ELECTRE I Decision Model of Reliability Design Scheme for Computer Numerical Control Machine

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***Abstract*—The ELECTRE I is one of the most extensively used methods to solve multiple criteria decision making (MCDM) problems. In this paper, we propose a novel AHP-based ELECTRE I method of reliability design scheme decision for computer numerical control (CNC) machine. Based on the AHP method combined with ELECTRE I, the decision model is built to select the optimal design scheme. The AHP method is applied to determinate the weights of reliability design factors through the decision model. ELECTRE I method is then designed to rank reliability design scheme in order of decision maker's preference. To evaluate performance of the developed algorithm, an illustrative example of CNC machine is given. The computational results show that the proposed approach is reliable and performs well.**

***Index Terms*—reliability design, scheme decision, multiple criteria decision making, electre, analytic hierarchy process**

I. INTRODUCTION

Reliability design of CNC machine has been widely applied during the past decades. High reliability proves not only successful experience in manufacturing field, bust also strategic need for manufacturing enterprises improving market competence. Strictly speaking, performance is less important than reliability in a CNC machine. It is the key for quality of the products to realize the value of reliability design. Furthermore, the optimization reliability design scheme has played an important role to ensure the reliability and rationality of the product development design [1]. More and more enterprises attach great importance to vouch for the reliability of the mechanical products in the development and application of reliability design [2].

On the other hand, customers require high quality CNC machine with high performance, high reliability and security. Therefore, at the product development and design stage, adequate decision method that select the optimal reliability design scheme for the CNC machine are essential. However, reliability design is also a complex task because of the large number of reliability factors that have to be taken into consideration in the product design process [3]. The enormous complexity of reliability design makes product designers hard to select an optimum scheme from many design schemes.

Much research has been done on reliability-based design optimization. Youn et al. [4] presented the conjugate mean value (CMV) method for the concave performance function in the performance measure approach (PMA) of reliability-based design optimization. Du and Chen [5] developed the sequential optimization and reliability assessment method for probabilistic optimization. Using a single-loop strategy with deterministic optimization and reliability assessment, their application results demonstrated the effectiveness of reliability-based design method. Gea and Oza [6] proposed a two-level approximation method to solve the reliability-based design optimization problem. Chwail and Choi [7] presented an improved method to solve reliability-based design optimization problem. To estimate the effect of the response surface error, the developed method used the prediction interval to obtain an optimum reliability design.

Because of CNC machines with their millions of components, reliability design evaluation and optimization is becoming more and more complex and difficult. This decision and optimization model is often called MCDM problem. In a recent paper [8], the authors have provided a reliability assessment method to improve the efficiency for solving problem of probabilistic optimization with changing variance. In order to improve the accuracy of nonlinear and multi-dimensional performance functions, Lee et al. [9] proposed an inverse reliability analysis method was applied to improve the accurate probability of failure calculation for reliability design optimization. Zhang et al. [10] provided probabilistic perturbation method multi-objective optimization problem of reliability optimization design.

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They put forward Ant Colony Algorithm to improve the road header operational reliability. Injoong [11] proposed a system design-for-reliability method and reliability object model tree for reliability design of complex systems. Bhattacharjee et al. [12] established reliability design optimization formulation based on response surface method under uncertainty environment. And then the structural reliability was evaluated by the Advanced First-Order Second-Moment Method.

This paper develops a decision method of reliability design scheme for CNC machine using AHP assessment model and elimination and choice translating reality (ELECTRE) method. The AHP method is applied to determinate the weight factors through the selecting and decision-making model. Then, the ELECTRE I method is used to select the alternatives combining AHP method. The objective is to select the optimal reliability design scheme, satisfying customers in the aspects of quality and reliability needs to the most degree.

The paper is organized as follows. Section 2 describes the AHP and ELECTRE I method. The framework of the proposed AHP-based ELECTRE I algorithm are demonstrated. In Section 3, the hierarchic architecture model for the reliability design scheme is established based on AHP method. It then proposes a novel method for the scheme decision during the CNC machine reliability design process. An illustrative example of CNC machine is provided in order to assess the contribution of the proposed approach. The final diction offers concluding remarks.

