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THE EXTENSION ADAPTIVE DESIGN MODEL FOR MECHANICAL PRODUCT LIFECYCLE

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ABSTRACT

Due to the complicated, multi-hierarchy, multi-attribute and creative process of the extension adaptive design for mechanical product lifecycle, the case reuse and extension design patterns of extension adaptive design for mechanical product lifecycle were studied, an improved similarity calculation method based on extension distance were presented, the design domain of adaptive design for mechanical product were expended, the extension model and extension rules of solving contradictions which is in the internal of design stages or between design stages were given, an extension adaptive design model for mechanical product lifecycle were presented.

Keywords: Lifecycle, Extension theory, Case reuse, Adaptive design.

1. INTRODUCTION

Product innovation design is a kind of deign activities driven by customer needs, and for the purpose of meeting customer demand. Modern product design theory is not only to meet customer's requirement in aspect of product function. With competition intensified and the establishment of buyer's market, customer's requirements became more and more diversified, such as requirement on function and product appearance structure even on the product service. So these design demands must be considered in the design of mechanical products. And more than half of mechanical product innovation design is adaptive design. In recent year, many scholars have researched the problem of mechanical products adaptive design and obtain the corresponding research findings [1-6]. But most researches are structure configuration design according to the requirements of design in a design domain. Research on adaptive design of multi design domain requirement is not enough, and the research did not give a model solution for the contradictory problem between design domains and in design domains. Extenics is a newly emerging discipline which is used to solve contradictory problems intelligent with characteristics of formal, logic and mathematics. It discussed the possibility of matters' extension, rules and method of innovation with formalized models [7-10]. Therefore, the research of Extenic has great significance, especially for the combination of Extenics with other intelligent technology and its application on intelligent adaptive design of mechanical products based on the whole lifecycle [11-16]. It is useful for solving the problems above and the study on the method of improve mechanical product intelligent adaptive design efficiency. But at present, there are still some problems of adaptive design. (1) Most research simply relying on functions or the design information exists in the process of structural design for knowledge reuse and adaptive design. However, actual mechanical product adaptive design in most case involves one or more aspects of demand, function, structure, process and service. And the knowledge reuse and adaptive design of multidimensional and in-depth information involved in the whole mechanical product lifecycle is not enough. It failed to give sufficient consideration to knowledge representation and reuse of the instance information which exist in various design stages of the whole lifecycle of mechanical product. (2) Most research is just adaptive modification based on conflict problems of a particular stage. And when it comes to the conflict problems existed between the design requirements of each design stage, they failed to provide a reasonable, effective and the whole lifecycle of product oriented method. Therefore, based on the achievement of research, this paper studies the retrieval method of similar case based on the improved extension distance. We put forward the adaptive modification method for the whole lifecycle of mechanical product, and set up the extension adaptive design model for the whole lifecycle of mechanical product based on case reuse. At last, we verified the effectiveness of the algorithm based on example.

2. RETRIEVAL OF SIMILAR INSTANCES BASED ON THE IMPROVED EXTENSION DISTANCE

As long as the value corresponding to the feature of element is the form of number, they can adopt the improved similarity retrieval method based on extension distance. Taking an example of the matter-element, O_0 refers to the object, c_o refers to the characteristic of O_0, and v_o refers to the value of c_o. The matter-element model is expressed as follows:

$$\mathbf{J}=\begin{bmatrix} O & C_1 & V(C)_1 \\ & C_2 & V(C)_2 \\ & \vdots & \vdots \\ & C_k & V(C)_n \end{bmatrix}.$$

