A kinematic Chain Topology Characteristics Of Hay Compressor Design Research And Innovation

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Abstract. If we choose one original mechanism as the object of study, treat it abstractly, and induce the topological properties of this mechanism, we can get basic chain of original mechanism. With the tool of graph theory, we can list the map of the kinematic chains based on the original mechanism in accordance with certain procedures. By doing so we can prevent the missing phenomenon or the isomorphic phenomenon. Then through the redistribution of the frame, original driving link and rod group, we can get a series of new mechanism which has a better performance.

1. Introduction
At present, the bottleneck of restricting China's transformation from a manufacturing country to a manufacturing power is that its independent innovation ability of mechanical products is far from enough. In some key areas, how to carry out product innovation and improve the ability of independent research and development has become an urgent problem to be solved in our manufacturing industry. From a worldwide perspective, with the increasing competition of products, the research on Mechanical Creative Design (MCD), especially in the theory and method of mechanical product innovation design, has attracted the attention from all countries. The United States and Germany are the first countries to carry out the research of mechanical innovation and design, and have obtained a lot of research results. However, based on the complexity of mechanism design, most of the existing innovation methods focus on experiential and theoretical models. Especially for designers who are not yet rich in practical experience and deep theoretical basis, these methods are more difficult and less operative. In this paper, based on the theory of graph theory and regenerative kinematic chain, together with the basic chain type of original mechanism, a series of variation designs were carried out according to certain methods and steps, and several new mechanisms with the same functions as the original institutions were obtained. Through the analysis and screening of it, we can create a number of new type of mechanism with better performance than the original mechanism. This method is simple and easy to follow. It is a kind of mechanism innovation design method which is easy to operate and imitate.

2. Design steps
First, the topology of the original mechanism is analyzed, and the original mechanism scheme is abstracted, and the link information of the mechanism is expressed by the motion chain. After recording the main constraint information of the original scheme, we get the general motion chain map through the topological diagram of the kinematic chain loop, then eliminate the isomorphic kinematic
chain, and transform it into a generalized kinematic chain according to a specific program. In the process of transformation, the topological attachment and adjacency relationship between the component and the motion pair and the degree of freedom must remain unchanged. After the identification of ground link, original driving link and link group on the general movement chain, a series of specific movement chain will be obtained. Then in accordance with the general principle of inverse, we can get all the new mechanic chain.

2.1. Determine the original mechanism
The original mechanism is an existing one. We can pick out the mechanism which are similar to the design requirements and have high cost performance in practice as the original mechanism in the existing machinery. After determining the original mechanism, it is necessary to analyze its topology to determine the specific composition of the original mechanism.

Figure 1 shows the main mechanism of a certain type of hay compressor, link 5 shows the sliding pair of performing links and the ground link; link 2, 3, 4 make up a conforming hinges at C point with link 1 as driving component.

![Figure 1. Chematic motion diagram of a hay compressor](image)

2.2. Analysis of the topology of the original mechanism
The topology of the mechanism reflects the type, number and connection of the components and motion pairs contained in the mechanism. Topological structure only studies the internal structural characteristics of an mechanism, without considering the external factors such as the shape, size and material of components and kinematic pairs. It is an abstract expression of the structural type of the mechanism, reflecting the inherent attributes of the kinematic chain. Therefore, the topological structure of a mechanism is a very important factor determining the performance of an mechanism, which is of great significance for us to systematically and efficiently develop new mechanism.

The analysis of Figure 1 shows that it is a 1 DOF mechanism of 6 links and 8 kinematic pairs. It has 6 links, including 1 ground link, 3 slide links (numbered 1, 3, 5), 2 complex flat links; The mechanism has 7 pairs of motion, including 6 rotating pairs and 1 moving pairs.

2.3. Determining the number of inner rings of a topological graph L
From the Euler formula in graph theory, we can see that a polygonal network graph is composed of N points and P edges, the number of inner ring L (simple loop number and sub chain number) is:

\[ L = P - N + 1 \]  

(1)

In the formula, P is the number of kinematic pairs, which is equivalent to the number of edges of polygonal network graph. N is the number of rods in the kinematic chain, which is equivalent to the number of nodes in polygonal network graph. The polygon network graph is generally called a topological graph. The Euler's theorem establishes the relation between the number of vertices, the number of edges and the number of inner rings of the topological graph. According to this design
example, the number of bars in the kinematic chain is known to be \( N = 6 \), and the number of motion pairs is \( P = 7 \). The number of inner rings in the kinematic chain of the mechanism is \( L = 7 - 6 + 1 = 2 \).

