Application of Augmented Reality in Thermal Control Implementation of Satellite Pipe

Wei Zhang¹, Changyu Chen¹, Fanwei Meng¹, Jun Hou¹ and Haibao Qu¹

¹ Beijing Institute of Spacecraft Environment Engineering, Beijing Engineering Research Center of the Intelligent Assembly Technology and Equipment for Aerospace Product, Beijing, China

Corresponding author’s e-mail: zhangwei308308@163.com

Abstract. This paper reviews the traditional thermal control implementation of satellite pipe in AIT process. As the thermistors and heating devices are too small compared to the satellite 3D model, the 3D design input is inconvenient to use. In order to improve efficiency and quality of thermal control implementation of satellite pipe, a system based on AR technology is designed. With the help of the system, the code and specification of the thermal control components are clear at a glance, so an ordinary operator can verify the polarity correctness of the thermal control implementation and the efficiency can be doubled.

1. Introduction

The propulsion system is the actuator of the satellite attitude orbit control system. The main task is to provide the force or torque required for the tasks such as orbital maneuvering and attitude maintenance according to the requirements of the attitude orbit control to ensure the completion of the satellite mission. In order to ensure the normal operation of the propulsion system in orbit, each component needs meet certain temperature indicators, so the thermal control implementation of the propulsion system. The thermal control implementation of the propulsion system includes the thermistor paste, electric heating device of piece shape paste, electric heating device of tape shape installation, and the heating circuit welding and temperature control multilayer coating. The number of the thermistors in the propulsion system is large, the specifications and quantities of electric heating device of polyimide film type are many, and the number of heating devices involved in each heating circuit is also many.

Since most satellites belong to one-piece customized production, and the propulsion system layouts of different satellite have large differences, the assembly of the pipe thermal control implementation of satellite is heavily dependent on manual work(1-2). The final assembly space in AIT process of satellite is small, and the operation conditions are complex, so easy access to process information is important. As the thermistors and heating devices are too small compared to the satellite 3D model, and the various layouts of thermal control components are scattered and coded, work efficiency is reduced significantly because the 3D design input is inconvenient to use and workers have to bear a lot of additional cognitive burden. Due to the symmetry of the cabin structure, the identification of small thermal control components such as the thermistors and heating devices is error-prone, quality problems with incorrect polarity installation of thermal control components occur from time to time.

In recent years, Augmented Reality technology has been extensively studied and has reached a good preliminary application(3-10). An assembly guiding method based on AR technology is designed in order to improve efficiency and quality of pipe thermal control implementation of satellites. This
method automatically matches the thermal control information with the real physical environment, and guides the workers to complete the thermal control implementation of satellite pipe.

2. Thermal Control Implementation of Satellite Pipe in AIT Process

The final assembly of propulsion system is the first stage in AIT process of satellite, and it consists of 2 parts, separated by the pipe welding and screwing. After pipe welding and screwing, the operators start the pipe thermal control implementation, which includes the thermistor paste, the electric heating device of tape shape installation, the heating circuit welding and multilayer coating. The process of satellite pipe thermal control implementation is showed in Figure 1.

| Pipe Welding and Screwing | Pipe Thermistor Paste | Electric Heating Device of Tape Shape Installation | Heating Circuit Welding | Multilayer Coating |
|---------------------------|----------------------|-----------------------------------------------|------------------------|-------------------|

Figure 1. the Process of Satellite Pipe Thermal Control Implementation

The diagram of pipe thermal control implementation is showed in Figure 2, the number of the thermistors on pipe is large, the number of heating devices involved in each heating circuit is also many, and there are many specifications and quantities of electric heating device of Polyimide film type which include tape shape and piece shape. All those components are distributed to various locations on the satellite.