II. Decision Of The Proposed Model for Reliabilty Design Scheme

The decision of reliability design scheme for CNC machine is a MCDM problem in engineering worlds. The decision of reliability design scheme is a choice made from two or more reliability design schemes. The selection of reliability design scheme is very critical for product development staff because the optimum design adds vital value on the product quality and reliability. When a new product is under study, product development teams should make a major strategic decision of reliability design scheme.

In the decision making process considered in this paper, it is very important to find a suitable method to solve the alternatives selection problem. The best decision of product development team is pursuing high reliability and quality for the good design product. Therefore, the AHP-based ELECTRE I method is developed to make the decision of reliability design scheme.

The decision making process of reliability design scheme for CNC machine is shown in Fig.1. Since the decision of reliability design scheme for CNC machine is a quite complicated process, AHP method is first applied to build the decision model so as to aid decision support. When the weights of reliability design indicators are confirmed by using AHP approach, ELECTRE I method must be taken to determine the rank of reliability design scheme. The following sections describe the decision process of reliability design scheme for CNC machine.

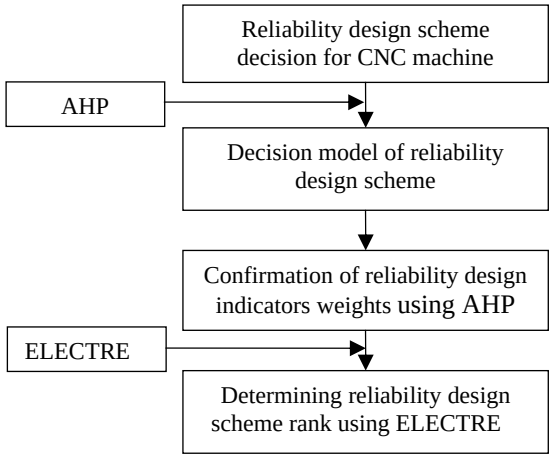

Figure 1. Decision making process of reliability design scheme

A. Application of AHP in weighting design indicators

The analytic hierarchy process (AHP) method was first proposed by Saaty [13]. The AHP is widely used as one of the popular methods in solving all kinds of problems of MCDM and calculating weighting vector method [14-15]. The primary advantage of the AHP approach is to incorporate judgments on qualitative and quantitative data [16]. First, AHP breaks down a complex MCDM problem into a hierarchy of interrelated decision indicators and alternatives. Then, the indicators and alternatives are compared in pair-wise comparison within each level. The standardized comparison scale of 9 levels is used to compare the importance of all indicators, such as “3” means “moderately more important”.

Once the weights of reliability design indicators are calculated by AHP method, the ELECTRE I approach will be used to obtain the four ranking scheme scores of the CNC machine.

B. Decision of reliability design scheme by using ELECTRE Ⅰ

To rank a set of alternatives, the ELECTRE method as outranking relation theory was used to analyze the data of a decision matrix. The Elimination and Choice Translating Reality (ELECTRE) method was first introduced in [17]. It is one of the most extensively used outranking methods reflecting the decision maker’s preferences in many fields. The ELECTRE I approach was then developed by a number of variants [18]. Teixeira [19] utilized the ELECTRE I method in a multi criteria decision model supports decision makers. Shanian and Savadogo [20] provided ELECTRE I method to select the material of bipolar plates based on multiple conflicting objectives. The transport sustainability was firstly evaluated by ELECTRE method in [21], then the modification of ELECTRE I was used to reduce the subjectivity of decision makers.

ELECTRE method reflect the dominance of relations among alternatives by outranking relations [22]. It is possible that the alternatives can be compared by these

outranking relations built in the way. Different ELECTRE method, concordance and discordance indexes are two types of indices pair-wise comparison between alternatives in ELECTRE I. With a simple analysis of the concordance reliability index, ELECTRE I method was applied to select the optimal reliability design scheme in this paper.

