

Research on Rapid Assembly Technology of Helicopter Transmissions

Wang Haiwei^{1,*}, Li Lulu¹, Yuan Sheng²

¹Shaanxi Engineering Laboratory for Transmissions and Controls, Northwestern Polytechnical University, Xi'an, 710072, China

²Meteorological Bureau of Zhejiang Province, Hangzhou, 310000, China

Abstract. Research and application of rapid assembly technology can widely improve the design efficiency of helicopter transmissions. An assembly model of helicopter transmissions is presented by introducing Geometric Constraint Graph (GCG) method. A hierarchical model is obtained by multi-shrink decomposition. A corresponding data structure is generated according to the hierarchical model. CATIA based a parametric component database is built up. The Assembly modelling software is implemented by using VB. Finally, a helicopter transmissions example is taken as application and the rapid assembly for helicopter transmission system is achieved.

1 Introduction

Modern helicopter has developed into a high performance aircraft with heavy load, low weight, low noise, new technology, new materials, new equipment and advanced electronic equipment. The research of helicopter transmission system focuses on two aspects: transmission system component and transmission system configuration. Through component research to reduce the weight of the transmission system, improve the carrying capacity and enhance gear transmission performance [1]. The purpose of configuration research is to develop a new type of gear transmission system, transmission system layout and its rapid assembly design [2-3]. Configuration design is a design method based on the arrangement and combination of predefined components and parts. The configuration of helicopter transmission system directly affects the transmission form and transmission scheme and it is an important part of the scheme design stage. The design process is as follows: in a set of predefined components or parts, an assembly or combination that satisfies a series of requirements and follow a series of constraints is sought.

Assembly design is a crucial link in the life cycle of helicopter transmissions system design, the earlier the assembly problem is considered, the more obvious the cost, quality and time effect will be. In a broad sense, assembly process is the spatial embodiment of configuration design process. The rapid assembly of the helicopter transmission system is conducive to the rapid verification of the transmission system configuration, the analysis of its spatial structure and interference status, and the improvement of the design efficiency of the helicopter transmission system configuration.

Compared with traditional CAD assembly technology, virtual assembly technology has become the focus of research at home and abroad. Virtual assembly is to complete the assembly model of the designed parts on the CAD system and assemble different parts into a general assembly, its basic function is to define the relative position relationship between different parts through assembly constraints. After the assembly is completed, the spatial structure analysis and dynamic interference inspection between the parts are carried out to find the unreasonable parts design, so as to improve the design and complete the three-dimensional model design of the assembly. Boeing used virtual assembly technology to design and build a virtual prototype of a Boeing 777 with more than three million parts, allowing designers to walk through the virtual plane. Designers can call out anyone part which they want, and view and modify designs [4]. Abe [5] designed and developed a set of visual system for the assembly problem of mechanical parts, in the virtual environment, it supported designers to conduct assembly analysis and performance evaluation, new employees can systematic operation training when assembling machines, which greatly improves the efficiency. Wu [6] aimed at the problem of product model expression in the field of virtual assembly, put forward the assembly model compound expression method based on process. Gao [7] proposed a method based on the degree of freedom reduction to conduct constraint analysis. On the basis of identifying and understanding the designer's assembly intention and operation, the assembly constraint diagram of tree structure was established based on the assembly relationship, and the positioning and navigation of assembly in the virtual environment was realized through the analysis of spatial geometry.

* Corresponding author: whw@nwpu.edu.cn

In this paper, aiming at the problem of rapid assembly of helicopter transmissions system with complex spatial relations, a transmissions assembly model based on geometric constraint diagram was proposed, and a layered data structure including assembly constraint relation and assembly model was constructed, the assembly modeling of helicopter transmissions system was developed based on CATIA.

2 GCG based assembly model

The assembly model of transmissions system is a complex geometric constraint system, which organically combines various parts with certain assembly constraint relations. Because the helicopter transmission system has many parts and complex structure, the constraint relationship between the parts or components in the assembly model is very complex. An ideal assembly model system should be consistent in expression, maintenance and solution, so it is necessary to establish an effective assembly model expression method for helicopter transmission system.

