Study on BIM-based Optimization of Integrated Metro Pipeline Design

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***Abstract*—The implementation content and methods of BIM-based optimization of integrated metro pipeline design is presented by this paper, and the establishment of a network based on collaborative work mode for a smooth communication is proposed to solve the problem of untimely communication among all participants in the project during the joint examination of the drawings. Meanwhile, the collision point optimization and spatial layout optimization in the comprehensive pipeline optimization are mainly emphasized. Furthermore, a BIM-based optimization process for the three dimensional design is put forward and the whole optimization process is detailed. The search and optimization of collision point are realized through collision detection while the optimization of building space is simulated through 3D roaming and 4D. Finally, the advantages of BIM integrated pipeline optimization are summarized.**

***Index Terms*—BIM, pipeline design, optimization method**

I. INTRODUCTION

As an excessive complex system, Metro MEP pipeline usually involves numerous professional with interrelated interaction among the majors, which is too difficult to complete on MEP designers' optimization solely[1]. However, it is commonly believed that teamwork is required to share their professional knowledge and work experience and to optimize the design to solve this problem. BIM is an information mutual interaction and collaborative work platform, by which the design, construction, management and related participants, architecture, structure, HVAC, water supply and drainage design are integrated into a digital building model[2]. Furthermore, the three-dimensional simulation of the spatial and equipment relationship among the building structure and equipment and pipelines is carried out, and the comprehensive pipeline system of the engineering project is optimized by BIM technology[3].

II. OPTIMIZATION PROCESS OF MEP INTEGRATED PIPELINE DESIGN

For the complex integrated pipeline system in the building, all the professional data of the entire building project are integrated by BIM into a three-dimensional architectural space model. The created model may be viewed and modified with a project information barrier-free communication by each participant[4], in which the spatial relationship among the building structure and pipelines as well as pipelines and equipment can be also viewed arbitrarily[5]-[8]. According to the professional experience, the optimal space allocation and pipeline layout can be designed, and the optimized integrated pipeline design scheme can be finally obtained[9].

Revit software platform is a data-driven system that can automatically update and synchronize building information model data, by which any modification can be updated timely to the whole model. On the basis of its model creation, the comprehensive pipeline network conflict analysis, 3D roaming and 4D simulation construction can be carried out, the professional pipelines can be re-arranged in a reasonable space and the equipment pipe fittings can be replaced, by which the optimization of MEP design can be realized in an intuitive and efficient way[10].

III. OPTIMIZATION OF MEP INTEGRATED PIPELINE COLLISION POINT

The pipelines shall be inspected by the professional personnel against any cross conflict during the joint examination of the drawings and any detected problem should be solved before the construction to avoid rework. However, due to the workload and difficulty of the work itself, it is necessary to rely on the professional experience for a long-time check, while it is also difficult to detect the pipeline crossing in complex parts with low search efficiency. However, it is a great advantage of BIM technology to quickly and accurately detect and modify the location of collision points among different majors, among which collision detection is commonly accepted as the main method to realize the accurate searching and modification of collision points.

A. Advantage Analysis of Professional Collision Detection

In the traditional design process, each specialty is divided into different designs, which is insufficient in design synergy. It is inevitable that problems of professional collision will be generated after summarizing the professional drawings. And if such problems are not solved in time before construction, a delay of construction period and an increase of cost will be caused. Compared with manually searching the collision point, obvious advantages of the collision detection technology through BIM in indicated:

It is significant in solving the difficult searching problem for the collision of complex parts. In large complex projects, it is difficult to find all the problems through the naked eye analysis of various professional drawings, planes and facades, while all professional models are integrated into the same model with the same size with that of the real project through collision detection. Moreover, the collision position can be obtained through the analysis of the software calculation rules, and the three-dimensional model can be comprehensively sectioned to review any relation of any professional position.

It is commonly known that collision detection is much more efficient than manual lookups. On the basis of computer technology, the positional relationships among graph elements in the model can be examined by collision detection to detect any collision, in which the omnibearing search of the project is not judged by professional experience. The experience of the professionals themselves is heavily relied on in the manual search process. However, due to the uneven quality and capability of various professionals and limited key analysis for the parts with high frequency of collision, the pipeline collision in other parts is easily ignored.

B. Realization of Collision Detection

Before establishing the model and comprehensively optimizing the pipeline, the three-dimensional building information model of the project and the three-dimensional building information model of the project are required to be firstly established, which serves as the basis of engineering design optimization by BIM technology. In the design stage, the professional modelling is completed by the designers on the same working platform, by which the team's cooperation ability and efficiency are greatly improved. The 3D model in BIM technology is designed on a common basis and is gradually perfected into a comprehensive model with the deepening of the project, in which numerous data models are contained as a good foundation for later management.

Collision detection: collision detection is functioned by Revit and is further facilitated by the presence of Navisworks greatly. However, there is a difference among the two: Revit is only suitable for the inspection of a related entity within a system or collision detection among two majors; while Navisworks can link multiple models for detection, and can quickly and accurately detect the collision point with a collision report.

C. Technology to Improve the Efficiency of Collision Detection

There may be over-long detection time and over-large collision points in the detection. Meanwhile, there will be lots of unreal collisions found, of which the reports need to be screened one by one. Furthermore, such situation arises from the project itself due to various professionals involved by the subway project as well as the inappropriate rules contained in the software itself, by which the requirements of the project cannot be satisfied. The following are the techniques summarized in the process of practice.

