A method of coding for aerospace product quality DNA

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Abstract: Aiming at the problem that the manufacturing process of our aerospace products is relatively discrete and the lack of appropriate quality monitoring and feedback mechanism, a method of coding for aerospace product quality DNA was proposed. Based on the structure of biological DNA and the theory of quality assessment, equipment diagnosis and quality traceability, the biological DNA structure was transformed into the structure of aerospace product quality DNA, and the concept of aerospace product quality DNA was defined, including the genetic and variation characteristics of aerospace product quality DNA. The coding rules of aerospace product quality DNA were designed, and the designed encoding rules are applied to the case of welding of wall panels in the manufacturing process of aerospace products. The results show that the coding method can monitor and feedback the core information related to quality in the manufacturing process of aerospace products.

1 Introduction

Aerospace manufacturing industry is an important part advanced manufacturing industry in China, but also an important application area of national scientific and technological innovation and traction forces. It is a symbol of comprehensive national strength, reflecting a country's ability to use space and the development of space technology. In recent years, although our aerospace manufacturing industry has made great progress, there is still a big gap compared with the advanced level of the world[1,2].

Aerospace products are mostly aluminum alloy welded structure, with large size, light, thin wall, complex and other typical features, including machining, welding and riveting three manufacturing processes. The quality standard of aerospace products is very high and requires zero defects. However, due to the fact that the manufacturing process of our aerospace products is relatively discrete and the information level is low, the lack of appropriate quality monitoring and feedback mechanism[3] leads to the difficulty of tracing product quality information and low production efficiency. These problems seriously affect the development of our aerospace manufacturing industry[4].

In view of the above problems, this paper proposes a method of coding for aerospace product quality DNA based on biological DNA, which is used to monitor and feedback the core information related to quality in the process of manufacturing aerospace products, including product quality assessment information, equipment diagnosis information, product quality traceability information, in order to trace back quality information, predict product performance, improve the intelligent diagnosis of manufacturing process, achieve the goal of zero defect quality of aerospace products.

Product quality DNA is evolved from the concept of product DNA. In 2007, the University of Michigan proposed the concept of product DNA. They believe that the product lifecycle management has a lot of manufacturing and process data. In order to improve the process, predict the performance[5,6], they defined product DNA. Compared with product lifecycle management, product DNA will be more accurate to guide the optimization of product processing[7,8] and quality defect diagnosis[9,10].

In order to gain a better understanding of the connotation of the product DNA, it is necessary to proceed from the similarity between biological and mechanical products. At present, many scholars at home and abroad demonstrate that there are similar properties between biological and mechanical products from a variety of perspectives[11,12].From the origin, the creature is created by nature through physical and chemical reactions, and the mechanical product is created by the manufacturer through a series of processing methods, so the biological and mechanical products are similar in origin, but the difference is that the creature is created by nature, and the mechanical product is created by mankind. In terms of composition, a highly evolved creature usually contains many independent systems, each consisting of different cells; Mechanical products usually contain many components, each component consists of many parts, so mechanical products and biological are similar in composition.

In this paper, based on the structure of biological DNA and the theory of quality assessment, quality diagnosis and quality traceability, the biological DNA

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structure was transformed into the structure of aerospace product quality DNA, and the concept of aerospace product quality DNA was defined, including the genetic and variation characteristics of aerospace product quality DNA. The coding rules of aerospace product quality DNA were designed, and the designed encoding rules are applied to the case of welding of wall panels in the manufacturing process of aerospace products.

2 Composition of aerospace product quality DNA

2.1 Composition of biological DNA

DNA, also known as deoxyribonucleic acid, is a kind of genetic information with biological macromolecules. It is composed of four deoxyribonucleotides linked by phosphodiester bonds, with genetic and variation characteristics. The basic unit of DNA is deoxynucleotides, consisting of phosphoric acid, deoxyribose, nitrogen-containing bases. There are four nitrogen-containing bases, namely: A-adenine, G-guanine, C-cytosine, T-thymidine.