2.4. Determining the kinematic chains combination of 6 rods and 7 pairs
In order to get the topology of the mechanism, first of all, it is necessary to determine the combination scheme of the rod type in the kinematic chain. The combination of rod type refers to the number of various rod types, such as two pairs of rods and three pairs of rods, which are included in a movement chain. This paper is expressed in \( N_n \).

In determining the rod type combination of the motion chain, it is necessary to first determine the rod type \( M_{\text{max}} \), which is the most moving pair in the motion chain. It can be obtained from the next type.

\[
M_{\text{max}} = L + 1
\]

In the formula (2), \( L \) is the number of inner rings (subchains) in the topological graph. As known, \( L = 2 \), the rod type which contains the most motion pairs in the chain is \( M_{\text{max}} = L + 1 = 3 \). \( N_3 \), the number of ternary links in the topology diagram, can be obtained by the next Formula:

\[
N_3 + 2N_4 + \ldots + (n-2)N_n = 2(P-N)
\]

It can be obtained by the formula: \( N_3 = 2 \). That is, there are only 2 ternary links in the 6 rod & 7 pairs mechanic chains. Then the number of the two sub rods is the number of 3 pairs of rods subtracted from the number of the total rods in the motion chain. The number of binary links is: \( N_2 = 6 - 2 = 4 \), that is, the 6 rod and 7 pairs mechanic chains have 4 binary links and 2 ternary links. The rod type matching scheme is shown as in Figure 2.

![Figure 2. Rod type matching scheme for 6 rod & 7 pairs mechanic chains](image)

2.5. Determining the topological graph of the kinematic chain loop and the general kinematic chain map
As only a few link is multiple in the kinematic chain, topological contracted graph, can be firstly only composed of multi points and lines, then by inserting proper binary points according to different assortments, as shown in figure 3. The total points, contained in each loop, should be greater than or equal to 4 during the construction of a topology diagram.

![Figure 3. Topology graph for kinematic chain](image)
After removing the isomorphic topological graph, according to the one-to-one correspondence between topological graph and kinematic chain, the topological graph can be reduced to a non-isomorphic motion chain map corresponding to its corresponding composite hinge. Considering the situation of compound hinge, we can get 4 non-isomorphic generalized kinematic chain maps based on 6 rods and 7 mechanisms after excluding the isomorphic kinematic chains and the chains of chains, as shown in Figure 4.

Figure 4. Kinematic chain maps based on 6 rods and 7 mechanisms

2.6. Specific kinematic chain map

According to the engineering practice and the designer's decision, we assign each component and the kinematic pair type in the generalized kinematic chain map, and find out the available kinematic chain maps that meet the design constraints.

2.6.1. Determine design constraints. Constraint conditions refer to the constraints of mechanism size and motion space in the actual design process, such as the position of the rack, the interference of components and the ratio of the rod length. The constraint conditions can be set as follows: there must be a fixed rod G as a rack; there must be a slider Z as the executive component, Z and rack are connected by mobile pairs. Because of the limit of article, the first non-isomorphic kinematic chain in Figure 4 is illustrated here, and the rest can be analogous to this.

2.6.2. Determine the fixed rod. The non-isomorphic kinematic chains, as shown in Figure 5, are identified according to the constraints of the frame.

Figure 5. Non-isomorphic kinematic chains after rod G

2.6.3. Determine the execution component Z. After determining the fixed rod, according to the design constraints, we can allocate the execution component Z sequentially on the basis of Figure 5, and eliminate the isomorphic kinematic chain, then get 5 non-isomorphic kinematic chains as shown in Figure 6.

Figure 6. Non-isomorphic kinematic chains after rod G & Z

2.7. New mechanism

The last step of the design method is to push back according to the general principle, and transform each available kinematic chain shown in Fig. 6 to the corresponding structure sketch of the mechanism. Figure 7 is a schematic diagram of the main body of 5 new hay compressors.
After removing the original mechanism and the components which do not meet the technological requirements, we can carry out the technical evaluation of the residual mechanism, such as dynamic analysis, dimensional synthesis and optimization design, and get a reasonable and optimized main body of the hay compressor.

3. Conclusion
The basic idea of this method is based on the existing well performance machinery as the original mechanism, through the analysis of the topology characteristics of the original mechanism, with the help of graph theory, to determine the link assortment scheme of planar 6 rod and 7 pair mechanism, and construct the topology graph of the mechanism. On this basis, the topology map and the general kinematic chain map are obtained by assigning binary points. Furthermore, on the specific principles and constraints, all of the mechanic graphs with the same or similar functions as the main body of the original hay compressor are listed. After specifying the types of each component, the design of a number of new mechanisms has been obtained. This method not only makes the innovative design of the mechanism regular, but also is easy to be applied and grasped. This makes us easily acquire multiple plans and excavate the structural designs that have not been seen before, so as to develop new mechanical systems.

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