There are many computing method of similarity of mechanical product, such as hamming distance, Minkowski distance and so on. The characteristics value of most information is the number $v=a$ which meets certain demand. And the design demand generally is interval $v_o=\langle c,d\rangle$. But in classical distance, the distance between any point in interval and the interval is zero. So computing similarity based on classical distance cannot distinguish the difference of information within the scope of the design demand. In order to describe the difference of things in a class, we compute similarity by introducing the extension distance to the case reuse. The similarity obtained by extension distance is more accurate than that obtained by classical distance. And it can distinguish the difference of the similarity of different elements in the same interval. The proximity degree between the ith characteristic about rth instance information and ith design requirement interval of the corresponding demand information matter-element is:

$$R\left(S_{ij}\right) \tag{1}$$

Given interval $v_0=\left[c_{oi}\ d_{oi}\right]$. If $a_i^r \notin v_0$, then $\rho\left(v,v_0\right)>0$. If $a_i^r=c_{oi}$ or $a_i^r=d_{oi}$, then $\rho\left(v,v_0\right)=0$. If $a_i^r \in v_0$, then $\rho\left(v,v_0\right)<0$. And when a_i^r is the middle point of interval $v_0=\left[c_{oi}\ d_{oi}\right]$, then $\rho\left(v,v_0\right)$ achieve the minimum. Because the magnitude of eigenvalue in different information matter-element is different, so we need to process the proximity got by formula (1) normalized. And the normalized process of proximity in the past is like formula (2). When the optimal point is the middle point of interval, the similarity between the ith characteristic about the rth instance information matter-element and the characteristic of corresponding demand information element is:

$$\begin{cases} K_i^r = {-\rho\left(v_i^r,v_{oi}\right)} \Big/ {\max\limits_{1\le r\le m}\rho\left(v_i^r,v_{oi}\right)}, when\ \rho\left(v_i^r,v_{oi}\right)>0 \\ K_i^r=0, when\ \rho\left(v_i^r,v_{oi}\right)=0 \\ K_i^r = {-\rho\left(v_i^r,v_{oi}\right)} \Big/ {\max\limits_{1\le r\le m}\left|\rho\left(v_i^r,v_{oi}\right)\right|}, when\ \rho\left(v_i^r,v_{oi}\right)<0 \end{cases} \tag{2}$$

This method of calculating similarity is affected by instance information in the database. And the change of data or data volume of database will affect the similarity. And if the optimal point is not the middle point of interval, this method still reflects the similarity to the middle point. The size of the interval reflects the accurate requirement of demand information. On this point, this paper proposes a new and more generality formula (3) based on extension distance. It avoids the change of similarity brought by increase or delete data of the database compared with tradition formula. And it reflects the similarity to the optimal point no matter whether the optimal point is the middle point or not. So, the formula (3) is more objective and accurate in the calculation of similarity. The optimal point x_{oi} is not the middle point of interval $v_{oi}=\left[c_{oi},d_{oi}\right]$, the similarity between the ith characteristic x_i about the rth instance information element and the characteristic of corresponding demand information element based on extension distance is expressed as:

$$\begin{cases} K_i^r = {\rho\left(v_i^r,v_{oi}\right)} \Big/ {\left(d_{oi}-x_{oi}\right)}, when\ v_i^r \ge x_{oi} \\ K_i^r = {\rho\left(v_i^r,v_{oi}\right)} \Big/ {\left(x_{oi}-c_{oi}\right)}, when\ v_i^r < x_{oi} \end{cases} \tag{3}$$

If $K_i^r<0$, the matter-element characteristic of demand information is not similar to that of instance information. If $K_i^r=0$, the matter-element characteristic of demand information is critical similar to that of instance information. If $K_i^r\in(0,1)$, the matter-element characteristic of demand information is similar to that of instance information. And the higher the value K_i^r is, indicates more similar to common characteristics. Only if $K_i^r=1$, the matter-element characteristic value v_i^r of instance information is just in the optimal point.

The weight of the same m characteristics of the demand information matter-element is determined according to the degree of importance of them. And the weighted similarity of the first r instance information-element and the demand information matter-element is:

$$K^r=\sum_{i=1}^{k} j_i K_i^r \tag{4}$$

Wherein, $j_1+j_2+\cdots+j_k=1$. j_i is the weight of the number i characteristic. k is the number of common characteristic between demand information matter-element and instance information matter-element.

