The Pipeline Soil Corrosion Comprehensive Prediction Method of Multi-method Integration

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Abstract — **In order to improve the prediction evaluation method accuracy of the pipeline soil corrosion, identified the core indicators in different geological conditions in the light of the pipeline soil corrosion characteristics and increased the adaptability to the environment, established the decision table to the original soil corrosion data of multi-factors and indexes by the rough set approach, then simplified it and extracted the core index. Brought out the core multi-factors and indexes with the set pair theory by the integrated use of a specific connection degree mathematical model, determined the index weight and improved the prediction model accuracy by means of the entropy method, calculated the distance of the contact degree between the forecast system to test and the classification system on the contrary identical discrepancy model according to choosing the nearly principle in the clustering analysis thought, thereby carried out the multi-factor comprehensive prediction. Set Liang ping section of the East gas pipeline in Sichuan as an example, through the above model, the predicted evaluation results conform to the actual situation. It provides a methodological guidance for the region soil corrosion comprehensive prediction.**

Keywords - pipeline; soil corrosion; rough sets; set pair theory; evaluation index

I. INTRODUCTION

With the increasing demand for energy in China, the pipeline energy transport plays an important role. Pipeline safety is the basic requirements for ensuring the pipeline energy transmission, its soil corrosion prediction and evaluation is the important part of the pipeline corrosion safety management. Because of the different regions, the factors and sizes which the soil corrosion multi-factors affect are also different, which creates the difference of distinguishing [1,2]. The current methods of the pipeline soil corrosion evaluation are showed the following, the fuzzy comprehensive evaluation method of the analytic hierarchy process method and the grey relational analysis method, the entropy weight fuzzy comprehensive evaluation method [3,4], the principal component analysis method [5], the extension evaluation method of the soil corrosion [6], the logical structure analysis method [7], the failure probability analysis method [8]. The prominent influence factors which the above methods lay particular stress on are different, the suitability and effectiveness of the method under different geographical conditions are considered inadequately, the above methods exist the widespread problems of the following, the precision and accuracy of the prediction not high, timeliness issues too poor.

In view of the different characteristics of the pipeline soil corrosion which the multi-factors and different geographical conditions affect, data mining based on the rough set method was put forward, and analysis the multiple index factor information in the original soil data sets, establish a decision table, take reduction, and in particular environment soil found in multi-factor index reflects the core of the region. Through the analysis to the critical range (value) of the soil corrosion multi-factor index attribute, put forward the following thought according to the set pair theory, make a variety of corrosion property factors and the soil corrosion level in a set pair, use the entropy calculation method to determine each index's weight coefficient of the set connection degree, thus to set up the set pair connection degree of the classification model system ,which is determined according to the soil corrosion level, and combined with the clustering analysis method, calculate the SDO (Same, Different, Opposite) distance between the set pair connection degree of the system under test and the set pair connection degree of the soil corrosion level classification model system , according to choosing the nearly principle, identify the level of the soil corrosion system under test. The modeling process is shown in Fig.1

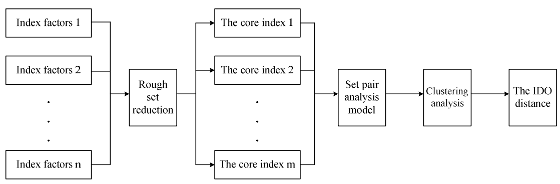

Fig.1 RS-SPA Evaluation Model

II. THE RELATED THEORY

A. *The Set Pair Theory.*

The SPA theory is, take the objective things as a sure uncertain system. Use the contact of the system properties to constitute two collections and a set pair, use the set pair connection degree to classify the quantitative description, the connection degree expression is: $U = a + b\mathrm{i} + c\mathrm{j}$, including 'a' for the same degree of the set pair, called the same degree; 'b' for the different uncertainty degree of the set pair, which is called the different degree; 'c' for the contrary degree of the set pair, called the opposite degree. 'i' is the mark symbol for difference degree or equivalent coefficient with the value range [-1, 1]; 'j' is the mark symbol of the opposition degree, its value is set as -1; a, b, c, satisfy the normalization condition of a+b+c=1 [9,10].