2.1 Geometric Constraint Graph (GCG)

GCG method is the combination of graph theory and computer geometry [8-10]. The modeling of geometric constraint system based on GCG method can directly manage and express geometric entities and associated geometric constraints in two or three dimensional space, it has the characteristics of good expansion of geometric space and interpretability of geometry.

Taking a typical helicopter transmission system as an example, the process of recursion from its relational model to layered model is researched, and the assembly model of helicopter transmission system is further illustrated. The hierarchical model of transmission system is consistent with the layered structure of product assembly model in CAD system, this is beneficial to the modeling of assembly model in CAD system. At the same time with the help of the CAD system assembly design module function, complete the assembly of the transmission system. This provides the direction and foundation for the automatic assembly of helicopter transmission system in the scheme design phase.

Applying the structure of graph to express GCG is not only clear and straightforward, but also has good stability and high efficiency of graph correlation algorithm, so it is widely used [11-12]. The helicopter transmissions system is abstractly expressed as GCG, by analyzing the GCG, forming a separable and solvable sub-problem, and the solving strategy of sub-problem can be properly combined, which can effectively solve the assembly constraints of system. The established GCG is the relationship model of helicopter transmissions assembly. The mathematical expression of transmission system assembly model and GCG is as follows.

(1) Let $S = (X, C, A)$, S represent a transmission assembly model; X is collection of parametric parts, such as the sun wheel, planet wheel and other parts; C is a collection of geometric constraints, such as angle

constraints, distance constraints, vertical constraints, parallel constraints; A is the value of geometric constraint parameters, such as distance value, angle value etc.

(2) Let $GCG = (V, E)$, GCG represents the geometric constraint diagram of the assembly model of the transmission system; V is the vertex in GCG and $V = X$, each vertex represents a geometry entity, a part of transmission system; E is the side of GCG and $E = C$, each side boundary represents a set of geometric constraints.

Fig. 1 is a configuration diagram of a certain type of helicopter transmission system, including the main reducer, intermediate reducer and tail reducer. The main reducer is divided into three levels of transmission, the first stage is the input level, which is reversing deceleration by the spiral bevel gear. The second stage is the parallel drive, which is decelerated by the spiral bevel gears. The third stage is planetary gear reducer transmission, the number of planetary wheel is three, and the total reduction ratio is 81. The intermediate reducer is installed on the base of the inclined beam, and is driven by a pair of spiral bevel gears to transfer the torque of the main transmission device to the tail reducer and change the direction of transmission. The angle of shaft intersection is about 58° , input speed is 4117r/min, and output speed is 3319r/min. The tail reducer is installed on top of the inclined beam and is driven by a pair of spiral bevel gears to reverse reduction. The angle of shaft intersection is about 105° , input speed is 3319r/min, and output speed is 1190r/min.

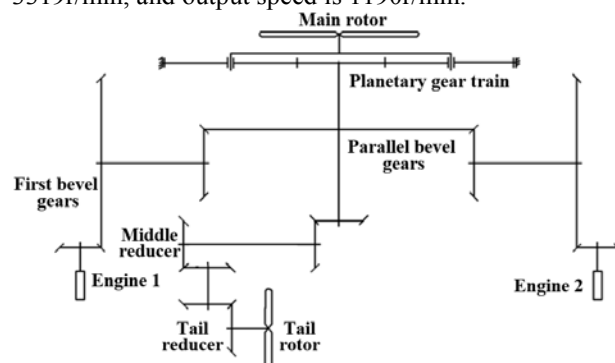


Fig. 1. A helicopter transmissions configuration

According to the composition of helicopter transmission system, GCG is introduced to express the assembly model of the transmission system, as shown in Fig. 2. There are two kinds of nodes in the GCG, the first type of rounded corner and square node represents parametric parts, such as sun wheel, planet wheel, transmission shaft, and each part contains modeling parameters. The second rectangular node represents the assembly constraint set between parts or components, for example, C1 represents the assembly constraint set between the sun wheel and the plant wheel.

