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UG-based research and development of 3D pipe layout system of the aircraft engine

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Abstract

Standardized design method is important for the airworthiness certification. Based on the principles and features of the aircraft engine external pipe system, in this paper, the research on the theory of automation of pipe layout has been done. We also put forward the process of automatic and mixed generation of pipe layout, the design of pipe layout system and the resolution of arbitrariness of pipe layout. In order to improve the efficiency of the system, a parameterized component library has been built, on the basis of the secondary development of UG. Therefore, the automation pipe layout and the real-time modification have been achieved. According to the predefined rules, constraint test and result output of the system can be conducted.

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Keywords: airworthiness certification, aircraft engine, pipe, UG;

1. INTRODUCTION

Pipe layout system plays an important role in the aerospace, automotive, oil and other fields. The U.S. General Electric Company finds that 50% accidents of air parking events are caused by the damage or failure of external pipe, wires and sensors, after they summarize the cause of air parking events [1-2]. In China, the pipe layout of aircraft engine is still on the stage based on experience and experiments [3], and relying on manual work. The quality and efficiency of pipe layout is very low.

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When laying pipe by manual work, it is not only time-consuming, high cost, labor intensive, but also difficult to achieve optimal design results, which will lead to frequent failures of pipe system, and possible to affect the overall performance of the engine. Facing the increasingly fierce market competition and the consequent shorter product life cycles, it is extremely required of the enhancement of design efficiency. For product developers, a design system to help conduct production corresponding with market demand, with shortest production cycle and least cost is in great need, and at the same time, standardize the process of pipe design, optimize pipe layout can improve the engine's stability, benefit the airworthiness certification and maintenance of the engine, so for us, the reformation of pipe laying system is on the way.

The digital 3D design method gives a novel resolution to speed up the pipe layout efficiency in mechanical systems and to improve the quality [4-6]. If we design the external pipe of aircraft engine with the aid of computer pipe layout system, the design intent can be understood intuitively through the 3D model and the unreasonable designs will be aware and modified in time, so the intuition and operability will be improved. In addition, it will combine the design and analysis well at the same time, so the interference phenomenon can be completely avoid. Thanks to the operation on digital prototype model, it avoids the repeat of construction, shortens the development cycle and reduces the development costs. What is more important is that it changes the developers' design methods and modes of thinking. It can help the designers to understand the spatial location, shape, size and so on to improve the design success rate. Though some CAD software has provided pipe layout module, it doesn't play well in product design, so it has some limitations to satisfy the users' needs. So this kind of software isn't widely used to do the pipe layout. For example, when using the pipe layout module of UG, users have to choose all control point one by one by mouse selection. Especially, for a three-dimension point, it is hard to be selected precisely in a two-dimension plane. Even though with the provision of the function to generate a pipeline through assigning the start and end point, it constrains the pipeline just by the means of setting the shortest length and least segments condition, so the result of the path isn't practicable in engineering. It does not work well to create a pipeline satisfying certain constraints. Therefore, in this paper, based on UG developing object-oriented technology, the research develops the 3D pipe layout system catering to the users, makes up the deficiency of the pipe layout modules of UG, and realizes the function of the automation of laying pipe.

2. DESIGN OF PIPE LAYOUT SYSTEM

Pipe layout system is consist of four modules that are the component library module, pipe laying module, constraint checking module and the result output module which are shown in Fig 1. The parameterized model is used for the pipe connecting and fixing and stored in the component library, such as plug, nut, T-connector, etc. Pipe laying module is used to create the route path, set bend radius, show solid route model and then check the interference. If the interference exists, it adjusts the route path using route editing tools. On the term of the machinability, manufacturability and heat distortion, the pipe has to meet certain constraints. If the checking result of the constraints on the pipe does not satisfy the requirements, adjustment is needed. At last, the output of the bending document report, through the result output module for the manufacturing of pipe bending machine, can be obtained. And the materials list shows the pipe laying information of the entire route.