B. The Rough Sets.

The RS theory is the mathematical tools for dealing with issues of uncertainty. This does not need to take into account any prior information to the conditions, directly carry out the analysis to the observation data, remove the repeated and redundant information from the decision table based on rough set algorithm, simplify the condition property, and thereby simplify the decision-making index [11].

C. The Entropy Calculation Method.

In the regional system with T-predictors (factors), Y-objects of classification, in accordance to the principle of combining qualitative and quantitative, Y-classified objects correspond to T-factor values of the prediction indexes form the evaluation matrix R:

$$R = \begin{pmatrix} a_{11} & \cdots & a_{1T} \\ \vdots & \ddots & \vdots \\ a_{Y1} & \cdots & a_{YT} \end{pmatrix} \quad (1)$$

After standardized treatment of the evaluation matrix R, get matrix R':

$$R' = \{a'_{iv}\}_{Y\times T} \quad (2)$$

Among them:

$$a'_{iv} = \frac{a_{iv} - \min\{a_{iv}\}}{\max\{a_{iv}\} - \min\{a_{iv}\}}, \quad 0 \le a_{iv}' \le 1 \quad (3)$$

Define the entropy of the prediction index. In the regional system with T-predictors (factors) and Y-objects of classification, define the number 'v' entropy value of the prediction index as the following:

$$H_v = -K\sum_{i=1}^{Y} f_{iv} \ln f_{iv}, \ (v=1, 2, 3,\dots, T) \quad (4)$$

Formula (4), $f_{iv} = \frac{a'_{iv}}{\sum_{i=1}^{Y} a'_{iv}}$, $K = \frac{1}{\ln Y}$, and assume that the $f_{iv} = 0$, $f_{iv} \ln f_{iv} = 0$, the number v entropy weight ω_v is :

$$\omega_v = \frac{1 - H_v}{T - \sum_{v=1}^{T} H_v} \quad (5)$$

Obviously, $0 \le \omega_v \le 1$, $\sum_{v=1}^{T} \omega_v = 1$ [12].

III. THE PREDICTION MODEL EXAMPLE ANALYSIS OF THE SOIL CORROSION ON PIPELINE

The soil corrosion on pipeline is considered as a whole system, as thing C. Set Liang ping section of the East gas pipeline in Sichuan as an example, from the 6 factors and the calculated average rate which the corrosion influences, randomly chose 20 groups of buried data of the corrosion factors, shown in Table I [13].

TABLE I. THE INDEX FACTOR VALUE OF THE ACTUAL ORIGINAL SAMPLE OF LIANG PING SECTION SOIL CORROSION ON PIPELINE

Serial number	Soil resistivity /$\Omega\cdot$m	REDDOX potential / mV	Chloride-ion %	Sulfuric acid root ion content%	Water content %	PH value	Average corrosion rate /$\mathrm{g\cdot dm^{-1}\cdot a^{-1}}$	Soil corrosion grade
1	61.9525	323.553	0.0142	0.01728	8.28	7.43	5.2258	Serious
2	255.7157	302.052	0.0128	0.01536	22.45	7.54	2.8381	Mild
3	84.9082	334.592	0.0128	0.03456	34.45	7.55	3.8467	Medium
4	37.6574	306.648	0.0142	0.00768	34.12	6.98	6.2745	Serious
5	33.0159	385.396	0.0142	0.02112	12.35	7.12	6.8462	Serious
6	62.2309	310.642	0.0171	0.01152	9.05	7.19	4.7197	Medium
7	25.7722	420.164	0.0143	0.05184	8.85	7.26	6.3122	Serious
8	113.7052	502.084	0.01732	0.03648	21.96	7.32	3.2286	Medium
9	77.6334	167.152	0.0155	0.02496	16.95	6.83	6.2758	Serious
10	154.0207	459.587	0.0113	0.03648	20.81	7.54	2.9504	Mild
11	14.2288	513.172	0.0143	0.03456	26.55	7.11	6.9762	Serious
12	57.4991	422.035	0.0115	0.03456	8.72	6.79	4.3621	Medium
13	36.443	157.121	0.0141	0.03072	14.85	7.03	5.9398	Serious
14	28.2099	488.604	0.0100	0.04001	33.91	7.12	6.0968	Serious
15	102.0561	167.012	0.017	0.04992	15.55	6.84	5.9956	Serious
16	108.9684	451.888	0.0128	0.02304	7.43	7.35	3.2398	Medium