DNA molecules are double helix structures, from two reverse parallel deoxynucleotides long chain hovering. DNA molecules in the phosphoric acid and deoxyribose are alternately connected, they are arranged on the outside, the base arranged in the inside. The bases on the two long chains are linked by hydrogen bonds, which follow the principle of complementary pairing to form base pairs, A with T, C with G. The genetic information of DNA is expressed by the order of the bases, as shown in Figure 1. Under the influence of the environment, DNA information in the genetic process will be mutated, sometimes accompanied by the emergence of defects.

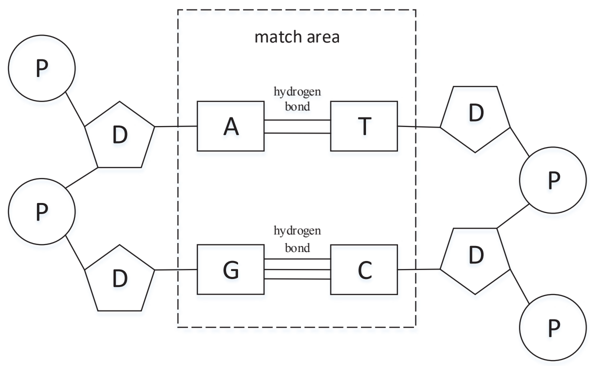

Figure 1. Composition of biological DNA

2.2 Evolution of aerospace product quality DNA

Aerospace product quality DNA evolution process is divided into two steps. The first step is to transform the phosphoric acid and deoxyribose in the biological DNA into the identification code and signature code. "Identification code + signature code " constitutes the code of aerospace product quality DNA. The identification code is composed of part number, and the signature code is composed of evaluation code, diagnostic code and traceability code.

The second step is to change the pairing principle of base pairs in biological DNA into the principle of comparison between standard manufacturing information and actual manufacturing information, and then change the hydrogen bond into the result of comparison, as shown in Figure 2. The value of the signature code is determined by the result of the match.

The value of the evaluation code is determined by the result of the comparison between the product process standard and the processing result. The value of the diagnostic code is determined by the result of the comparison between the equipment process standard and the real-time processing information. The value of the traceability code is determined by the result of the comparison between the defect case library and the product manufacturing information, as shown in Figure 3.

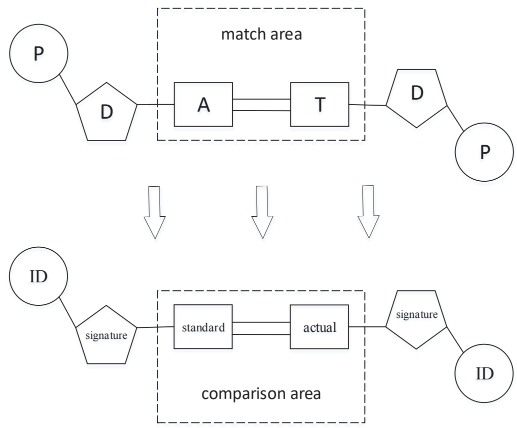

Figure 2. Evolution of aerospace product quality DNA

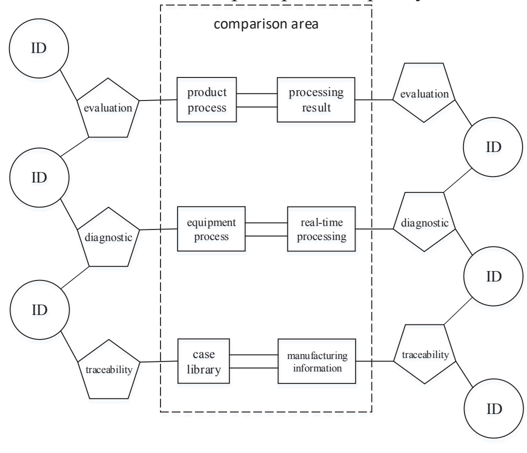

Figure 3. Composition of aerospace product quality DNA

Therefore, aerospace product quality DNA has a similar structure with biological DNA, including quality assessment model, equipment diagnostic model, quality traceability model and related code, and genetic and mutation characteristics. The quality of aerospace products is inherited on the basis of the previous processing quality, continue to carry out the current processing, and then the current processing quality genetic to the subsequent processing. Under the influence of the environment, aerospace product quality DNA will be mutated in the genetic process, sometimes accompanied by the emergence of defects.