Finally, the instance information matter-element with maximum similarity is chosen according to the similarity K^r that between demand information matter-element and instance information matter-element. If $K^r=1$, it shows instance information matter-element meet the design requirement completely. And it can be applied to the design of new product directly. But the value of K^r is the number between 0 and 1. So we need to choose the information matter-element with maximum similarity from the instance information element which meets the similarity threshold, and conduct extension adaptive modification on it.

The similarity of compound element is obtained by the similarity of element. Taking K_i , K_j and K_s as the similarity of all matter-element, affair element and relation-element in the compound element. And ω_i , ω_j , ω_s represent the corresponding weight of these matter-element, affair-element and relation-element. Then the total similarity of compound-element is:

$$K = w_i * K_i + w_j * K_j + w_s * K_s \tag{5}$$

And if the compound element does not entirely contain matter-element, affair-element and relation-element, then the weight of the missing element is 0. It is always retreve the similarity of coumpound element in the knowledge reuse of design information at first. When it does not retrive the compoun element that meet the similarity threshold, we need to decompose the compound-element into matter-element, affair-element and relation-element. Then retrieve the similarity of the element, and conduct extension transformation on the element that meets the condition. Finally we will get the compound-element that meets the design requirement by extension transformation.

3. THE EXPANSION OF DESIGN DOMAIN IN THE EXTENSION ADAPTIVE DESIGN

There is a large number of design information in the design example of mechanical products. This information can be used to design new products, especially the extension adaptive design for the large and complex mechanical products. With the increase of the complexity of the mechanical products, the reusable design information in the mechanical product instance will be more and more complex. And this design information can be used in new product design. It is difficult to meet the requirement of adaptive design of new product if only reuse the knowledge of design results. So we need to classify the design information in the design instance of mechanical products according customer, function, structure, technology, structure, service and other aspect for region management and reuse. And this will provide support for a comprehensive, effective reuse of mechanical product design instance information.

The design process is divided into four different design activities according axiomatic. They are Customer Domain, Function Domain, Physical Domain and Process Domain [17]. And in the extension adaptive design of mechanical product, the design process can be expanded up to six domains (Customer Domain, Function Domain, Principle Domain, Physical Domain, Process Domain and Service Domain) according to the actual design requirement. There is a mapping relationship between neighborhood domains as well as between the two alternate domains. The mapping relationship can be built according the design requirement of the actual product adaptive design. If there is no requirement about principle or service, one or more domain can be reduced according actual requirement. This is to ensure reuse fully of the design information in the product design examples so as to reduce the adaptive change. And also it will not increase the complexity of adaptive design of product with the increase of the domain. The number of domain in the design activity can be chosen according to requirement of actual adaptive design.

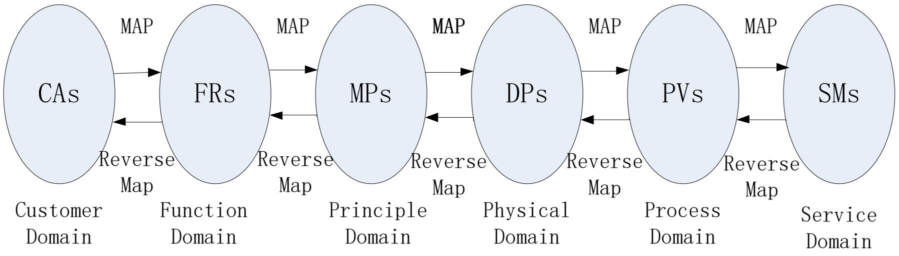

Figure 1. design domain of extension adaptive design

The customer domain refers to client's requirement information about product attribute which in the design information of existing product instance. Function domain is the information about function. It is the functional properties determined according to customer demand. And the element in this domain shows functional characteristics and design constrain. The principle domain refers to the design information of implementation rationale or method which adopted to meet the product functional requirements. Physical domain is design parameters decided to meet function requirement. The data in this domain is shown as structure characteristic parameter. Process domain is process variables formulated by the design parameters of physical domain. And the service domain refers to the information about after-sale service, repair, maintenance, etc.