17	168.7966	375.781	0.017	0.02112	24.44	7.27	2.0772	Mild
18	36.1939	624.984	0.0128	0.02496	10.25	6.82	5.3441	Serious
19	135.9356	473.784	0.0128	0.02688	36.15	7.48	3.3374	Medium
20	71.3031	456.568	0.0156	0.01728	7.41	7.21	2.7912	Mild

Table I can be used as a decision table, make the selected point of the soil corrosion on pipeline as the object for study U={X1,X2, ... X20}, the selected influencing factors as the condition attribute A={soil resistivity, REDDOX potential, chloride ion ,..., average corrosion rate}, the pipeline corrosion grades as the decision attribute D={very serious, serious, medium, mild, extremely low}={5,4,3,2,1}. Carry out standard normalized processing to Table I, according to the corrosion grades in accordance with the discretization requirements of the rough sets, make the standard return together and carry out the discretization, the result is shown in Table II,the discretization table of the original test sample, take attributes reduction to the new decision table according to reduction decision rules, delete the data redundancy item 3 (or 6), 2 (or 17), 7 (14), 16 (19), the non-core index factors chlorine ion, and the soil resistivity, the results are shown in Table III, The Core Index Factor Table to The Measured Original Sample of The Pipeline Soil Corrosion.

TABLE II. THE DISCRETIZATION TABLE TO THE MEASURED ORIGINAL SAMPLE OF THE PIPELINE SOIL CORROSION

Serial number	Soil resistivity $/\Omega\cdot m$	REDDOX potential / *mV*	Chloride-ion %	Sulfuric acid root ion content %	Water content %	PH value	Average corrosion rate $/g\cdot dm^{-1}\cdot a^{-1}$	Soil corrosion grade
1	3	3	2	2	3	2	4	Serious
2	2	3	2	2	5	2	2	Mild
3	3	3	2	2	3	2	3	Medium
4	3	3	2	1	3	3	4	Serious
5	3	3	2	2	5	2	4	Serious
6	3	3	2	2	3	2	3	Medium
7	3	2	2	3	3	2	4	Serious
8	2	1	2	2	5	2	3	Medium
9	3	4	2	2	5	3	4	Serious
10	2	2	2	2	5	2	2	Mild
11	4	1	2	2	4	2	4	Serious
12	3	2	2	2	3	3	3	Medium
13	3	4	2	2	5	2	4	Serious
14	3	2	2	3	3	2	4	Serious
15	2	4	2	3	5	3	4	Serious
16	2	2	2	2	3	2	3	Medium
17	2	3	2	2	5	2	2	Mild
18	3	1	2	2	4	3	4	Serious
19	2	2	2	2	3	2	3	Medium
20	3	2	2	2	3	2	2	Mild

TABLE III. THE CORE INDEX FACTOR TABLE TO THE MEASURED ORIGINAL SAMPLE OF THE PIPELINE SOIL CORROSION

Serial number	REDDOX potential / *mV*	Sulfuric acid root ion content %	Water content %	PH value	Average corrosion rate $/g\cdot dm^{-1}\cdot a^{-1}$	Soil corrosion grade
1	323.553	0.01728	8.28	7.43	5.2258	Serious
2	302.052	0.01536	22.45	7.54	2.8381	Mild
3	334.592	0.03456	34.45	7.55	3.8467	Medium
4	306.648	0.00768	34.12	6.98	6.2745	Serious
5	385.396	0.02112	12.35	7.12	6.8462	Serious
6	420.164	0.05184	8.85	7.26	6.3122	Serious
7	502.084	0.03648	21.96	7.32	3.2286	Medium
8	167.152	0.02496	16.95	6.83	6.2758	Serious
9	459.587	0.03648	20.81	7.54	2.9504	Mild
10	513.172	0.03456	26.55	7.11	6.9762	Serious
11	422.035	0.03456	8.72	6.79	4.3621	Medium
12	157.121	0.03072	14.85	7.03	5.9398	Serious
13	167.012	0.04992	15.55	6.84	5.9956	Serious
14	451.888	0.02304	7.43	7.35	3.2398	Medium
15	624.984	0.02496	10.25	6.82	5.3441	Serious
16	456.568	0.01728	7.41	7.21	2.7912	Mild

A. Determine The Classification Reference System of The Soil Corrosion on Pipeline.

Define the classification model system of the pipeline soil corrosion C as thing $C=\{C_1,C_2,......,C_n\}$, *n*=5,in which C_1=（low soil corrosion ）, C_2=（mild soil corrosion）, C_3=（medium soil corrosion）, C_4=（serious soil corrosion）, C_5=（very serious soil corrosion）.