We assume that A_1, A_2,…, A_m are *m* possible alternatives for optimum reliability design scheme of CNC machine, C_1, C_2,…, C_n are criteria that used to describe the alternative characters, after the assignment, defined as x_{ij} for the degree of alternative A_i with respect to criteria C_j. Let W_n be the weight for importance of C_n, which is determined by AHP method. The computation flow process of ELECTRE I method is stated in the following paragraphs.

Step 1. Normalization of matrix and weighted matrix

Considering concepts on the interval numbers of decision matrix, the normalized matrix of $R_{ij} = [r_{ij}]$ is calculated by (1):

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^2}}, \quad i = 1,2,\ldots,n \quad j = 1,2,\ldots,m \tag{1}$$

Thus, the weighted matrix depends on normalized matrix assigned to it is given by:

$$V_{ij} = R \times W = \begin{vmatrix} r_{11} \cdot w_1 & r_{12} \cdot w_2 & \ldots & r_{1n} \cdot w_n \\ r_{21} \cdot w_1 & r_{22} \cdot w_2 & \ldots & r_{2n} \cdot w_n \\ \vdots & \vdots & \ddots & \vdots \\ r_{m1} \cdot w_1 & r_{m2} \cdot w_2 & \cdots & r_{mn} \cdot w_n \end{vmatrix} \tag{2}$$

Where $0 \le w_1, w_2, \ldots, w_n \le 1$. The weights of the attributes are expressed by these constants. Besides, the correlation coefficients of normalized interval numbers are between 0 and 1.

Step 2. Ascertainment of concordance and discordance interval sets

Considering that reliability design scheme decision is a multi-attribute decision with preference information, the decision rules are reasoned by the concordance and discordance interval sets, and then the attribute sets are obtained through these decision rules. Let $A = \{a, b, c, \cdots\}$ denote a finite set of alternatives, in the following formulation we divide the attribute sets into two different sets of concordance interval set (C_{ab}) and discordance interval set (D_{ab}). The concordance interval set is applied to describe the dominance query if the following condition is satisfied:

$$C_{ab} = \left\{ j \middle| x_{aj} \ge x_{bj} \right\} \tag{3}$$

On complementation of C_{ab}, we obtain the discordance interval set (D_{ab}) using (4):

$$D_{ab} = \left\{ j \middle| x_{aj} < x_{bj} \right\} = J - C_{ab} \tag{4}$$

Step 3. Calculation of the concordance interval matrix

According to the deciders' preference for alternatives, the concordance interval index (C_{ab}) between A_a and A_b can be obtained using (5):

$$C_{ab} = \sum_{j \in C_{ab}} w_j \tag{5}$$

The concordance index indicates the preference of the assertion "A outranks B". The concordance interval matrix can be formulated as follows:

$$C = \begin{vmatrix} - & c(1,2) & \ldots & c(1,m) \\ c(2,1) & - & \ldots & c(2,m) \\ \vdots & \vdots & \ddots & \vdots \\ c(m,1) & c(m,2) & \cdots & - \end{vmatrix} \tag{6}$$

Step 4. Calculation of the discordance interval matrix

First, we consider the discordance index of d(a,b), which can be viewed as the preference of discontent in decision of scheme *a* rather than scheme *b*. More specifically, we define:

$$d(a,b) = \frac{\max_{j \in D_{ab}} \left| v_{aj} - v_{bj} \right|}{\max_{j \in J, m, n \in I} \left| v_{mj} - v_{nj} \right|} \tag{7}$$

Here scheme *m*, *n* is used to calculate the weighted normalized value among all scheme target attributes. Then, using discordance interval index sets, we can obtain discordance interval matrix as:

$$D = \begin{vmatrix} - & d(1,2) & \ldots & d(1,m) \\ d(2,1) & - & \ldots & d(2,m) \\ \vdots & \vdots & \ddots & \vdots \\ d(m,1) & d(m,2) & \cdots & - \end{vmatrix} \tag{8}$$