3 Coding rules of aerospace product quality DNA

3.1 Category of code

There are many types of code. According to their attributes, they can be divided into two categories: identification code and signature code. The identification code is used to identify the identity of the object, and the signature code is used to identify the characteristics of the object.

Code according to whether it has meaning can be divided into meaningless code and meaning code. The meaningless code includes sequence code and disorder code, and the meaning code includes series sequential code, numerical alphabetical order code, hierarchical code, feature combination code and composite code. The hierarchical code is a code that follows the order of the object's dependencies and hierarchies. It is from left to right, that the level from high to low level. The leftmost code is the highest level code, and the rightmost code is the lowest bit level code. Each level of code can be used in sequence code or series of sequential code. Feature combination code is the object according to its characteristics into a number of "face" and then were encoded separately. There is no hierarchical relationship between the "face" and "face" code, and there is no affiliation.

3.2 Design of the coding rules

Aerospace product quality DNA coding consists of identification code + signature code. The identification code is part number, and the signature code consists of evaluation code, diagnostic code and traceability code, as shown in Figure 4.

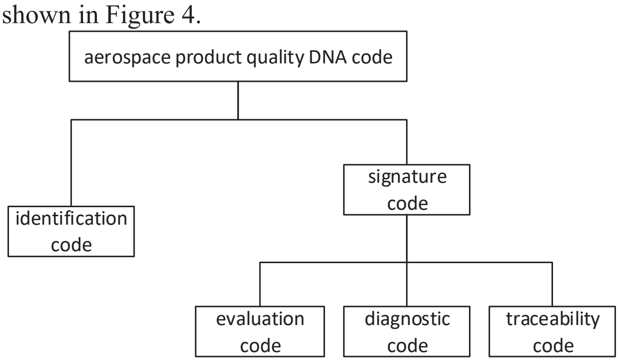

Figure 4. Composition of aerospace product quality DNA code

The evaluation code consists of the results of evaluating machining, welding and riveting. The diagnostic code consists of the diagnostic results of the equipment. The traceability code consists of the results of tracing machining, welding and riveting.

The signature code is encoded in alphabetical and digital hybrid code. The length of the code is 19 bits, as shown in Figure 5.

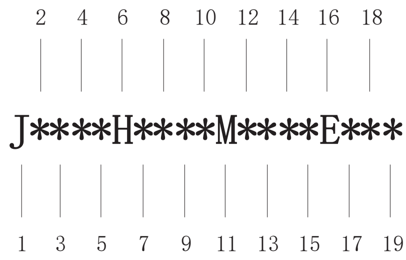

Figure 5. Length of the signature code

Evaluation code and traceability code are composed of "J****", "H****", "M****" composition. They indicate the results of the evaluation and traceability of the product quality after machining, welding and riveting. 1 to 5, 6 to 10, 11 to 15 bits are encoded in hierarchical code + feature combination code. The second to fifth bits are subordinate to the first bit, the 7th to 10th bits are subordinate to the sixth bit, and the 12th to 15th bits are subordinate to the 11th bit.The first, sixth, and eleventh bits are the classification codes, which are represented by capital letters. They are J (machining), H (welding) and M (riveting). 2, 7, and 12 bits are the evaluation status codes, which are the result of the evaluation of the 1st, 6th and 11th places. 3 to 5, 8 to 10, 13 to 15 bits are traceability status codes, which are the result of the first, sixth, and 11th tracebacks. There is a hierarchical relationship between the evaluation status code and the traceability status code, and there is no hierarchical relationship and no affiliation.

The evaluation status code (bits 2, 7, 12) is encoded in series sequential code, indicated by the numbers 0 to 3. "3" indicates that the evaluation result is "good", "2" indicates that the evaluation result is "normal", "1" indicates that the evaluation result is "poor" and "0" means "no evaluation".