B. Establish The Classification Model System of The Soil Corrosion on Pipeline.

Eight groups of data are chosen from the sample data in Table III as the training sample, which is shown in Table IV. As the test sample, the remaining eight groups of data is used to check the forecast effect of the model predictions.

Define the classification model system of the pipeline soil corrosion things C={C1,C2,C3,C4,C5},REDOX potential, sulfuric acid root ion content, water content, pH value, average corrosion rate, five factors (T=5), According to the SPA principle, make the five factors as the first set of the indicator sets, the five levels of the pipeline soil corrosion levels are made as the second set, and then form a set pair with the two sets.

According to the "*NACE SP0502-2010*", "*THE PIPELINE RISK ASSESSMENT MANUAL*", and the related reference [3-6] [14-15], set up the property critical interval value of the corresponding reference sample index factors. The reference sample index factors of the pipeline soil corrosion are shown in Table V.

TABLE IV. THE CORE INDEX FACTOR VALUES CLASSIFICATION TABLE TO THE ORIGINAL SAMPLE OF THE PIPELINE SOIL CORROSION

Classification model	Index factors					
	REDDOX Potential / *mV*	Sulfuric acid root ion content %	Water content %	PH value	Average corrosion rate $/ g\cdot dm^{-1}\cdot a^{-1}$	Soil corrosion grade
C2	302.052	0.01536	22.45	7.54	2.8381	Mild
	456.568	0.01728	7.41	7.21	2.7912	Mild
C3	334.592	0.03456	34.45	7.55	3.8467	Medium
	502.084	0.03648	21.96	7.32	3.2286	Medium
C4	323.553	0.01728	8.28	7.43	5.2258	Serious
	385.396	0.02112	12.35	7.12	6.8462	Serious
	420.164	0.05184	8.85	7.26	6.3122	Serious
	167.152	0.02496	16.95	6.83	6.2758	Serious

TABLE V. THE CORE INDEX FACTORS CRITICAL RANGE TABLE TO THE REFERENCE SAMPLE OF THE PIPELINE SOIL CORROSION

Classification model	Index factors				
	REDDOX potential / *mV*	Sulfuric acid root ion content %	Water content %	PH value	Average corrosion rate $/ g\cdot dm^{-1}\cdot a^{-1}$
C1	> 500	< 0.009	< 3	> 8.5	< 1
C2	[400, 500]	[0.009， 0.04]	[3, 7) or > 40	[7.0, 8.5]	[1, 3]
C3	[200, 400)	(0.04， 0.08]	[7, 10) or [30, 40]	[5.5, 7.0)	(3, 5]
C4	[100, 200)	(0.08， 0.65]	[10, 12) or [25, 30)	[4.5, 5.5)	(5, 7]
C5	< 100	> 0.65	[12, 25)	< 4.5	> 7

At the request of the corrosion level five, make the five-level transformation according to the SPA principles, the expression of the connection degree is: $U=a+b_1\mathrm{i}_1+b_2\mathrm{i}_2+c\mathrm{j}$, including ‘a’ for the same degree of the two sets, called the same degree; the different uncertainty degree of the original bi sets, is divided into b_1i_1 set as the same difference degree and b_2i_2 set as the opposite difference degree; ‘c’ as the opposition degree of the two sets, called the opposite degree. i_1 is the mark symbol of the biased same difference degree or the corresponding coefficient values [-1,1]; i_2 is the mark symbol of the biased opposite difference degree or corresponding coefficient values [-1,1]; ‘j’ is the mark symbol of the opposite degree, set the value as -1; a, b1, b2, and c satisfy the normalization condition of a+b1+b2+c=1[16]. For the critical interval range of the sample attribute index set, in the smallest optimal index case, the following is the calculation formulas of the SPA principle to the sample attribute index critical value set and the classification model set:

$$\mu_{PK}=\begin{cases}1+0i_1+0i_2+0j, & (x_{PK}<S_{1K})\\ \frac{S_{2K}-x_{PK}}{S_{2K}-S_{1K}}+\frac{x_{PK}-S_{1K}}{S_{2K}-S_{1K}}i_1+0i_2+0j, & (S_{1K}\le x_{PK}\le S_{2K})\\ 0+\frac{S_{3K}-x_{PK}}{S_{3K}-S_{2K}}i_1+\frac{x_{PK}-S_{2K}}{S_{3K}-S_{2K}}i_2+0j, & (S_{2K}<x_{PK}\le S_{3K})\\ 0+0i_1+\frac{S_{4K}-x_{PK}}{S_{4K}-S_{3K}}i_2+\frac{x_{PK}-S_{3K}}{S_{4K}-S_{3K}}j, & (S_{3K}<x_{PK}\le S_{4K})\\ 0+0i_1+0i_2+1j, & (S_{4K}<x_{PK})\end{cases} \quad (6)$$

Among them: P=n=1、2、3、4、5 (category); K=T=(1、2、3、…、5)(the property index factors); $S_{1K}=$ the critical value of C1, $S_{2K}=$ the critical value of C2, $S_{3K}=$ the critical value of C3, $S_{4K}=$ the critical value of C4, which are the sample attribute index factor critical values of the corresponding category. To the situation, in which the critical interval value is larger and optimal, is for the reciprocal type of the calculation Eq. 6.

Put the data in Table IV into the Eq. 6 or its inverse model according to the requirements in Table V, and build the SDO connection vector for the classification model system of the soil corrosion, which is shown in Table VI.

TABLE VI.THE SDO CONNECTION VECTOR OF THE CLASSIFICATION MODEL SYSTEM AND THE REFERENCE MODEL SYSTEM OF THE PIPELINE SOIL CORROSION

Classification model	Index factors				
	REDDOX potential / mV	Sulfuric acid root ion content %	Water content %	PH value	Average corrosion rate / $g\cdot dm^{-1}\cdot a^{-1}$
C1	1+0i1+0i2+0j	1+0i1+0i2+0j	1+0i1+0i2+0j	1+0i1+0i2+0j	1+0i1+0i2+0j
C2	0+0.8966i1+0.1034i2+0j	0.7645+0.2355i1+0i2+0j	0+0i1+0i2+1j	0.25+0.75i1+0i2+0j	0.0674+0.9326i1+0i2+0j
C3	0.1834+0.8166i1+0i2+0j	0.0045+0.9955i1+0i2+0j	0+0i1+0.641i2+0.359j	0.29+0.71i1+0i2+0j	0+0.138i1+0.0507i2+0j
C4	0+0.6203i1+0.3797i2+0j	0.3613+0.6387i1+0i2+0j	0+0i1+0.1963i2+0.8037j	0.1067+0.8933i1+0i2+0j	0+0i1+0.4175i2+0.5825j
C5	0+0i1+0i2+1j	0+0i1+0i2+1j	0+0i1+0i2+1j	0+0i1+0i2+1j	0+0i1+0i2+1j

C. The Entropy Weight Calculation Method to Determine The Weight of Each Index Attribute Factor.

Using the entropy weight method, put the data in Table IV into Eq. 1 to Eq. 5, calculate the weight coefficient of each soil corrosion property index factor, and they are: REDOX potential =0.1867; sulfuric acid root ion content =0.1715; water content =0.2283; pH value =0.2248; the average corrosion rate =0.1887.

D. Determine The SDO Connection Degree for The Classification Model System of The Pipeline Soil Corrosion.

Put the above attributes factors weight coefficient in Table IV, and then get the weighted SDO connection degree of each classification model system of the pipeline soil corrosion as follows:

$C_1=1+0i_1+0i_2+0j$ (low soil corrosion);

$C_2=0.2+0.5524i_1+0.0193i_2+0.2283j$ (mild soil corrosion);

$C_3=0.1002+0.6208i_1+0.197i_2+0.082j$ (medium soil corrosion);

$C_4=0.086+0.4261i_1+0.1945i_2+0.2934j$ (serious soil corrosion);

$C_5=0+0i_1+0i_2+1j$ (very serious soil corrosion).