The extension adaptive design process of mechanical product is described as follows: its principal line is domain mapping driven by customer demand; it gives priority to with reuse of the existing product design information in eachdomain, adaptability revision of the reused design information as the auxiliary pole; its object is to meet the design requirements of each phase. For each pair of adjacent domain, the left domain represent what to get, the right domain represent how to get or realize. And the establishment of contact between the two domains need though design equation. This paper takes function domain and physical domain as an example to verify how to handle conflict problems between different design domains.

4. THE EXTENSION MODEL OF ADAPTIVE DESIGN OF COMPLEX MECHANICAL PRODUCT FOR THE WHOLE LIFECYCLE

The design requirement of each design domain is increasing. And there will be many conflicting problems between the upper level design domain and the next stage domain or in the design domain. Then it need extension transform for the design requirement that produce the conflicting problem or the existing design conditions, and transform conflicting problems into non-conflicting problems, that is the process of extension adaptive modification. The process of extension adaptive modification can be divided into adaptive expansion process and adaptive convergence process. The key to solve conflicting problems reasonably and carry out adaptive design for mechanical product favoring is how to expand or astringe the design requirement of conflicting problems and the existing design condition. The extension model and expanding direction of complex mechanical product adaptive design will be given as follows.

4.1 Extension model of conflicting problems between design domains

The target element $g_n \mid g_n \in G_n(J)$ is the design requirement of upper level. The conditional element $l_{n+1} \mid l_{n+1} \in L_{n+1}(J)$ is the design condition that the next level can provide. And the two are contradictory. Then the extension model of the compatible problem of mechanical product can be established with the two elements. Extension transformation of design features and design values can be carried on with the combination of design knowledge in the domain and related design constraints. Then we can obtain a series of adaptive design schemes that can meet the requirement of upper level design. So the extension process of adaptive design can be formalized shown as in definition 1, and it can meet the upper level design requirement.

Destination 1 The extension model of adaptive design that can meet the design requirement of upper level

$$P_n = \left(\left(g_n \mid g_n \in G_n(J)\right) \otimes \left(l_{n+1} \mid l_{n+1} \in L_{n+1}(J)\right) \wedge F_{V_P}\left(g_n \otimes l_{n+1}\right)\right) \quad (6)$$

Wherein, is the extension solving problem which meet the design requirement of upper level. is the design result of that hoped to meet the design requirement of upper level, that is the target element. is the conditional element which realize the design requirement of upper level, including similar case element, working conditions, design rules of next level and other factors. is the objective function which meet the design requirement of upper level, using to represent the compatibility of condition and target in the process of the adaptive design.

The nature of the extension adaptive design which to meet the design requirement of upper level is to make the objective function meet the compatibility requirements of design condition and design goals. The key is to find the extensible design direction, and modify the design feature in this direction to get design scheme.

The idea for the resolution of incompatible problems in extenics can be summarized into three categories. First, the target element is constant, the incompatible problem can be translated to compatible problem though extension transformation on the existing condition element . Second, the existing condition element is constant, carry extension transformation on target element to resolve incompatible problem. Third, the target element and the condition element are changed at the same time to resolve incompatible problem.

This paper gives priority to choose the first approach. Because we need to meet the design requirement of upper level while take meeting the design requirement of next level into account. So when conducting extension transformation to meet design requirement of upper level should guarantee the function demand remains the same and conduct extension transformation for the design condition of next level. So the priority is to transform the condition element of next level.

