The main difficulty of deciding on a grinding wheel occurs when the workpiece has high hardness or viscosity. In either case, since it is always necessary to continue cutting with sharp edge, we should select a grinding wheel that promotes the inherent cutting action characteristic of grinding wheels. Figure 1 visualizes the extracted knowledge in conditions summarized from decision trees for bonding strength of JIS standard dataset derived from R (CART) in this study. The two elements that appeared most often in the decision tree are placed on the vertical and horizontal axes, and the branch order of the first branch (thermal conductivity) and second branch (hardness, outside diameter) are shown in Fig. 2 (① to ④). When anything other than an element used on the axis appears, it is surrounded by a square in the figure as a branch in another dimension.

4. Grinding wheel selection tendency for JIS 4051

Decision tendency of grain type, grain size and bonding strength were visualized by derived decision trees. As for decision tendency for bonding strength (Fig. 2), workpiece hardness often appeared as a factor in the decision tree. The effect of the workpiece hardness on the choice of grinding wheel is that as the workpiece hardness increases, the grinding resistance increases and the bonding strength becomes lower for promoting self-sharpening of grinding wheel. In general, the larger outside diameter become, the faster the cutting speed can set as initial cutting condition. Therefore, tendency to select lower bonding strength can be seen to adjust the self-sharpening cutting action. Lower bonding strength to promote the inherent cutting action of the abrasive grain and suppress the occurrence of dulling and shedding. For a larger outside diameter, the working hardness can be adjusted by reducing the grain size and bonding strength, and it is thought this is why the outside diameter factors appeared in the determination of bonding strength. Figure 3 shows the tendency visualization result for abrasive grain type. JIS standards recommend that the selection of grinding wheels for hard workpieces should use GC or HA abrasive grain with good abrasive performance.

5. Conclusion

In this study, decision trees were used to construct a system that visualizes the cylindrical grinding wheel selection decision tendency and produces patterns to support the selection of grinding wheels. Using decision trees, we were able to visualize the method of selecting an appropriate grinding wheel for the workpiece material, and the grinding wheel selection conditions using the parameters necessary for determining the grinding conditions and parameter values.

References

[1] T. Shimamune and K. Ono., 1980, Tool life in grinding (1st report) –Variation of grinding force components with the progress of grinding time-, Journal of Japan Society for Precision Engineering, Vol. 46, No. 11, pp. 1379-1385, (in Japanese).

[2] N. Matsumori et. al., 1993, Decision on five factors of wheel using fuzzy pule-based technology –Study on automated design of grinding wheel (3rd report)-, Journal of Japan Society for Precision Engineering, Vol. 59, No. 8, pp. 1263-1268, (in Japanese).

[3] H. Kodama et. al., 2014, Experimental verification of end-milling condition decision support system using data-mining for difficult-to-cut materials, Advanced Materials Research, Vol. 1017, pp. 334-339.