Satellite design has entered 3D mode, but efficient and accurate information transfer methods from design to operation have not yet been formed. Traditional pipeline thermal control 2D Drawings is shown in Figure 3, the number with a box in the figure is the code of the heating devices, the number with the circle is the code of the heating belt, and the two identical numbers indicate the beginning and the end of the heating belt, respectively. In order to reduce the size of the 3D model, there is only one thermistor modeling entity object, multiple thermistor objects reference the same entity but give different characteristics. The heating belt is still represented by the starting and ending points as shown in Figure 4. The operators need to frequently confirm status back and forth between satellite and computer stations, because the 3D mode of thermistor is too small compared to the propulsion system, the beginning and the end of the heating belt are also small, what's more, the code and the specification are not obvious. so new technology is needed to improve assembly efficiency for the current 3D model based on desktop computer has poor human-computer interaction.
3. Augmented Reality

Virtual reality and augmented reality accomplish two very different things in two very different ways, despite the similar designs of the devices themselves. Compared with Virtual Reality technology, Augmented Reality technology can not only see virtual scenes, but also superimposes virtual scenes in real scenes by calculating operator position and perspective in real time. Industrial augmented reality has numerous practical applications; AR provide operators with more intuitive process guidance in the manufacturing process of an enterprise, rather than just complex, boring work instructions and drawings. The Microsoft HoloLens is an excellent AR HMD which is the best choice for AR assembly application. The optical AR is to place the optical combiner in front of the user's eyes. The combiner is partially transparent, used as a picture to display the real environment, and the other part is reflective for displaying virtual information. The projector inside the glasses projects virtual information onto the optical combiner, which reflects the virtual information into the user's eyes. The AR system has three salient features: information integration in the real world and the virtual world, real-time interactivity, and the addition of positioning virtual objects in the three-dimensional scale space.

4. The Process of Application of Augmented Reality in Pipe Thermal Control Implementation

An assembly guiding method based on AR technology is designed to improve efficiency and quality of thermal control implementation of satellite propulsion system, the flow chart of the method is showed in Figure 5. Compared with the traditional method, this method automatically matches the propulsion system information with the real physical environment, and guides the workers to complete the propulsion assembly.

![Figure 5. the Process of new Assembly Guiding Method Based on AR Technology](image)

4.1 Generation of the Dedicated Model

The pipeline thermal control dedicated model tree which is show in Figure 6 is producer-oriented; it includes pipe structure, heating circuit, thermistor and multilayer. Heating circuit contains several heating devices of tape and heating devices of piece shape, electric-heating device of tape contains 2 parts, the starting part is indicated by a plus sign, and the ending part is indicated by a minus sign. Before pasting the thermistor and installing electric heating device, the operator needs to know the code and specification, so it is necessary to extract process information in design 3D model through secondary development of software. If the specification is not expressed in the model, we need to add it to the model tree, so the name of electric-heating device includes code and specification which can be easily read by the machine.
4.2 3D Registration
As one of the most critical and difficult to solve effective technologies in augmented reality technology, 3D registration technology has become the research object of many universities, research institutions and scholars at home and abroad, the accuracy of 3D registration is directly related to the success of an AR system. The 3D registration technology mainly realizes the correct fusion of virtual propulsion components and real assembly scenes through the conversion between coordinate systems. Three-dimensional registration is divided into two types: identifiers and no markers. In this assembly guiding method based on AR technology, 2D QR code which is pasted on satellite deck structure is used in 3D registration.

4.3 Fusion and Display of 3D Models and Objects
The assembly guiding method based on AR technology was developed using Unity and Vuforia. Unity is Microsoft's official application development engine. To achieve higher precision, the embedded Vuforia has always been the developer's favorite AR SDK, with numerous features and high-quality recognition technology. After 3D registration, the HoloLens can properly track position as the user moves around in the assembly area using Simultaneous Localization and Mapping technology. An assembly application with a user friendly UI has been built to improve the user experience and he code and specification display orientation of thermal control component is set to always face to user for the convenience of users to view.