The section encircle by the dotted line in Fig. 2 represents the nodes to be condensed and aggregated in GCG, corresponding to the basic components in the helicopter transmissions such as the planetary gear train. A component is an assembly unit that realizes a certain function or multi-function of a transmission system, a

component can be composed of multiple parts or a single part. The transmission system contains the following basic components: planetary gear train, parallel bevel

gear transmission, spiral bevel gear pair, transmission shaft and other components.

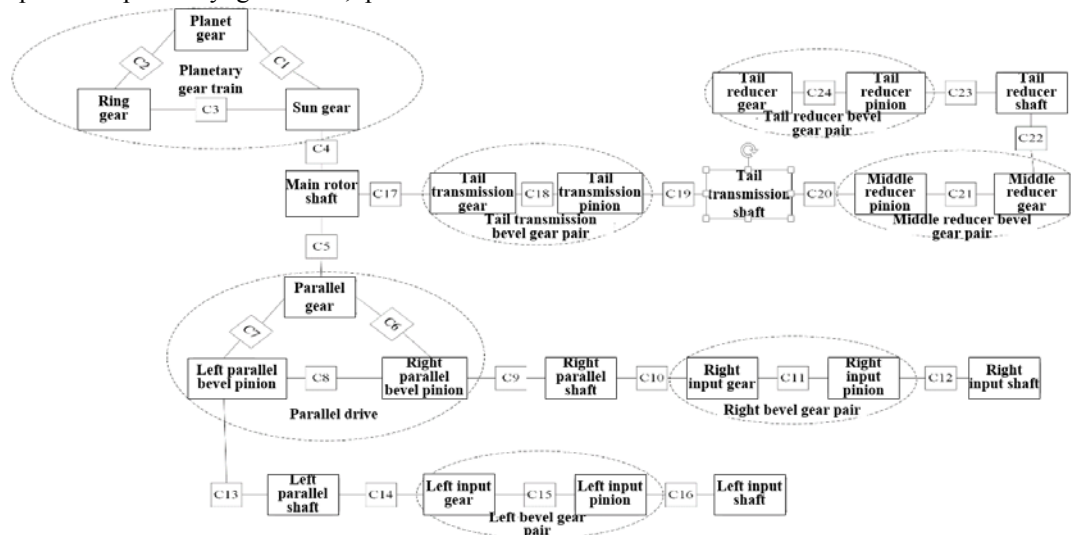


Fig.2. The GCG of the helicopter transmissions

2.2 Components condensed of GCG

Through the recursive assembly method, the components are condensed into a node, which changes the constraint distribution of the transmission and the assembly scale of the assembly system is also reduced. The constraints in the components such as planetary wheel become internal constraints and are separated from other external constraints, which is also the decomposition process of geometric constraint system. Fudos and Bouma[13-15] introduce the concept of cluster into GCG, they solved the problems of geometric constraints by graph-based construction method. In essence, the component is regarded as a group of parts cluster, if the remaining degrees of freedom in the part cluster are zero, the cluster is rigid, that is rigid body, if it is not zero, it is a pseudo-cluster, in the pseudo-cluster the rotational degrees of freedom around its axis of symmetry do not affect the assembly of the transmission system. The shrinking process of the basic components is called the

first shrinking of the transmission system. Fig. 3(a) indicate the GCG by first shrink.

In the process of the first shrink, the constraints between planetary gear train, bevel gear parallel drive, bevel gear pair and the outside remain unchanged, and the constraints between the original parts become internal constraints. C1, C2 and C3 become internal constraints of planetary gear trains. C6, C7 and C8 become internal constraints of parallel drive, C15 and C11 become internal constraints of left bevel gear pair and right bevel gear pair, respectively, and C18, C21 and C24 become internal constraints of tail transmission bevel gear pair, mid-subtraction bevel gear pair and tail-subtraction bevel gear pair in turn. After the first shrink of the transmission system, a new cluster of parts forms a new node to replace, for example, the planetary gear train becomes the planetary gear train node.