3. COMPONENT LIBRARY

There will be lots of standard connector used in pipe laying, as shown in Figure 2. If the similar connector has to redesign just for the size reason, it will waste lots of time and energy of engineer. By building 3D Parametric Modeling of the connector as shown in Fig 3, performing parametric analysis,

creating parametric table, putting all kinds of information (including dimensions, materials, number and other attributes) [7] into the database, we can edit and manage the part family by operating on the database [8] and generate a new entity through size driven. So the connector template and parametric table set up the component library collaboratively.

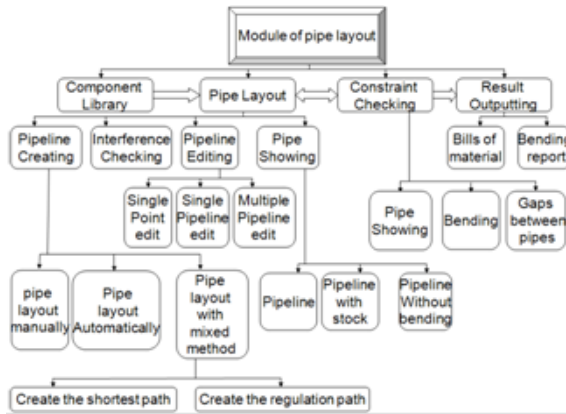


Fig. 1 Design of pipe layout system

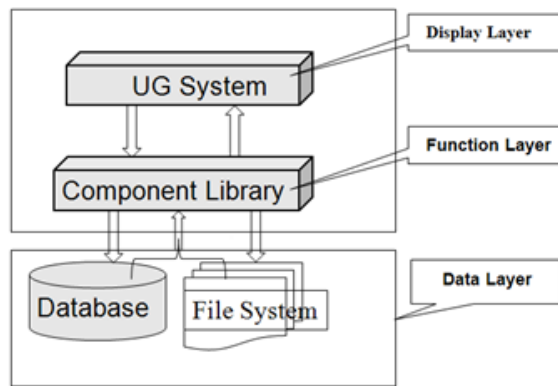


Fig. 2 Architecture of component library

Piping component library is composed by three layers: presentation layer, function layer and database layer. Show in Fig 2. Data layer consists of two parts: database and file system. Database is used to store information on the size, materials and etc. of the connector. File system is used to store the connector template. Function layer provides operations on component library, including adding, deletion, and searching template and so on. It can get the spare parts' dimension information from part table, the template from file system and then create the instance of the CAD model for users. Display layer is the

interface of UG from which the functions can be called to insert all kinds of standard pipe part into the workspace for pipe layout.



Fig. 3 Pipe connector

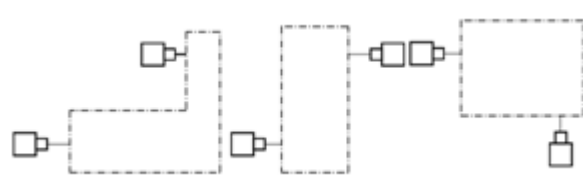


Fig. 4 Trend model of pipeline

4. PIPE LAYOUT

The principle of pipe layout is to ensure the safety and reliability of the system, to make its structure compact, easy to maintain on the basis of meeting the need of design and operating. It is also required to satisfy the priority rule with the following path mode: the prior rule of laying pipe along the side of the engines, the prior rule of laying pipe in dense area, the prior rule of laying pipe parallel, the prior rule of laying thicken pipe and the rule of laying pipe axial and circumferential and etc. under the premise of meeting the design, using and technical requirements. To make the structure of pipe lay compact and easy to fix, laying the pipe axial and circumferential along the engine surface as close as possible, so better vibration characteristics and outline size can be obtained.

The path isn't the only way in three-dimensional space. For the pipeline whose direction is axial or circumferential, according to the direction and coordinates of the initial path, Three basic pipeline trend modes are summarized (line segment on behalf of the starting path, rectangle on behalf of connectors, broken line is a black box which contains the middle section of the path). They are the abstraction for three-dimensional elements in two-dimensional plane.