4.2 The extension model of the conflicting problem in the design domain

The extension transformation for the next level design domain element to solve the conflicting problem in the design domain easily lead to opposition between the new element and other domain in this design domain. We take the new expanding element as question G_1, and the element without extension transformation as question G_2. And the condition element L_1 is the existing condition of this design domain. If the existing condition L_1 cannot meet question G_1 and G_2 at the same time, then establish the opposite problem. The extension processes of adaptive design to meet the requirement of function and structure can be formalized shown as in definition 2.

Definition 2 The extension model of conflicting problem in design domain

$$\begin{aligned} P_1 = (&\left(g_{n1} \mid g_{n1} \in G_{n1}(J)\right) \wedge \left(g_{n2} \mid g_{n2} \in G_{n2}(J)\right) \\ &\otimes \left(l_{n1} \mid l_{n1} \in L_{n1}(J)\right) \wedge F_{p_1}\left(g_{n1} \wedge g_{n2} \otimes l_{n1}\right)) \end{aligned} \quad (7)$$

Wherein, P_1 is the extension solving problem of G_1 and G_2. $g_{n1} \mid g_{n1} \in G_{n1}(J)$ and $g_{n2} \mid g_{n2} \in G_{n2}(J)$ is the hoped design result when the question P_1 meet the condition of existing design domain, that is the target element. $l_{n1} \mid l_{n1} \in L_{n1}(J)$ is the condition element that can realize G_1 and G_2. $F_{p_1}\left(g_{n1} \wedge g_{n2} \otimes l_{n1}\right)$ is the target element that meet G_1 and G_2. And it is used to represent the coexistence of target $g_{n1} \mid g_{n1} \in G_{n1}(J)$ and $g_{n2} \mid g_{n2} \in G_{n2}(J)$ in the process of adaptive design which to meet G_1 and G_2.

The nature of the extension adaptive modification which to meet the conflicting problem in design domain is to make the objective function $F_{p_1}\left(g_{n1} \wedge g_{n2} \otimes l_{n1}\right)$ meet the compatibility requirements of design goals in the upper level design domain and design condition in the next level. The key is to find the extensible design direction, and modify the design feature in this direction to get design scheme.

The idea for the resolution of opposite problems in extenics can be also summarized into three categories. First, the target element $g_n \mid g_n \in G_n(J)$ and $g_{n2} \mid g_{n2} \in G_{n2}(J)$ are constant, the opposite problem can be translated to coexistence problem though extension transformation on the design condition $l_{n+1} \mid l_{n+1} \in L_{n+1}(J)$ in this design domain. Second, the existing condition element $l_{n1} \mid l_{n1} \in L_{n1}(J)$ is constant, carry extension transformation on target $g_n \mid g_n \in G_n(J)$ or $g_{n2} \mid g_{n2} \in G_{n2}(J)$ to resolve opposite problem. Third, the target and the design condition in this design domain are changed at the same time to resolve opposite problem. If choose the third idea, we will get too many expand directions, and it is difficult to find the expanding portfolio which meet the design condition. The target element $R(S_{ij})$ consists of the necessary condition to meet the design requirement of upper level design domain. So we give priority to transform the design condition $l_{n1} \mid l_{n1} \in L_{n1}\left(J\right)$ and the target element $g_{n2} \mid g_{n2} \in G_{n2}\left(J\right)$ at the same time.

4.3 The whole lifecycle oriented extension adaptive design model and algorithm for the complex mechanical product

The whole lifecycle oriented extension adaptive design process of complicated mechanical product mainly includes tree parts. They are classification of existing design information by design domain, retrieval of similar design information based on design domain and adaptive modification based on design information. First, to establish element or compound element model of the design information by customer domain, function domain, physical domain, process domain and service domain. And we can add principle domain between function domain and physical domain based on the product design requirement. Second, to retrieve the design domain information library based on the similarity of the existing information element and the corresponding demand information element, and choose the existing design information with maximum similarity. Then we make adaptive changes to the product on this basis. So the extension adaptive design model based on the whole lifecycle of mechanical product is shown as FIGURE 2.