Fig. 3(b) shows the secondary shrinking of the transmission system. It can depend on the transmission shaft for shrinking, such as the rotor shaft, planetary gear train, tail transmission bevel gear pair and parallel bevel gear drive shrink into the rotor shaft system, etc.

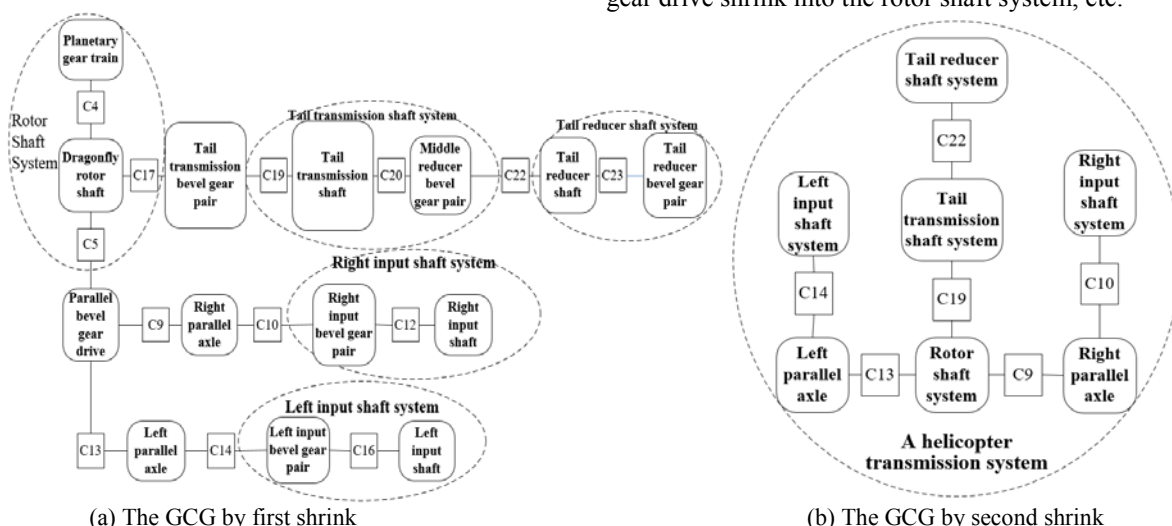


Fig. 3. The two shrink and aggregation process of the GCG

2.3 Layered model of transmission system

The layered model of the transmission system can be obtained from the process of the first shrinking to the second shrinking of the transmission system. Therefore, the assembly of a helicopter transmission system needs to be realized through its layered model, which is the result of GCG shrinking operation. Essentially, it is the inevitable result of decomposition of geometric constraint system. Fig. 4 is a layered model of helicopter transmission system. The layered model of the

transmission system is divided into four layers, the first layer is the overall layer, which represents the general assembly of the helicopter transmission system; the second layer is the shafting layer, which is the result of the second shrinking, and the sub-assembly built with the transmission shaft as the core, such as the rotor shafting and the tail transmission shafting; the third layer is the component layer, which is the result of the first shrinking and expresses the basic components; the fourth layer is the part layer, It is the basis of basic components.