E. Calculate The SDO Connection Degree of The Actual Sample U_{Bl} to Test.

In Table VII that is the attribute index factor value of the actual sample U_{Bl} to test, l=8, put it into the Eq. 6 according to the requirement of the above step methods, and put in the corresponding weight coefficient into it, then get the SDO connection degree of the sample U_{Bl} under test and the reference model system, the connection degree is:

$U_{B1}=0.1715+0.4154i_1+0.2929i_2+0.1202j$;

$U_{B2}=0.2164+0.5553i_1+0i_2+0.2283j$;

$U_{B3}=0.2337+0.3449i_1+0.073i_2+0.344j$;

$U_{B4}=0.0712+0.6379i_1+0.2909i_2+0j$;

$U_{B5}=0.056+0.3404i_1+0.2066i_2+0.3970j$;

$U_{B6}=0+0.3672i_1+0.249i_2+0.3838j$;

$U_{B7}=0.2431+0.7016i_1+0.0553i_2+0j$;

$U_{B8}=0.2699+0.2861i_1+0.383i_2+0.061j$;

TABLE VII. THE INDEX FACTOR VALUES OF THE ACTUAL SAMPLE U_{Bl} TO TEST

Test sample	Index factors					
	REDDOX potential / mV	Sulfuric acid root ion content %	Water content %	PH value	Average corrosion rate $/ g \cdot dm^{-1} \cdot a^{-1}$	Soil corrosion grade
UB1	306.648	0.00768	34.12	6.98	6.2745	Serious
UB2	459.587	0.03648	20.81	7.54	2.9504	Mild
UB3	513.172	0.03456	26.55	7.11	6.9762	Serious
UB4	422.035	0.03456	8.72	6.79	4.3621	Medium
UB5	157.121	0.03072	14.85	7.03	5.9398	Serious
UB6	167.012	0.04992	15.55	6.84	5.9956	Serious
UB7	451.888	0.02304	7.43	7.35	3.2398	Medium
UB8	624.984	0.02496	10.25	6.82	5.3441	Serious

F. Calculate The SDO Distance of The Actual Sample U_{Bl} to Test and The Classification Categories.

Make d_{PBl} as the SDO vector distance of the sample U_{Bl} to test and the categories, then get it [17,18,19]:

$$d_{PBl}=\sqrt{(a_P-a_{Bl})^2+(b_P-b_{Bl})^2+(c_P-c_{Bl})^2} \qquad (7)$$

There into：(P=C1, C2, C3, C4, C5), (l =1, 2, 3, 4, 5, 6, 7, 8).

Put U_{Bl} into Eq. 7 and calculate the corresponding SDO distance, then:

The SDO distance of unknown U_{B1} :

$$d_{C1B1}=\sqrt{(1-0.1715)^2+(0-0.4154)^2+(0-0.2929)^2+(0-0.1202)^2}=0.9794$$
$$d_{C2B1}=\sqrt{(0.2-0.1715)^2+(0.5524-0.4154)^2+(0.0193-0.2929)^2+(0.2283-0.1202)^2}=0.3367$$
$$d_{C3B1}=\sqrt{(0.1002-0.1715)^2+(0.6208-0.4154)^2+(0.197-0.2929)^2+(0.082-0.1202)^2}=0.2408$$
$$d_{C4B1}=\sqrt{(0.086-0.1715)^2+(0.4261-0.4154)^2+(0.1945-0.2929)^2+(0.2934-0.1202)^2}=0.2170$$
$$d_{C5B1}=\sqrt{(0-0.1715)^2+(0-0.4154)^2+(0-0.2929)^2+(1-0.1202)^2}=1.0304$$