The head and tail section are involved with the connector. They have close relationship with the type and interface direction of the connector. The pipeline is divided into three segments, head segment, middle segment and tail segment, which are created separately to simplify the process of pipe layout. The first and tail segments are the creation of single pipeline. The middle segment is composed by several polylines, each of which has three elements: start point, end point and several segments on the surface. The schematic of polylines in the three-dimensional space and the projection of it in the two-dimensional space are shown in Figure 5. As any pipeline of the engine is consist of a number of line segments, whose main parameters are the coordinates of the start and the end. Therefore, after finding out the coordinates of every control points, connecting with line, setting the bend radius, you can build a complete path. The create process of pipeline is shown in Figure 6.

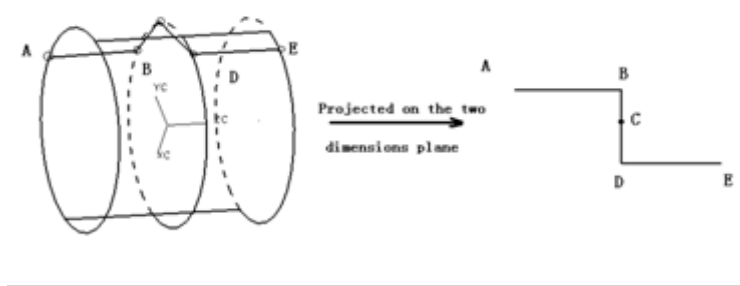


Fig. 5 Projection of middle pipe on two-dimensional plane

4.1. PIPE LAYOUT MANUALLY

This pipe layout method is used mainly for the pipeline which is arranged irregular. The process of manual pipe layout is to input the coordinates of every control points of the pipe, or select the control points using mouse and so on to complete the formation of pipe's centreline, and then assign the characteristics such as the diameter of the pipeline, bend radius and so on to finish the pipe laying.

4.2. PIPE LAYOUT AUTOMATICALLY

The engine casing has the characters of cylinder. In this paper, engine casing has been treated as a combination of cylinder and cone, and the pipe as lay axial and circumferential along the engine surface commonly. According to the distribution character of the head and tail segments of the pipe, in the same cylinder; in the cylinder and cone separately; in the same cone and so on, different algorithms that generate control points of pipeline have been adopted. Users just need to choose the start and end points, the rules of laying pipes and set the initial condition of pipe layout. The system will generate the pipeline according to the rule of laying pipe axial and circumferential along the engine surface. Figure 6 shows the process of using the method of pipe layout automatically to generate pipeline when the pipes lay along the cylinder-cone surface.