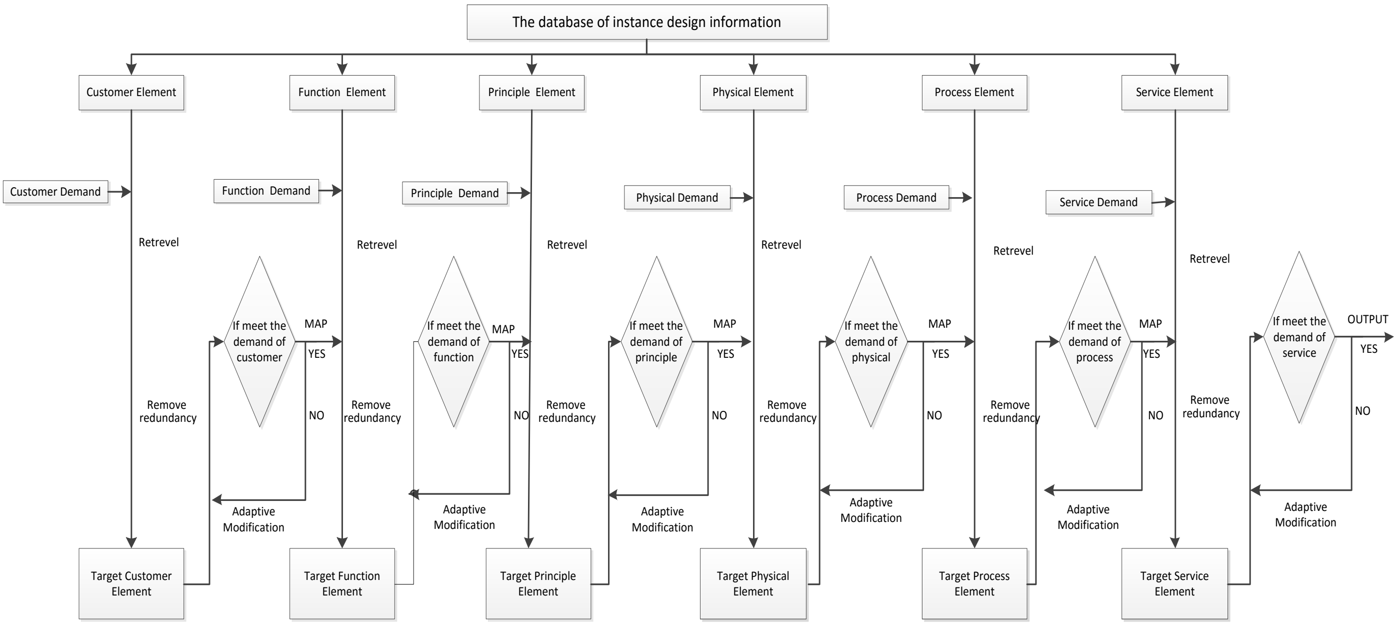

Figure 2. The extension adaptive design model based on the whole lifecycle of mechanical product

The steps of extension adaptive design process based on the whole lifecycle of mechanical product can be described as follows:

Step 1 To establish element or compound element model of the design information by customer domain, function domain, physical domain, process domain and service domain. And we can add principle domain between function domain and physical domain based on the product design requirement. Then we can get the design information database of customer element, function element, process element and service element.

Step 2 To retrieve the design information database of customer element based on customer's demand and find the target customer element with maximum similarity. Then judge if the target customer element meets customer's demand. If meet, then establishing a mapping between costumer and function for target customer element. If it does not meet the demand then conducting adaptive revision though extension transformation until it meets the demand, and establishing a mapping between demand and function for target demand element.

Step 3 To retrieve the design information database of function element based on function demand and find the target function element with maximum similarity. By combining with the function element with maximum similarity that mapped from step 2 and reduce redundancy, then we will get the target function element which meet customer demand and functional demand. If it does not meet functional demand, then conducting adaptive revision though extension transformation until it meets the demand. If meet, then establishing a mapping between function and physical for target function element.