Step 5. Determine the concordance index matrix

The concordance index matrix for satisfaction measurement problem can be written as follows:

$$\bar{c} = \sum_{a=1}^{m} \sum_{b}^{m} c(a,b) / m(m-1) \tag{9}$$

Here $\bar{c}$ is the critical value, which can be determined by average dominance index. Thus, a Boolean matrix (E) is given by:

$$\begin{cases} e(a,b) = 1 & if \quad c(a,b) \ge \bar{c} \\ e(a,b) = 0 & if \quad c(a,b) < \bar{c} \end{cases} \tag{10}$$

Step 6. Determine the discordance index matrix

On the contrary, the preference of dissatisfaction can be measured by discordance index:

$$\bar{\mathrm{d}} = \frac{\sum_{a=1}^{m}\sum_{b}^{\mathrm{m}} d(a,b)}{m(m-1)} \tag{11}$$

Based on the discordance index mentioned above, the discordance index matrix (F) is given by:

$$\begin{cases} f(a,b)=1 & if \quad d(a,b) \le \bar{d} \\ f(a,b)=0 & if \quad d(a,b) > \bar{d} \end{cases} \tag{12}$$

Step 7. Calculate the net superior and inferior value

Let c_a and d_a be the net superior and net inferior value respectively. c_a sums together the number of competitive superiority for all alternatives, and the more and bigger, the better. The c_a is given by:

$$\mathrm{c}_a = \sum_{b=1}^{n} c_{(a,b)} - \sum_{b=1}^{n} c_{(b,a)} \tag{13}$$

On the contrary, d_a is used to determine the number of inferiority ranking the alternatives:

$$\mathrm{d}_a = \sum_{b=1}^{n} d_{(a,b)} - \sum_{b=1}^{n} d_{(b,a)} \tag{14}$$

Smaller is better. This is the biggest reason that smaller net inferior value gets better dominant then larger net inferior value by sequence order.

III. Illustrative Example

As an illustration of the use of the proposed method for reliability design scheme decision for CNC machine, a numerical example is presented in this study. To examine the potential applications of the AHP-based ELECTRE I, we taken into account the design standards data obtained from CNC machine.

A. Confirmation of reliability design indicators weights using AHP

The AHP method was utilized to calculate the indicators weights of the reliability design scheme (RDS). Based on a basic reliability design, CNC machine was taken as one of the references to estimate the design schemes. The all reliability design indicators were selected: Mean Time To First Failure (MTTFF, hour), Mean Time Between Failures (MTBF, hour), Mean Time To Repair (MTTR, hour), Annual Maintenance Charge Rate (AMCR, %), Inherent Reliability (IR, %) and Failure Rate (FR). The structure of decision hierarchy is shown in Fig.2.

Then, the task of the experts in the expert team is to create individual pair-wise comparison matrix for all design indicators. The matrices of these values are given in Table I.

By applying the AHP method, the importance weights of the all reliability design indicators with respect to the main objective were obtained, the details of the calculated results are shown in Table II.

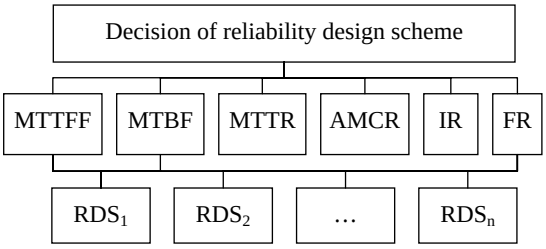

Figure 2. Decision model of reliability design scheme

TABLE I.
PAIR-WISE COMPARISON MATRIX FOR RELIABILITY INDICATORS

	MTTFF	MTBF	MTTR	AMCR	IR	FR
MTTFF	1	2	1	1	4	3
MTBF	1/2	1	1/2	2	3	2
MTTR	1	2	1	3	7	5
AMCR	1	1/2	1/3	1	2	1/2
IR	1/4	1/3	1/7	1/2	1	1/7
FR	1/3	1/2	1/5	2	7	1