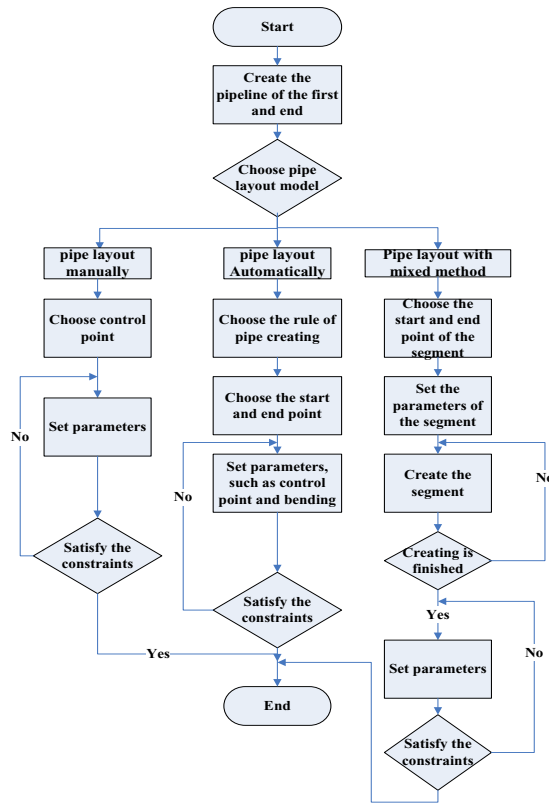


Fig. 6 Flow chart of pipeline creating cylinder-cone surface

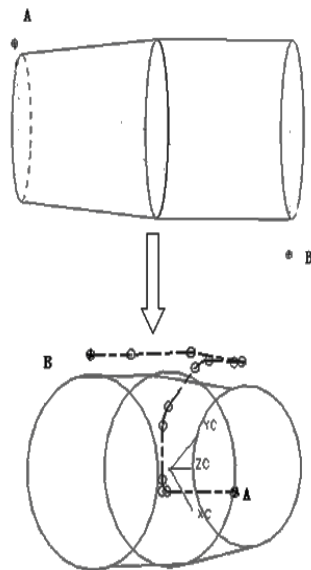


Fig. 7 Pipe layout automatically along

4.3. PIPE LAYOUT WITH MIXED METHOD

With the mixed method of pipe layout, the control points are divided into two types in the pipeline: generated by mouse selecting or inputting the coordinates; generated automatically after given initial conditions by the pipe layout system. If the whole path is divided into n segments, the sets of every segments control points are $C_1, C_2 \dots C_n$, and the set of control points for the whole pipeline is $AC(C_1, C_2 \dots C_n)$. Users can divide the complex pipeline into simple parts, and select pipe layout rules for each segment, and then the pipeline will be generated automatically. The system will connect the control points of all segments to generate the whole pipe automatically after users finish the creation of these segments. Pipe layout with mixed method is suitable for the generation of complex pipeline as it can divide complex pipelines into simple ones to control respectively and then join them together to form a complex pipeline. This method adopts the pipe layout algorithms which have been built according to the pipe layout rules separately. It simplifies the complexity of pipeline generating algorithm, improves the stability of the system.

Shown in Figure 8, as to generate a pipeline between two points of A and B, we divide the pipeline into segments of AC and BC. AC segment adopts cone pipe layout algorithm to lay the pipe automatically and BC segment adopts cylinder-cone layout algorithm. Figure 8 shows the segmentation, creation and finally pipeline entities.

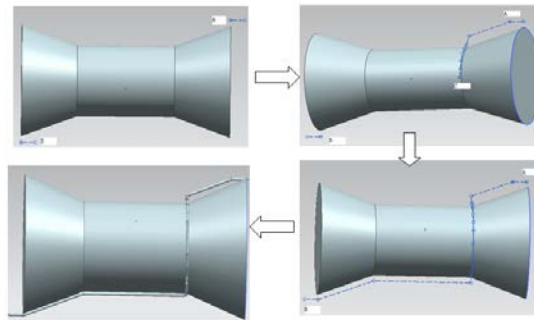


Fig. 8 Mixed method of pipe layout generating process

5. CONSTRAINT CHECKING

According to the principle of pipe layout, the reliability, assembling, manufacturability machinability and so on, the constraints between parameters can be generated, such as that the length of every segment should not less than 4 times of the pipe diameter and the gaps between pipes should not less than 3mm and so on. If it is not satisfied with the requirements, the system will give warning or error message.

6. RESULT OUTTING

After user completes pipe layout and chooses the pipe, the system will output the length of the pipe, the bend radius, corner messages, material and so on. The output data can be used to the production of bent pipe with CNC tube bending machine directly.

7. EXSMPLSE

In the environment of UG, we test the 3D pipe layout system of the aircraft engine. The result shows that it makes up the disadvantage of the original pipe layout module, achieves the function of laying pipe automatically, changing association, and testing the constraints and so on. All of these make pipe layout more standardized, reduce the costs, shorten the development cycle, improve the quality of the product and design success rate. Standardized pipe layout method which changes the arbitrary of pipe layout implements the airworthiness requirements into the aircraft design work, it is important to get the airworthiness certification and gain the market competition.

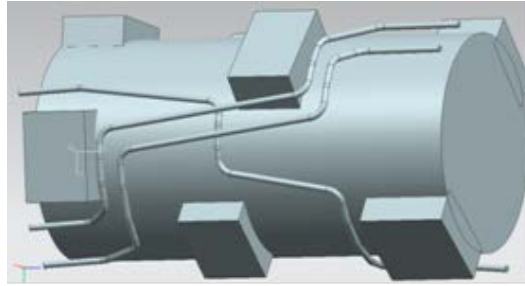


Fig. 9 Pipe layout instance

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