The SDO distance of unknown U_{B2} :

$$d_{C1B2}=\sqrt{(1-0.2164)^2+(0-0.5553)^2+(0-0)^2+(0-0.2283)^2}=0.9872$$
$$d_{C2B2}=\sqrt{(0.2-0.2164)^2+(0.5524-0.5553)^2+(0.0193-0)^2+(0.2283-0.2283)^2}=0.0265$$
$$d_{C3B2}=\sqrt{(0.1002-0.2164)^2+(0.6208-0.5553)^2+(0.197-0)^2+(0.082-0.2283)^2}=0.2793$$
$$d_{C4B2}=\sqrt{(0.086-0.2164)^2+(0.4261-0.5553)^2+(0.1945-0)^2+(0.2934-0.2283)^2}=0.2751$$
$$d_{C5B2}=\sqrt{(0-0.2164)^2+(0-0.5553)^2+(0-0)^2+(1-0.2283)^2}=0.975$$

The SDO distance of unknown U_{B3} :

$$d_{C1B3}=\sqrt{(1-0.2337)^2+(0-0.3449)^2+(0-0.073)^2+(0-0.344)^2}=0.9109$$
$$d_{C2B3}=\sqrt{(0.2-0.2337)^2+(0.5524-0.3449)^2+(0.0193-0.073)^2+(0.2283-0.344)^2}=0.246$$
$$d_{C3B3}=\sqrt{(0.1002-0.2337)^2+(0.6208-0.3449)^2+(0.197-0.073)^2+(0.082-0.344)^2}=0.4134$$
$$d_{C4B3}=\sqrt{(0.086-0.2337)^2+(0.4261-0.3449)^2+(0.1945-0.073)^2+(0.2934-0.344)^2}=0.214$$
$$d_{C5B3}=\sqrt{(0-0.2337)^2+(0-0.3449)^2+(0-0.073)^2+(1-0.344)^2}=0.7805$$

The SDO distance of unknown U_{B4} :

$$d_{C1B4}=\sqrt{(1-0.0712)^2+(0-0.6379)^2+(0-0.2909)^2+(0-0)^2}=1.1637$$
$$d_{C2B4}=\sqrt{(0.2-0.0712)^2+(0.5524-0.6379)^2+(0.0193-0.2909)^2+(0.2283-0)^2}=0.3870$$
$$d_{C3B4}=\sqrt{(0.1002-0.0712)^2+(0.6208-0.6379)^2+(0.197-0.2909)^2+(0.082-0)^2}=0.1288$$
$$d_{C4B4}=\sqrt{(0.086-0.0712)^2+(0.4261-0.6379)^2+(0.1945-0.2909)^2+(0.2934-0)^2}=0.3748$$
$$d_{C5B4}=\sqrt{(0-0.0712)^2+(0-0.6379)^2+(0-0.2909)^2+(1-0)^2}=1.2332$$

The SDO distance of unknown U_{B5} :

$$d_{C1B5}=\sqrt{(1-0.056)^2+(0-0.3404)^2+(0-0.2066)^2+(0-0.3970)^2}=1.0988$$
$$d_{C2B5}=\sqrt{(0.2-0.056)^2+(0.5524-0.3404)^2+(0.0193-0.2066)^2+(0.2283-0.3970)^2}=0.3594$$
$$d_{C3B5}=\sqrt{(0.1002-0.056)^2+(0.6208-0.3404)^2+(0.197-0.2066)^2+(0.082-0.3970)^2}=0.4241$$
$$d_{C4B5}=\sqrt{(0.086-0.056)^2+(0.4261-0.3404)^2+(0.1945-0.2066)^2+(0.2934-0.3970)^2}=0.1378$$
$$d_{C5B5}=\sqrt{(0-0.056)^2+(0-0.3404)^2+(0-0.2066)^2+(1-0.3970)^2}=0.7248$$

The SDO distance of unknown U_{B6} :

$$d_{C1B6}=\sqrt{(1-0)^2+(0-0.3672)^2+(0-0.249)^2+(0-0.3838)^2}=1.1594$$
$$d_{C2B6}=\sqrt{(0.2-0)^2+(0.5524-0.3672)^2+(0.0193-0.249)^2+(0.2283-0.3838)^2}=0.3886$$
$$d_{C3B6}=\sqrt{(0.1002-0)^2+(0.6208-0.3672)^2+(0.197-0.249)^2+(0.082-0.3838)^2}=0.4096$$
$$d_{C4B6}=\sqrt{(0.086-0)^2+(0.4261-0.3672)^2+(0.1945-0.249)^2+(0.2934-0.3838)^2}=0.1487$$
$$d_{C5B6}=\sqrt{(0-0)^2+(0-0.3672)^2+(0-0.249)^2+(1-0.3838)^2}=0.7593$$

