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A Measuring Method of Steel Plate Defect Uncertain Correlation Information based on Rough Set and Functional Dependency

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Abstract: There are multitudinous, multispecies, nonlinearity, multiphase and so on complex system time and space scales characteristics in steel plate production process, whose defects are divided into dominant defects and hidden defects. Real-time dynamic steel plate defects information can not be effectively and quickly converted, it is difficult to find the relationship among defects facts, defects reasons and defects controls in production elements. To reduce steel plate defects as the research object, through building-up steel plate defect information database, we can get a uncertain correlation information measurement method between steel plate defect and the production process elements by study associated information concept model of steel plate defects, measurement of uncertainty defects associated information based on Rough Set theory and mapping membership calculation based on Functional Dependency, which provides a useful theoretical support for reducing defects, improving the finished product rate. *Copyright © 2013 IFSA.*

Keywords: Steel plate defects, Correlation information, Uncertainty, Rough set, Functional dependency.

1. Introduction

According to the statistics, the total output global crude steel is 1.5478 billion tons in 2012, and the output of Chinese mainland crude steel is 716 million tons, which is 46.3 % of global production. Deeply influenced by downstream demand growth reduced drastically, productivity and yield continued promoting, and the contradiction of trade credit is sharpened, the iron and steel industry sales margins down, reach 0.13 % in 2012, which is at the lowest level in the national industry. In steel products output stage, the high defect rate, lower finished product rate caused enormous losses, which become one of the main factors that restrict iron and steel industry profits.

Steel plate defects stems from its production process's complex features, iron and steel metallurgy production process including sintering, iron making, steelmaking, continuous casting, rolling and etc. The whole production process is a typical hybrid industrial process integrated by chemical and physical process. It has multitudinous, multi-species, nonlinearity, multiphase and so on complex system time and space scales characteristics. Defect is very informative and heterogeneity exists. How to min the association rules of steel defect 'Fact- Reasons-Controls' (*FRC*), analysis reasons that cause the defects, and explore the feasible solutions to control defects become the difficult problems confused iron and steel industry.

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2. Pretreatment of Steel Plate Defect Information

2.1. The Classification and Description of Steel Plate Defect Information

2.1.1. The Classification of Steel Plate Defect Information

Steel defects are classified based on defects characteristics in steel production process, defects can be divided into major classification and small classification. Major classification is the total classification of defects, such as surface defects, internal defects, shape defects, bad SPEC, bad SIZE, single weight shortage and others, which can be expressed in English letters as (A, B... V). Small classification is detailed defects classification, which can be expressed with Arabic numerals.

2.2.2. The Description of Steel Plate Defect Information

In order to describe the associated attributes of defect information effectively, the defect information in defect information database is described, whose description method is shown in Table 1. There are two types of defects in steel plate production process, the first kind of defect is dominant which can be discovered by existing detection technology, the second kind of defect is hidden defects that remains from previous process or hidden in the engineering and technical personnel. Hidden defects is hysteretic and remain to be domination, the dominant defects should be further quantitative in order to implement control.

Table 1. Description method of the defect facts.

Defect Information access	Storage location	Defect type	Attribute counter-measures
The existing detection technology	Defect information warehouse	Dominant defects	Reasons controls quantization
Experience	Engineering technicians	Hidden defects	Reasons controls domination

2.2. The Space Model of Steel Defect Information Resources

To improve efficiency of plate defect information storage and retrieval, the space model of steel defect information resources is build as Fig. 1 [1]. The model is composed by defect information level, defects types and storage location of defect information. Each point in the space model determines one or one type of defect information [2], and the storage location in defect information database is determined.

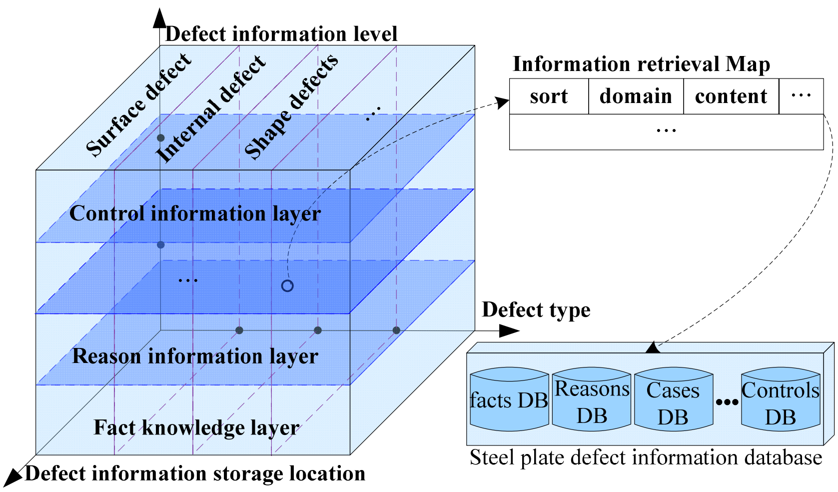

Fig. 1. The space model of steel defect information resource.