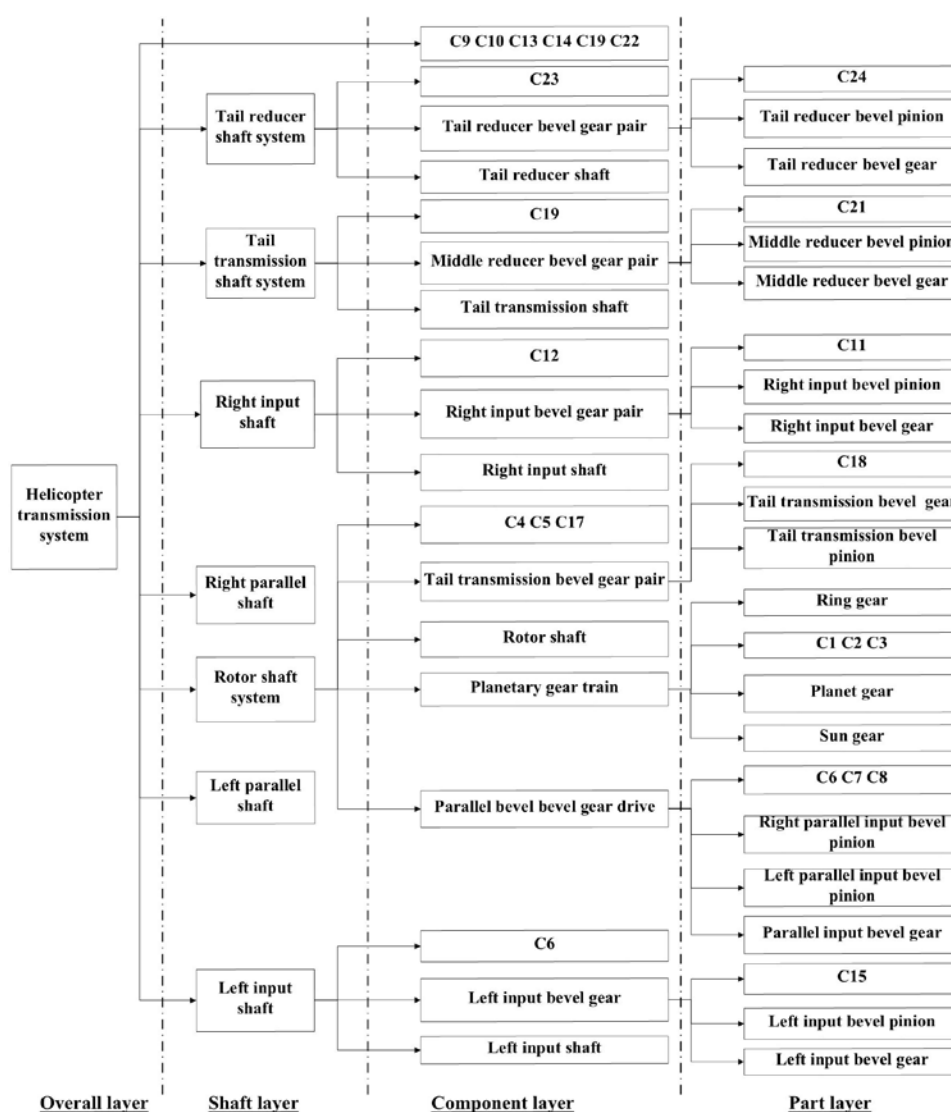


Fig. 4. The layered model of the helicopter transmissions

3 Data structure of assembly model

In the helicopter transmission system assembly model, nodes are relatively independent assembly units, such as shafting, components and parts. The node is taken as an object, the attribute element of the object is defined, and the corresponding data structure is obtained. Data structure should include assembly constraint relation,

layered structure of assembly model and material attribute. The details are as follows.

(1) Ass (Assembly)

Name: the name of assembly

ID: unique identification of the assembly

Context: the ID number contains shaft system

Pointer: the constraint pointer point to shaft system

(2) SS (Shaft system)

Name: the name of shaft system
 ID: unique identification of the shaft system
 Context: the ID number contains component
 Pointer: the constraint pointer point to component

(3) Com (Component)

Name: the name of component
 ID: unique identification of the component
 Context: the ID number contains part
 Pointer: the constraint pointer point to part

(4) Par (Part)

Name: the name of part
 ID: unique identification of the part
 Parameter: part parameters
 Material: material properties of parts

(5) Con (Constraint)

Name: the name of constraint
 Type: the type of constraint
 ID: unique identification of the part constraint
 Value: constraint value

Assembly is the top node, it is expressed as the total assembly of the transmission system of the helicopter, contains Name, ID, Context and Pointer, the pointer describes assembly constraint information between the next layer. Shaft System refers to the sub-assembly after the second shrinking, such as rotor shaft system, etc. Shaft system that depend on shafts are used as sub-assembly. In fact, during the second shrinking, designers can specify partitioning shaft system interactively, but be careful that the components that connect each other are composed. Components are the basic units that make up transmission system, component can be a part or a combination of several parts to achieve a certain function, in interactive assembly, components in the component library can be directly called for combinational design. Part is the most basic unit; it is the basis of components. Constraint corresponding to CATIA assembly constraints, we can judge constraint type by specifying the constraint ID and discerning ID.