TABLE II.
THE IMPORTANCE WEIGHTS BY AHP METHOD

	MTTFF	MTBF	MTTR	AMCR	IR	FR
W	0.2336	0.1652	0.3355	0.1021	0.0424	0.1212
Rank	2	3	1	5	6	4
$\lambda_{\max}$	6.5162					
CI	0.1032					
RI	1.24					
CR	0.0833					

The importance weights of reliability design indicators were accepted because the associated CR were smaller than 0.1, as is shown in Table II. Therefore, the decision matrix of the proposed hierarchical structure for decision model of reliability design scheme is consistent. The results indicate that the calculation and analysis are accurate and rational.

B. Determining the scheme rank using ELECTRE

a. Confirming normalized and weighted matrix

In this case study, four reliability design schemes for CNC machine are compared with respect to six reliability design indicators (see Fig.2). There is a close relation between reliability design scheme and reliability design indicators measured by quantitative index. Thus, the system of decision index to estimate the reliability must be established with the quantitative data. In addition, since it takes much decisive data to select an optimal scheme by using the proposed approach, the values of

qualitative research on indicators for reliability design scheme are presented in Table III.

TABLE III.
THE VALUES OF RELIABILITY DESIGN SCHEME

	MTTFF	MTBF	MTTR	AMCR	IR	FR
RDS_1	1350	1850	7.5	2.58	93.5	0.045
RDS_2	1680	1650	8.5	3.75	95.3	0.068
RDS_3	1560	1950	6.5	4.86	88.6	0.095
RDS_4	1470	1850	9.5	3.16	98.4	0.072

The indicators of MTTFF, MTBF and IR are the "bigger-the-better" type of indicators, and others are the "smaller-the-better" type. According to normalization method, the normalized matrix can be determined by using (1):

$$R=\begin{bmatrix} 0.4441 & 0.5059 & 0.4642 & 0.3500 & 0.4972 & 0.3116 \\ 0.5527 & 0.4513 & 0.5261 & 0.5088 & 0.5068 & 0.4708 \\ 0.5132 & 0.5333 & 0.4023 & 0.6594 & 0.4712 & 0.6578 \\ 0.4836 & 0.5059 & 0.5880 & 0.4287 & 0.5233 & 0.4985 \end{bmatrix}$$

Based on the importance weights (see Table Ⅱ) and (2), the weighted matrix is calculated as follows:

$$V=\begin{bmatrix} 0.1037 & 0.0836 & 0.1558 & 0.0357 & 0.0211 & 0.0378 \\ 0.1291 & 0.0745 & 0.1765 & 0.0519 & 0.0215 & 0.0571 \\ 0.1199 & 0.0881 & 0.1350 & 0.0673 & 0.0200 & 0.0797 \\ 0.1130 & 0.0836 & 0.1973 & 0.0438 & 0.0222 & 0.0604 \end{bmatrix}$$

b. Computing process by using ELECTRE

In this work, we are interested in making decision for the best alternatives. As a result, the computing process was proposed to rank four reliability design schemes of CNC machine by using ELECTRE I methods. With respect to (3), the concordance interval sets can be ascertained as follows:

$$\begin{aligned} &C_{12}=\{2,3,4,6\}, && C_{13}=\{4,5,6\}, \\ &C_{14}=\{2,3,4,6\}, && C_{21}=\{1,5\}, \\ &C_{23}=\{1,4,5,6\}, && C_{24}=\{1,3,6\}, \\ &C_{31}=\{1,2,3\}, && C_{32}=\{2,3\}, \\ &C_{34}=\{1,2,3\}, && C_{41}=\{1,2,5\}, \\ &C_{42}=\{2,4,5\}, && C_{43}=\{4,5,6\}. \end{aligned}$$