2.3. The Logic Relationship of Steel Defect Associated Information

After classifying, express, coding, sorting and other structured treatment, massive defect information is stored at specified location. Steel defect facts is stored in real-time defects database or historical defects database, steel defects reasons is stored in defect reasons database or defect dynamic reasons databases, steel defects controls is stored in defect control cases database or defect dynamic control measures databases. In addition, defect information relationship database is build based on uncertainty steel plate defect information measurement method. The logic relationship of steel defect associated information is shown as Fig. 2.

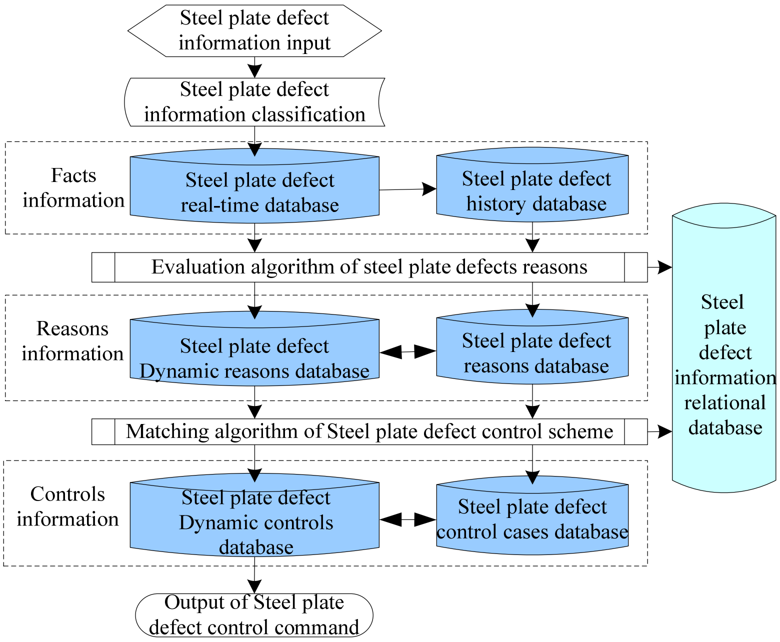

Fig. 2. The logic relationship of steel defect associated information.

3. Measurement Methods about Uncertainty Associated Information of Steel Plate Defects

Measurement about uncertainty associated information of steel plate defects is a creative activity based on knowledge processing and operation. It is a reasoning process from qualitative to quantitative, from uncertain information to determinate information [3]. And it is also a mapping process from defects facts to the defects reasons and from the defects reasons to defects control measures [4].

3.1. Associated Information Concept Model of Steel Plate Defects

In order to reveal the FRC association rules between plate defects and production process elements effectively, an associated information concept model of steel plate defects is build as Fig. 3.

Where, $\sum_{i=1,2,\cdots n} i = 100$, $\sum_{j=1,2,\cdots p} ij = 100$.

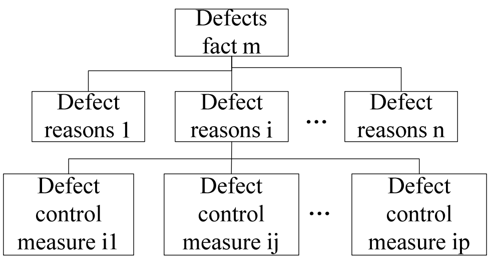

Fig. 3. Associated information concept model of steel plate defects.

3.2. Measurement of Uncertainty Defects Associated Information based on Rough Set Theory

Assume $\varphi = (F, R)$ is a defect information system, F is a finite object collection about defects facts, which is called the domain, X is a subset of the domain $X \in F$. R is a limited attribute collection of defect causes, B is a subset of R, $B \subseteq R$. The lower approximation and upper approximation of B are denoted as $B^{-}(X)$, $B\_(X)$ respectively. Set $BN_B = B^{-}(X) - B\_(X)$ boundary region of X. If boundary of X is empty set, that is $BN_B(X) = \phi$, set X is a precise set of B, otherwise X is rough set of B [5, 6].