The SDO distance of unknown U_{B7} :

$$d_{C1B7}=\sqrt{(1-0.2431)^2+(0-0.7016)^2+(0-0.0553)^2+(0-0)^2}=1.0335$$
$$d_{C2B7}=\sqrt{(0.2-0.2431)^2+(0.5524-0.7016)^2+(0.0193-0.0553)^2+(0.2283-0^2}=0.2786$$
$$d_{C3B7}=\sqrt{(0.1002-0.2431)^2+(0.6208-0.7016)^2+(0.197-0.0553)^2+(0.082-0)^2}=0.2317$$
$$d_{C4B7}=\sqrt{(0.086-0.2431)^2+(0.4261-0.7016)^2+(0.1945-0.0553)^2+(0.2934-0)^2}=0.4540$$
$$d_{C5B7}=\sqrt{(0-0.2431)^2+(0-0.7016)^2+(0-0.0553)^2+(1-0)^2}=1.2468$$

The SDO distance of unknown U_{B8} :

$$d_{C1B8}=\sqrt{(1-0.2699)^2+(0-0.2861)^2+(0-0.383)^2+(0-0.061)^2}=0.8748$$
$$d_{C2B8}=\sqrt{(0.2-0.2699)^2+(0.5524-0.2861)^2+(0.0193-0.383)^2+(0.2283-0.061)^2}=0.4859$$
$$d_{C3B8}=\sqrt{(0.1002-0.2699)^2+(0.6208-0.2861)^2+(0.197-0.383)^2+(0.082-0.061)^2}=0.4193$$
$$d_{C4B8}=\sqrt{(0.086-0.2699)^2+(0.4261-0.2861)^2+(0.1945-0.383)^2+(0.2934-0.061)^2}=0.3780$$

$$d_{C5B8} = \sqrt{(0-0.2699)^2 + (0-0.2861)^2 + (0-0.383)^2 + (1-0.061)^2} = 1.0877$$

G. Determine The Category of The Forecast System U_{Bl}.

According to choosing the nearly principle of the clustering analysis thought, the SDO distance and the results of each forecast sample are shown in Table VIII. We can see that the prediction results conform to the actual level of the soil corrosion degree.

TABLE VIII.THE SDO DISTANCE AND THE PREDICTED RESULTS OF EACH TEST SAMPLE

Test sample	The SDO distance						
	d_{C1Bl}	d_{C2Bl}	d_{C3Bl}	d_{C4Bl}	d_{C5Bl}	Judgment category	Soil corrosion grade
U_{B1}	0.9794	0.3367	0.2408	0.2170 the smallest	1.0304	C_4	Serious
U_{B2}	0.9872	0.0265 the smallest	0.2793	0.2751	0.975	C_2	Mild
U_{B3}	0.9109	0.246	0.4134	0.214 the smallest	0.7805	C_2	Serious
U_{B4}	1.1637	0.387	0.1288 the smallest	0.3748	1.2332	C_3	Medium
U_{B5}	1.0988	0.3594	0.4241	0.1378 the smallest	0.7248	C_4	Serious
U_{B6}	1.1594	0.3886	0.4096	0.1487 the smallest	0.7593	C_4	Serious
U_{B7}	1.0335	0.2786	0.2317 the smallest	0.4540	1.2468	C_3	Medium
U_{B8}	0.8748	0.4859	0.4193	0.3780 the smallest	1.0877	C_4	Serious

IV. CONCLUSIONS

Through the actual sample analysis to Liang ping section of the East gas pipeline in Sichuan based on the multi-method comprehensive prediction model on the RS-SPA evaluation model, we can get that only comprehensively consider the effect of soil corrosion factors and mutual connection can improve the accuracy of the pipeline soil corrosion prediction.

Use the entropy calculation method to analysis the objective information of the soil corrosion factors instance data, determine the size of the primary and secondary relations of each factor weight, this can effectively avoid the subjectivity of determining the index weight.

CONFLICT OF INTEREST

The authors confirm that this article content has no conflicts of interest.

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