The traceability status code (bits 3 to 5, 8 to 10, 13 to 15) is encoded in hierarchical code. Bits 4, 9, 14 are subordinate to bits 3, 8, 13, and bits 5, 10, 15 are subordinate to bits 4, 9, 14. The 3rd, 8th and 13th bits indicate the number of defects, denoted by the numbers 0 to 9. "0" means no defects, "1 ~ 8" indicates the number of defects, "9" indicates that the number of defects is 9 and above. The 4th, 9th, and 14th bits represent one of the most serious defects of the previous one, denoted by lowercase letters a to z. "A ~ x" represents a common 24 defects, "y" indicates a defect other than the previous 24 defects, and "z" indicates no defects (if bits 3, 8 and 13 are "0"). The 5th, 10th, and 15th bits indicate the cause of the previous defect, and are represented by the numbers 0 to 9. "0" indicates no reason (if the 3rd, 8th and 13th bits are "0"), "1 ~ 8" indicates the eight common causes of defects at the 4th, 9th and 14th positions. "9" indicates other reasons than the previous eight reasons.

The diagnostic code (bits 16 to 19) is encoded in hierarchical code + signature code. Bits 17 to 19 are subordinate to bit 16. The 16th bit is a class code, which is represented by the capital letter E (equipment). The 17th to 19th bits are diagnostic status codes, which are represented by the numbers 0 to 9. The 17th bit indicates the number of equipments whose diagnostic result are "good". The 18th bit indicates the number of equipments whose diagnostic result are "normal". The 19th bit indicates the number of equipments whose diagnostic result are "poor". "0 ~ 8" indicates the number of equipments. "9" indicates that the number of equipments is 9 and above.

4 Case study

The coding method is applied to the case of welding of wall panels in the manufacturing process of aerospace products. Table 1. shows the manufacturing information of the wall panels.

Table 1. Welding process of the wall panels

Process Elements	Standard	Actual
chamfering	40°	40°
gap(mm)	0.5~1	0.54
misalignment(mm)	0~0.5	0.28
weld width(mm)	14~18	16.32
weld reinforcement(mm)	0.5~2	1.33
leakage(mm)	0.5~1	0.93
groove width(mm)	3~4	3.56
groove depth(mm)	0.5~1	0.62

The quality of the welding of the wall panels was evaluated by fuzzy analytic hierarchy process. The results are shown in Table 2.

Table 2. Evaluation results

<table>
<tr><th>Process Elements</th><th colspan="3">Evaluation Results</th></tr>
<tr><td>chamfering</td><td>good</td><td rowspan="3">good</td><td rowspan="8">good</td></tr>
<tr><td>gap(mm)</td><td>normal</td></tr>
<tr><td>misalignment(mm)</td><td>good</td></tr>
<tr><td>weld width(mm)</td><td>good</td><td rowspan="2">good</td></tr>
<tr><td>weld reinforcement(mm)</td><td>good</td></tr>
<tr><td>leakage(mm)</td><td>normal</td><td rowspan="3">normal</td></tr>
<tr><td>groove width(mm)</td><td>good</td></tr>
<tr><td>groove depth(mm)</td><td>normal</td></tr>
</table>

Therefore, the evaluation code for the wall panels is "H3***". Table 3. shows the detection information of welding of the wall panels.

Table 3. Detection information of welding

Detection Process	Detection Results
radiographic	no defects
penetrant	no defects
ultrasonic	no defects

So the traceability code is "H*0z0". Finally, the evaluation and traceability code for the wall panels is "H30z0".

5 Conclusions

Aiming at the problem that the manufacturing process of our aerospace products is relatively discrete and the lack of appropriate quality monitoring and feedback mechanism, a method of coding for aerospace product quality DNA based on biological DNA was proposed.The coding method is applied to the case of welding of wall panels in the manufacturing process of aerospace products.The results show that the coding method can monitor and feedback the core information related to quality in the manufacturing process of aerospace products.

The research work of this paper is concentrated on the method of coding for aerospace product quality DNA, which is the first step to develop the entire framework of the concept. In order to complete the whole product quality DNA framework for different purposes of applications, a number of future research may be taken up following the studies in this paper. For instance, product quality DNA based performance analysis and prediction, and identify appropriate prediction tools to achieve product performance prognosis.

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