Accordingly, based on the concept of discordance interval set, we have the discordance interval sets using (4) as follows:

$$\begin{aligned} &D_{12}=\{1,5\}, && D_{13}=\{1,2,3\}, \\ &D_{14}=\{1,5\}, && D_{21}=\{2,3,4,6\}, \\ &D_{23}=\{2,3\}, && D_{24}=\{2,4,5\}, \\ &D_{31}=\{4,5,6\}, && D_{32}=\{1,4,5,6\}, \\ &D_{34}=\{4,5,6\}, && D_{41}=\{3,4,6\}, \\ &D_{42}=\{1,3,6\}, && D_{43}=\{1,2,3\}. \end{aligned}$$

Using (5), the concordance interval index can be obtained. For example, the concordance interval index of $c(1,2)$ and $c(1,3)$ can be calculated as follows:

$$\begin{aligned} c(1,2) &= \sum_{j\in c_{12}} w_j \\ &= 0.1652+0.3355+0.1021+0.1212=0.7240 \end{aligned}$$

$$\begin{aligned} c(1,3) &= \sum_{j\in c_{12}} w_j \\ &= 0.1021+0.0424+0.1212=0.2657 \end{aligned}$$

Similarly, the same procedure is applied to calculate the other concordance interval indexes. After all concordance interval indexes had been calculated, the concordance interval matrix is given as:

$$C=\begin{bmatrix} - & 0.7240 & 0.2657 & 0.7240 \\ 0.2760 & - & 0.4993 & 0.6903 \\ 0.7343 & 0.5007 & - & 0.7343 \\ 0.4412 & 0.3097 & 0.2657 & - \end{bmatrix}$$

Furthermore, the concordance index can be determined by (9), which is expressed as follows:

$$\bar{c}=\sum_{a=1}^{4}\sum_{b=1}^{4}\frac{c(a,b)}{4\times(4-1)}=\frac{6.1652}{12}=0.5138$$

Once the concordance index was calculated, according to (10), the concordance index matrix is given as:

$$E=\begin{bmatrix} - & 1 & 0 & 1 \\ 0 & - & 0 & 1 \\ 1 & 0 & - & 1 \\ 0 & 0 & 0 & - \end{bmatrix}$$

Therefore, the net superior values for each scheme are obtained by (13):

$$\begin{aligned} c_1 &= \sum_{b=1}^{4} c_{1b} - \sum_{b=1}^{4} c_{b1} \\ &= (0.7240+0.2657+0.7240) \\ &\quad -(0.2760+0.7343+0.4412)=0.2622 \end{aligned}$$

$$\begin{aligned} c_2 &= \sum_{b=1}^{4} c_{2b} - \sum_{b=1}^{4} c_{b2} \\ &= (0.2760+0.4993+0.6903) \\ &\quad -(0.7240+0.5007+0.3097)=-0.0688 \end{aligned}$$

$$\begin{aligned} c_3 &= \sum_{b=1}^{4} c_{3b} - \sum_{b=1}^{4} c_{b3} \\ &= (0.7343+0.5007+0.7343) \\ &\quad -(0.2657+0.4993+0.2657)=0.9386 \end{aligned}$$

$$\begin{aligned} c_4 &= \sum_{b=1}^{4} c_{4b} - \sum_{b=1}^{4} c_{b4} \\ &= (0.4412+0.3097+0.2657) \\ &\quad -(0.7240+0.6903+0.7343)=-1.1320 \end{aligned}$$

Similarly, the discordance index can be obtained by using (7) using the same count. For example, the discordance index of $d(1,2)$ and $d(1,3)$ can be calculated as follows:

$$d(1,2)=\frac{\max(|0.1037-0.1291|,|0.0211-0.0215|)}{0.0254}=\frac{0.0254}{0.0254}=1.0000$$

$$d(1,3)=\frac{\max(|0.1037-0.1199|,|0.0836-0.0881|,|0.1558-0.1350|)}{0.0420}=\frac{0.0208}{0.0420}=0.4949$$

Using the same counting method, the remaining discordance interval indexes are computed. After all discordance interval indexes had been determined by the similar computational process, the discordance interval matrix is given as:

$$D=\begin{bmatrix} - & 1.0000 & 0.4949 & 0.2220 \\ 0.8189 & - & 1.000 & 0.4351 \\ 1.0000 & 0.5455 & - & 0.3780 \\ 1.0000 & 1.0000 & 1.0000 & - \end{bmatrix}$$