Step 4 To retrieve the design information database of physical element based on physical demand and find the target physical element with maximum similarity. By combining with the physical element with maximum similarity that mapped from step 3 and reduce redundancy, then we will get the target physical element which meet functional demand and physical demand. If it does not meet physical demand, then conducting extension transformation until it meets the demand. If meet, then establishing a mapping between physical and process for target physical element.

Step 5 To retrieve the design information database of process element based on process demand and find the target process element with maximum similarity. By combining with the process element with maximum similarity that mapped from step 4 and reduce redundancy, then we will get the target process element which meet physical demand and process demand. If it does not meet physical demand, then conducting extension transformation until it meets the demand. If meet, then establishing a mapping between process and service for target physical element.

Step 5 To retrieve the design information database of service element based on service demand and find the target service element with maximum similarity. By combining with the service element with maximum similarity that mapped from step 5 and reduce redundancy, then we will get the target service element which meet process demand and service demand. If it does not meet physical demand, then conducting extension transformation until it meets the demand, and export the design scheme.

5. APPLICATION EXAMPLE

This paper takes function domain and physical domain for example, and verifies the retrieval methods based on the improved extension distance and how to handle the conflicting problem between design domains or in them.

Step 1 To establish demand function element according design function demand and physical demand. And it can represent as:

$$R_{nc}=\begin{bmatrix} \mathit{Energy\ Transfer} & \mathit{Transfer\ Direction} & \mathit{Syntropy} \\ & \mathit{Transfer\ Model} & \mathit{Rotation} \\ & \mathit{Transfer\ Power/MW} & ([480,520]) \end{bmatrix} \qquad (8)$$

The demand physical element is expressed as:

$$R_{n+1c}=\begin{bmatrix} & & \left(\begin{bmatrix} \mathit{Spindle} & \mathit{Material} & (\mathit{Forge\ 20SiMn},0.4) \\ & \mathit{Length/mm} & ([7700,7770],0.3) \\ & \mathit{Centre\ Hole\ Diameter/mm} & ([\phi1710,\phi1720]0.3) \end{bmatrix},0.7\right) \\ \mathit{Turbine\ Structure\ Instance} & \begin{matrix} \mathit{Spindle\ Characteristic} \\ \\ \mathit{Wheel\ Characteristic} \end{matrix} & \\ & & \left(\begin{bmatrix} \mathit{Wheel} & \mathit{Nominal\ size/mm} & ([6250,6265],0.4) \\ & \mathit{Maximum\ Overall\ Diameter/mm} & ([6350,6370],0.3) \\ & \mathit{Inner\ Diameter/mm} & ([3120,3140],0.3) \end{bmatrix},0.3\right) \end{bmatrix} \qquad (9)$$

Step 2 To retrieve the case library based on formula (1), (3)and (4), and we will get the instance function element with the maximum similarity as follows:

$$R_{ns}=\begin{bmatrix} \mathit{Energy\ Transfer} & \mathit{Transfer\ Direction} & \mathit{Syntropy} \\ & \mathit{Transfer\ Model} & \mathit{Rotation} \\ & \mathit{Transfer\ Power/MW} & 450 \end{bmatrix} \qquad (10)$$

The instance physical element with maximum similarity that obtained is:

$$R_{2s}=\begin{bmatrix} & \mathit{Spindle\ Characteristic} & \begin{pmatrix} \mathit{Spindle} & \mathit{Material} & \mathit{Forge\ 20SiMn} \\ & \mathit{Length/mm} & 7740 \\ & \mathit{Axle\ Body\ Diameter/mm} & \phi1980 \\ & \mathit{Centre\ Hole\ Diameter/mm} & \phi1600 \end{pmatrix} \\ \mathit{Turbine\ Structure\ Instance} & \mathit{Wheel\ Characteristic} & \begin{pmatrix} \mathit{Wheel} & \mathit{Nominal\ size/mm} & 6270 \\ & \mathit{Maximum\ Overall\ Diameter/mm} & 6375 \\ & \mathit{Inner\ Diameter/mm} & 3120 \\ & \mathit{Upper\ Crown\ Weight/t} & 33.4 \\ & \mathit{Bottom\ Ring\ Weight/t} & 22.6 \end{pmatrix} \end{bmatrix} \qquad (11)$$