Assume $S = \{X_1, X_2, \cdots X_n\}$ is a classification of F, which is independent of R. The sub collection $X_i (i = 1, 2, \cdots, n)$ is a classification of S. According to defects facts, $F(X)$ is a collection of objective reality defects information which all can be conclude to x, and $R(X)$ is collections of goal knowledge which may be reduce to defects reasons mapping collection x. The R lower approximation and the R Upper approximation of S are defined as $R\_(X)$ in formula (1), $R^{-}(X)$ in formula (2).

$$R\_(F) = \{R\_(X_1), R\_(X_2), \cdots, R\_(X_m)\}, \quad (1)$$

$$R^{-}(F) = \{R^{-}(X_1), R^{-}(X_2), \cdots, R^{-}(X_n)\}, \quad (2)$$

The approximate classification accuracy of S is as formula (3).

$$d_F(R) = \sum_{i=1}^{m} \left| R_-(X_i) \right| \Big/ \sum_{i=1}^{n} \left| R^-(X_i) \right|, \qquad (3)$$

Because vague concept is border, the mapping degree of defects facts - reasons is uncertain. Indiscernibility relation is used to define rough set membership function as formula (4).

$$\mu_x^B(x) = \left| X \cap B(x) \right| \Big/ \left| B(x) \right|, \quad \mu_x^B(x) \in [0,1], \qquad (4)$$

The value of the membership function $\mu_x(x)$ can be interpreted as conditional probability of defect facts - reasons mapping, which is certainty degree of x belongs to X . Membership value can be calculated by dependent function data.

3.3. The Mapping Membership Calculation based on Functional Dependency

The similarity matching input of defect 'fact-reason' is defined as defect facts F , defect reasons R , and candidate matching set K of each defect fact in 'fact-reason' model. The Similarity matching output is defined as mapping relationship $M(F,R)$ between defect facts F and defect reasons R [7]. The computational steps are as following.

1). Create the mode pattern $G(F)$ and $G(R)$ of defect facts F and defect reasons R .

2). For each candidate matching (f,r) , calculate the father structure similarity $asim(f,r)$ and the substructure similarity $csim(f,r)$. $asim(f,r)$ and $csim(f,r)$ are transmit According to the mode pattern $G(F)$ and $G(R)$.

Defect 'fact-reason' information is representing by mapping membership, for the candidate match (f,r) , generates function of element f in model F about function dependence set S_F , and decides elements closure $F^+_{R_f}$. Then generates function of element r in model R about function dependence set S_r , and decide elements closure $r^+_{S_f}$. And then we can calculate similarity $\delta(f,r)$ according to formula (5).

$$\delta(f,r) = \frac{\left| \begin{array}{c} \{x | x \in f_s^+ \wedge \exists y \in r_s^+, y \in K(X) \cup \} \\ \{x | x \in r_s^+ \wedge \exists y \in t_s^+, y \in K(X)\} \end{array} \right|}{f_s^+ \cup r_s^+}, \qquad (5)$$

After getting similarity φ , qualitative analysis the relationship among similarity $\delta(f,r)$, stability factor m and the substructure similarity $csim(f,r)$, their quantitative relationship can be represent by formula (6).

$$csim(f,r) = (\delta(f,r))^2 \times (\frac{m}{m+\alpha}), \qquad (6)$$

In the formula, the smaller the parameter α , the influence of stability factor m is smaller to substructure similarity. On the contrary, the influence of stability factor m is bigger to substructure similarity.

3). Create probability $psim(f,r)$ according to the adjusted $asim(f,r)$ and $csim(f,r)$.

For any element in the defects facts set, the higher the total value of all candidates matching similarity, the probability of actual matching degree to the defect reason is higher. Instead it is low. For any defect fact element x and the candidates match defect reason $K(x)$, the matching probability of x in defects reason can be calculated through formula (7).

$$P(x) = \frac{\sum_{y}^{y \in K(x)} sim(x,y)}{\sum_{y}^{y \in K(x)} sim(x,y) + d}, \qquad (7)$$

In the formula, d is parameter in the same situation, the bigger the numeric of d , the candidate match probability is lower, where the probability similarity is lower. The smaller the numeric of d , the candidate match probability is higher, where the probability similarity is higher.

4). Mapping relationship collection M between models is chosen according to similar probability.

The inference method between defect reason R and defect control C is similarity.

4. Conclusions

In steel products output stage, the high defect rate, lower finished product rate caused enormous losses, which becomes one of the main factors that restrict iron and steel industry profits. Steel plate defects stems from its production process's complex features, defect is very informative and heterogeneity exists. Take the research object as enhancing conversion efficiency of steel plate real-time dynamic defects information, find the relationship among defects facts, defects reasons and defects controls in production elements. Through building-up steel plate defect information database, we can get a uncertain correlation information measurement method between steel plate defect and the production process elements by study associated information concept model of steel plate defects, measurement of uncertainty defects associated information based on Rough Set theory and mapping membership calculation based on Functional Dependency, which provides a useful theoretical support for reducing defects, improving the finished product rate.

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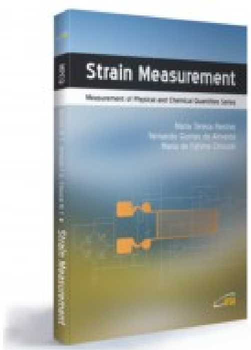

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