Furthermore, using the discordance interval matrix described above, the discordance index can be determined by (11):

$$\bar{d}=\sum_{a=1}^{4}\sum_{b=1}^{4}\frac{d(a,b)}{4\times(4-1)}=\frac{8.8945}{12}=0.7412$$

Based on the discordance index calculated above, the discordance index matrix (F) is obtained by using (12) as follows:

$$F=\begin{bmatrix} - & 1 & 0 & 0 \\ 1 & - & 1 & 0 \\ 1 & 0 & - & 0 \\ 1 & 1 & 1 & - \end{bmatrix}$$

Finally, based on the concept of net inferior ranking the alternatives, the net inferior values for each scheme are obtained by (14):

$$\begin{aligned} d_1 &= \sum_{b=1}^{4} d_{1b}-\sum_{b=1}^{4} d_{b1} \\ &= (1.0000+0.4949+0.2220) \\ &\quad -(0.8189+1.0000+1.0000)=-1.1020 \end{aligned}$$

$$\begin{aligned} d_2 &= \sum_{b=1}^{4} d_{2b}-\sum_{b=1}^{4} d_{b2} \\ &= (0.8189+1.0000+0.3936) \\ &\quad -(1.000+0.5455+1.000)=-0.3330 \end{aligned}$$

$$\begin{aligned} d_3 &= \sum_{b=1}^{4} d_{3b}-\sum_{b=1}^{4} d_{b3} \\ &= (1.000+0.5455+0.3780) \\ &\quad -(0.4949+1.000+1.000)=-0.5714 \end{aligned}$$

$$\begin{aligned} d_4 &= \sum_{b=1}^{4} d_{4b}-\sum_{b=1}^{4} d_{b4} \\ &= (1..000+1.000+1.000) \\ &\quad -(0.2220+0.3936+0.3780)=2.0064 \end{aligned}$$

After all the net superior values and net inferior values for each scheme are calculated, reliability design scheme can be sorted by the calculations.

c. Discussion of the sorting results of reliability design scheme

According to computing the net superior and net inferior values for each scheme, the sorting results are shown in Table IV.

TABLE IV.
SORTING RESULTS OF RELIABILITY DESIGN SCHEME

	Net superior values	Net inferior values	Ranking of Net superior values	Ranking of Net inferior values
RDS_1	0.2622	-1.1020	2	1
RDS_2	-0.0688	-0.3330	3	3
RDS_3	0.9386	-0.5714	1	2
RDS_4	-1.1320	2.0064	4	4

Table IV compares the performances of each design scheme with the net superior and net inferior values. The computation results of the net superior values show that RDS_3 have the max value, which is the best scheme (see Table Ⅳ). On the other hand, sorting the reliability design scheme based on the net inferior values, RDS_1 finished top while RDS_4 ranked last. According to the theory of ELECTRE I, excluding RDS_2 and RDS_4, the optimal schemes of reliability design for CNC machine include RDS_1 and RDS_3.

IV. CONCLUSION

The conclusion of this study is that the optimal reliability design scheme can be selected accurately by using AHP and ELECTRE I method. Firstly, we adopt AHP method to calculate the weights of reliability design indicators. Then, AHP-based ELECTRE I methodology were utilized synthetically to rank the design schemes. The approach proposed in this paper presents diverse choices for product designers select the best alternatives. Finally, the implementation of the novel method is demonstrated by the illustrative example of CNC machine. The results of computational experiments indicated that the proposed algorithms possess good application prospect.

As mentioned above, this research was motivated by a selecting problem of reliability design scheme. In practice, reliability design scheme decision for CNC machine usually consists of multi-objective optimization model. Thus, various effective factors of optimized model need to be considered in the decision process. The focus of future studies will concentrate on other ELECTRE methods such as ELECTRE II and III. We will also research other methods to select reliability design scheme for CNC machine.

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