Step 3 To establish incompatible conflicting problem, and we will find the core problem of conflicting problem. It is:

$$P=g_o\otimes l_o=\begin{bmatrix} \mathit{Energy\ Transfer} & \mathit{Transfer\ Power/MW} & [480,520] \end{bmatrix}\otimes\begin{bmatrix} \mathit{Spindle} & \mathit{Material} & \mathit{Forge\ 20SiMn} \\ & \mathit{Length/mm} & 7740 \\ & \mathit{Axis\ Body\ Diameter/mm} & \phi1980 \\ & \mathit{Centre\ Hole\ Diameter/mm} & \phi1600 \end{bmatrix} \qquad (12)$$

Step 4 To analysis the deign condition of physical design domain. The transmitted power is affected by material, diameter and length of principal axis. The sheer stress of principal can be increased by enlarge diameter appropriately, shorten the length and other extension transformation method. So the physical expand direction element is:

$$R_t=\begin{bmatrix} \mathit{Spindle} & \mathit{Meterial} & \mathit{High\ Strength} \\ & \mathit{Length/mm} & \mathit{Shorten} \\ & \mathit{Axis\ Body\ Diameter/mm} & \mathit{Enlarge} \\ & \mathit{Centre\ Hole\ Diameter/mm} & \mathit{Enlarge} \end{bmatrix} \qquad (13)$$

Step 5 The change of the diameter will lead to the change of the size of the part connected with the principal axis, such as the structure of wheel. So there will be opposite problem.

Then we can establish opposite problem $P_1=(G_1\wedge G_2)*L_1$. Wherein, the target element G_1 is the physical expand element R_t. The target element G_2 is the wheel in physical domain. The condition element L_1 is the interface condition of physical domain. By analyzing of target element G_1 and G_2, we give priority to change the size of connection flange which existed between principal axis and wheel, so as to realize the coexistence of target element G_1 and G_2. Next we should make sure that the diameter is constant. In order to meet the design requirement of function domain, we can shorten the length of principal axis and increase diameter of canter hole within the requirement of physical element. Then the principal axis that meets the demand of function domain and physical domain can be obtained by calculation of structural strength. And it is:

$$R_{n+1z} = \begin{bmatrix} Spindle & Meterial & Forge\ 20SiMn \\ & Length / mm & 7700 \\ & Axis\ Body\ Diameter / mm & \phi 2050 \\ & Centre\ Hole\ Diameter / mm & \phi 1715 \end{bmatrix} \quad (14)$$

The size of wheel is:

$$R_{n+1zl} = \begin{bmatrix} wheel & No\min al\ Size / mm & 6265 \\ & Maximum\ Overall\ Diameter / mm & 6360 \\ & Inner\ Diameter / mm & 3130 \end{bmatrix} \quad (15)$$

The designer of turbine engineer can design the size of flange and other parts based on the obtained size of principal axis and wheel.

6. CONCLUSION

This paper aims at extension adaptive design for the whole lifecycle of mechanical product with characteristics of multi-level, multi-attribute, creative and complexity. We study the knowledge reuse and extension design model in the extension adaptive design for the whole lifecycle of mechanical product, and give an improved to compute similarity based on extension distance. The method avoids similarity changes when add or delete data in a database. And it will not be affected by whether the most advantage point is in the midpoint of the interval. So it is more generality. Meanwhile, we expand the design domain for the adaptive design of mechanical product, and give the extension model and extension principle of the conflict problem which exist within or between each design stage. Then the model of extension adaptive design for the whole lifecycle of mechanical product is proposed.

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