Set up a characteristic set In the case of multiple system collisions: the resulting workload is screened and increased to ensure improved search efficiency. Before the multi-professional collision, it is necessary to establish a modelling working set according to project characteristics before collision. For example, in the complex case of project pipeline design, the set is established for each professional design according to the floor, and the set number is assigned to each set. In the collision analysis, the set of each floor is applied for collision, and the running speed is improved with the reducing of the results.

IV. Optimization of MEP Integrated Pipeline Spatial Layout

When the comprehensive pipeline optimization is completed, it is necessary to consider how to arrange the pipelines and equipment in the limited building space in an optimal way by BIM technology after the pipeline conflict detection is completed to satisfy all aspects.

A. The Spatial Layout Optimization Factors Shall be First Considered:

To satisfy people's needs for space comfort. It is commonly found that the professional designers of mechanical and electrical pipelines do not coordinate with each other in the design stage with serious wasted architectural space. There is no overall and reasonable arrangement of the space layout of all pipelines and the space resources are not fully utilized, which further reduces the efficiency of space use.

To satisfy the requirements of construction and maintenance space. The installation process, equipment material transportation, maintenance and operation space and so forth shall be considered in the space layout. For example, when the requirements in the design of MEP equipment size exceeds regular volume and it is not considered by the designer, the construction process will be limited by adjacent equipment with smaller working face if the channel is designed according to the usual experience. A thorny issue will be caused after the completion of the structure equipment installation and directly hindering the overall project duration and cost.

B. Spatial Layout Optimization Method

3D virtual roaming inspection: 3D virtual roaming refers to that the user sets the angle of view and movement speed with specified route and allow walking according to the set parameters to display the observed 3D effect of the spatial equipment pipeline, by which designers are enabled to observe the site installation situation of different parts and review the installation effect after the completion of the project. During the course of roaming, some obvious intersection points of the pipes can be identified through human eyes with the walking of the characters, and partial collision points can be found by marking.

4D construction simulation: 4D building information model refers to integrate the time dimension on the basis of the 3D model to carry out visual simulation of the construction process against times. Construction process has been commonly recognized as a highly dynamic process against times. The requirements of project personnel cannot be satisfied by the traditional 2D information expression for a good understanding of this dynamic process and its internal complex relations. It is commonly believed that only the subjective understanding and imagination of technicians can be relied on under such condition, but different understandings of the construction process are caused by different professional levels. The construction process can be simulated visually by the 4D building information model to indicate the relationship among each process and the construction object in the construction schedule, and the utilization of each construction space in the construction process can be realized.

V. BIM-based Optimization of Metro Integrated Pipeline.

Traditional CAD drawing design method is still accepted as the mainstream design method, and its efficiency improvement in the past is commonly recognized by all. However, two-dimensional drawing design will be eliminated with the development of computer technology. BIM technology is popularized with the development of informatization and its advantages applied in metro comprehensive pipeline optimization are derived from two aspects: on the one hand, three-dimensional modelling process; on the other hand, its design experience and management functions.

A. Three-Dimensional Modelling Process

Parametric design: the outstanding feature of BIM is a kind of parametric design compared with traditional design software. The design is not only shown as graphics, but also as illustrated data. When one of the data changes, other related data will be updated in a timely manner, which brings great convenience for the flexibility and changeability of the design and reduces the design error rate. For example, when the size of a window is adjusted, the size of the facade, plane, and profile of the window will be changed accordingly.

B. BIM Experience and Management Functions

3D roaming experience: the BIM model is created according to the real building size, and the realistic effect can be achieved by rendering. The actual effect after the construction of the building can be observed and he designer’s design effects can be checked by the roaming state through the third-person perspective. In the early stage of the project, the spatial layout after the actual construction can be fully understood, and the parts that need to be changed can be modified in advance.

Before construction, collision inspection shall be carried out for each specialty, and the collision location in the drawings shall be searched one by one. Moreover the collision point found shall be modified to realize zero collision of pipeline, and the conflict problem of pipeline shall be eliminated before construction. In the construction of the project, the problems existing in the design can be reduced as much as possible, which can both reduce the frequency of engineering changes and control the engineering cost.

4D simulation of construction: construction of 4D simulation refers to simulate the real construction process and building simulation according to the actual project construction plan to clearly understand the construction process, construction site layout, etc. It can detect any virtual environment problem of the unreasonable equipment and pipeline layout and solve the potential problems before construction to reduce the risk existing in the construction.

Quantities Statistics: Under the current environment, engineering quantity statistics account for about 60% of the preparation of a project planning. If a secondary modelling is required, additional energy and time will be costed. The calculation of engineering quantity can be completed quickly and accurately within a short time by using BIM technology. For example, calculation to be made by time dimension, regional dimension and process dimension.

VI. Conclusion

In this paper, a workflow for the optimization of MEP integrated pipeline design based on BIM is proposed and a model of collaborative work among all participants in the project is suggested to solve the problem of non-timely information communication among the participants. Furthermore, specific and detailed implementation plans are proposed for collision point optimization and spatial layout optimization in comprehensive pipeline design optimization. Collision detection, 3D roaming and 4D simulation construction are suggested to solve the problems of comprehensive pipeline conflict and spatial layout respectively.

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