5. The Typical Case of Application in Satellite Pipe Thermal Control Implementation
A guidance system of satellite pipeline thermal control implementation based on HoloLens is tested during the AIT process of a remote sensing satellite in the paper. Dedicated pipeline thermal control model of the service module is showed in Figure 7, the thermistors and heating devices are too small to see compared to the satellite 3D model. As is shown in Figure 8, a 2D QR code is printed on paper and pasted on the satellite deck structure where is easy to determine the location. The operator must first wear Microsoft HoloLens and use the gesture to enter the corresponding module of the remote sensing satellite, secondly, scan 2D QR code in the satellite deck structure to complete 3D registration, and then select thermistor or the electric heating device to be installed from the UI interface. The process of this system is very simple, and the assembly information is clear at a glance, thereby greatly improving the visibility of the 3D model. Figure 9 shows a typical case of application in a satellite thermistor pasting assembly, TK29B is the code of the thermistor, and the position on the pipe is clear. Figure 10 shows an electric heating device of tape shape installation, A4 is the code of electric heating.
belt, A4+ is the beginning position, and PH8 is the specification of the heating belt. With the help of the assembly system based on AR technology, an ordinary operator can verify the polarity correctness of the thermal control implementation and the efficiency can be doubled.

6. Conclusion
Satellite design has entered 3D mode, but efficient and accurate information transfer methods from design to operation have not yet been formed. As the thermistors and heating devices are too small compared to the satellite 3D model, the 3D design input is inconvenient to use. In order to improve efficiency and quality of thermal control implementation of satellite pipe, an assembly guiding method based on AR technology is designed. With the help of hololens, the code and specification of the thermal control components are clear at a glance, an ordinary operator can verify the polarity correctness of the thermal control implementation and the efficiency can be doubled. The successful application of this system provides a new solution for satellite thermal control implementation and marks a new step in the digital assembly capacity.
References

[1] Li Liancheng. (2008) Discussion on the installation method of satellite pipeline heating belt. SPACECRAFT ENVIRONMENT ENGINEERING. 25(4): 384-386

[2] ZHOU Yangeng, ZHANG Yu, et al. (2017) An Optimization Design Method for Thermal Control of Satellite Propulsion Subsystem. Chinese Journal of Space Science. 37(6): 748-751

[3] Zhang Wei, Zhang Jie, Chen Huajun, Zhang Bin, Liu Feng, Zhao Jun. (2019) Assembly Method for Satellite Propulsion System based on HoloLens. Materials Science and Engineering. 608: 012035

[4] WANG Zenglei, YAN Yuxiang, HAN Dechuan, BAI Xiaoliang, ZHANG Shusheng. (2019) Product Blind Area Assembly Method Based on Augmented Reality and Machine Vision. Journal of Northwestern Polytechnical University. 37(3): 496-502

[5] Zhong Denghua, Wang Zhining, Guan Tao, Wang Dong, Yan Yuling. (2018) Visual Simulation of Construction Schedule for Core Rock-Fill Dam Based on Augmented Reality. Journal of Tianjin University. 51(10): 1072-1085

[6] LI Wang, WANG Junfeng, LAN Shan, LI Shiqi, JIAO Sichen, WANG Meng. (2019) Content authoring of augmented reality assembly process. Computer Integrated Manufacturing Systems. 25(7): 1676-1684

[7] Xu Weipeng, Wang Yongtian, Liu Yue, Weng Dongdong. (2013) Survey on Occlusion Handling in Augmented Reality. Journal of Computer-Aided Design & Computer Graphics. 25(11): 1635-1643

[8] Gao Yuan, Liu Yue, Cheng Dewen, Wang Yongtian. (2016) A Review on Development of Head Mounted Display. Journal of Computer-Aided Design & Computer Graphics. 28(6): 896-904

[9] WANG Yue, ZHANG Shusheng, BAI Xiaoliang. (2019) A 3D Tracking and Registration Method Based on Point Cloud and Visual Features for Augmented Reality Aided Assembly System. Journal of Northwestern Polytechnical University. 37(1): 143-151

[10] G Evans, et al. (2017) Evaluating the Microsoft HoloLens through an augmented reality assembly application. In Proc. of SPIE Vol. 10197