4 Realization of Rapid Assembly

To apply the aforementioned assembly technology and method, a software flow for rapid assembly of helicopter transmission system is constructed, as shown in Fig. 5. According to the layered model and data structure of helicopter transmission system, the corresponding assembly input files can be designed. Based on the secondary development of CATIA by VB, the corresponding interface was customized, the assembly input file was driven by program, and the corresponding assembly information was obtained, including properties of modeling parameters, assembly constraints among components and material. Finally, the component library and CATIA API interface function are called to realize the output of the three-dimensional assembly model of a helicopter transmission system. At this time, the model established is a pre-assembly model, which needs to be adjusted and modified by the designer. The formed CATIA file can be connected to the database to form a scheme, which is convenient for users to call and modify.

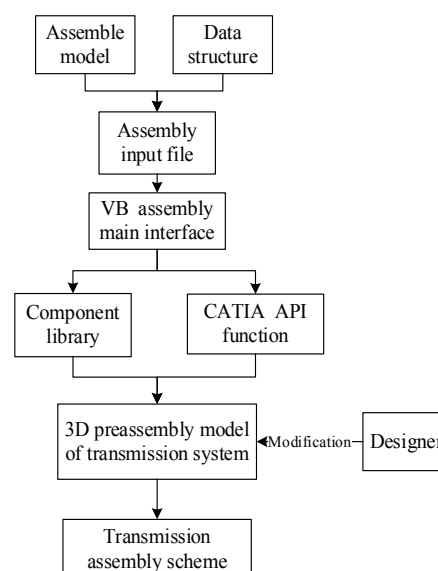


Fig. 5. The rapid assembly software process

According to the software flow framework of the transmission system rapid assembly, the bottom-up parametric assembly modeling design mode is adopted, and the secondary development of CATIA is carried out based on VB. The developed rapid assembly software can automatically generate the three-dimensional assembly of the transmission system by reading the basic parameters of the components and the position parameters of the parts in the CATIA environment according to the parametric data of the configuration results of the helicopter transmission system. The model is shown in Fig. 6.

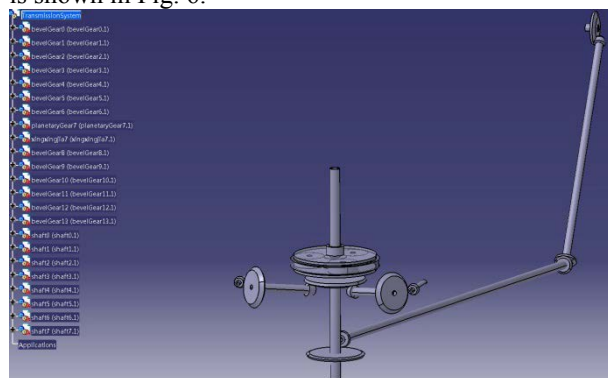


Fig. 6. Assembly 3D model of the helicopter transmissions

5 Conclusion

In this paper, geometric constraint graph is introduced to express the assembly model of helicopter transmission system. Through the development of a helicopter transmission system as an application example, it is proved that the assembly model of helicopter transmission system based on geometric constraint graph is an effective expression method, which can well achieve the consistency of expression, maintenance and solution. Combining with the assembly design function of CAD system, the layered model is corresponded to the feature tree of CAD system. Through parametric modeling and secondary development of CATIA, the

rapid assembly of three-dimensional model of helicopter transmission system driven by program is realized.

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