The Implementation of Mixed Reality (MR) Technology with Computational Fluid Dynamic in The Gas Removal System at PLN Indonesia Power Unit PLTP Gunung Salak

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***Abstract*— The utilization of renewable energy resources, particularly geothermal energy, is increasingly crucial in meeting global energy needs. This study focuses on the integration of Mixed Reality (MR) and Computational Fluid Dynamics (CFD) in the Gas Removal System (GRS) of the Gunung Salak Geothermal Power Plant (PLTP). An MR technology prototype, including the XR10 Trimble Hololens 2, was developed to enhance maintenance processes. The study involved creating a 3D mode that utilizes static 3D models and a virtual mode that allows interaction with 1:1 scale models. The CFD simulations, performed using ANSYS, focused on visual data to demonstrate flow characteristics within the closed system. Results showed consistent values aligning with existing databases. Respondents evaluated the MR system, and the scores ranged from 4.0 to 4.5 across five categories: program information, career development process, user interaction, technical aspects, and support services, indicating high satisfaction. The study concluded that MR and CFD integration could be achieved by synchronizing the ideal and existing conditions. However, the current system still needs to be interactive and real-time. Future research should implement real-time data processing using machine learning to support predictive maintenance. This integration is expected to improve maintenance operations and efficiency in geothermal power plants significantly.**

Keywords*— Computational Fluid Dynamics, Gas Removal System, Geothermal Power Plant, Maintenance Processes, Mixed Reality.

I. Introduction

The increasing of global energy demands turned renewable energy into one of crucial energy source [1]. One of these resources is geothermal energy. Geothermal power plants are a form of infrastructure that utilizes geothermal heat as a renewable energy source. The Gunung Salak Geothermal Power Plant, located in West Java, Indonesia, is one of Indonesia's significant geothermal power plants.

Geothermal power plant operational systems consist of multiple components and systems which require regular and temporary maintenance to be operational and safe [2] Among multiple systems that exist in geothermal power plant, gas removal system became the focus of this study. It's designed to eliminate hazardous gases such as Hydrogen Sulfide (H_2S) and Sulfur Dioxide (SO_2) from the steam before being supplied to the steam turbine. Efficient and safe gas management is crucial for maintaining the performance, efficiency and safety of the geothermal power plant workplace [3]-[5].

Therefore, in 2023, a prototype utilizing Mixed Reality technology was developed, and it has become one of the many promising technologies across various industries and a potential tool in supporting geothermal power plant operations. The principle of Mixed Reality involves combining elements and data from the real world with the virtual world, thereby creating an interactive environment that can simplify the maintenance process [6]-[8]. Numerous devices are available to implement this technology, including the XR10 Trimble Hololens 2.

The mixed reality prototype integrated with Computational Fluid Dynamics (CFD) simulation. CFD simulations offer engineers a competitive edge by being cost-effective, low-risk, and providing valuable insights. These tools enable users to generate accurate simulations and employ interactive tools for design and analysis. Furthermore, from a cognitive perspective, interpreting and visualizing fluid flow behavior poses a significant challenge [9]. Even though with all the benefits, current CFD post processor which responsible to visualize analysis result lacks collaborative features [10].

While previous studies have explored the use of augmented reality, virtual reality and mixed reality in various industrial settings [11][12], to the best of our knowledge, this is the first study to implement mixed reality integrated with CFD) in the Gas Removal System (GRS) at the Gunung Salak Geothermal Power Plant (PLTP). This implementation, utilizing the XR10 Trimble Hololens 2, not only introduces MR technology to this specific site but also addresses a significant gap in the scientific literature. By developing a prototype and evaluating its effectiveness, this study demonstrates the potential of MR technology to improve operational efficiency and safety in ways that have not been previously documented.

II. Methodology

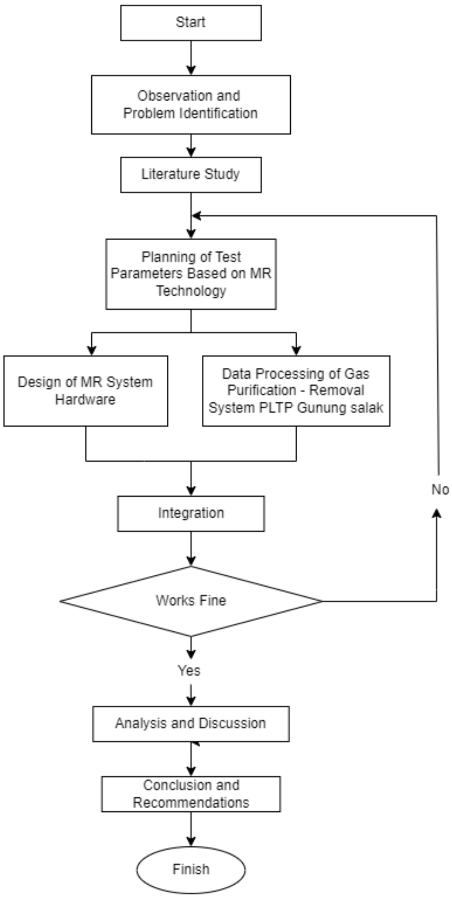

Fig. 1. Research methodology

Figure 1 shows the methodology employed in this study. It started with observing and identifying issues at PLTP Gunung Salak through online discussions and direct visits. This revealed the need for more effective maintenance systems supported by digital technology, specifically focusing on steam jet ejectors in the gas removal system.

Extensive literature reviews were conducted to gather insights and references pertinent to MR technology, steam maintenance (SM), and ejectors [13]. The research involves developing SM parameters incorporating MR technology, aligning maintenance operations with MR capabilities, and integrating MR devices with maintenance data to enhance system functionality. The software used in this context is Unity, which was employed to create the mixed reality system on the HoloLens. This integration facilitates monitoring, procedural guidance, and visualization, improving understanding and efficiency in maintenance operations. Analytical and discussion phases evaluate the effectiveness of the MR system in meeting SM parameters and the overall maintenance tasks. The research suggests further enhancements based on the evaluation outcomes, advocating for developing MR-based maintenance strategies in geothermal power operations.

III. Result

Based on the result of the implementation of mixed reality connected with computational fluid dynamics was categorized into two parts as follows:

A. Mixed Reality

The evaluation analysis of the MR system can be categorized into two distinct assessments: the evaluation of the mixed reality system about the steam maintenance (SM) concept (see Figure 2) and the review of the MR system regarding maintenance activities as shown in Figure 3. The MR system also can operated on two type mode as virtual mode and local mode.

- Virtual Mode: This application provides users with options by offering connectivity to sensor devices and MR equipment such as Head-Mounted Displays (HMD) used by the user. Through the User Interface (UI), users can interact with the application, including through voice commands.
- Local Mode: This application combines 3D and 360 modes, introducing a prototype system that allows users to switch between these two modes seamlessly.

Virtual mode is integrated so that when users are not on-site, they can still operate mixed reality on actual physical objects without the need for the physical equipment to be present. The gas removal system object is created on a 1:1 scale, ensuring that the conditions displayed on the UI match those in the field. In virtual mode, there is an advantage where the scale can be adjusted as desired using just the hands. This allows users to verify if the dimensions created are accurate to the real object. The output of the virtual mode can be viewed in Fig. 2 and Fig. 3. The image shows the virtual mode display in Unity on the rooftop of the gas removal system (GRS). The GRS consists of three floors, each featuring a different User Interface (UI) on every level.

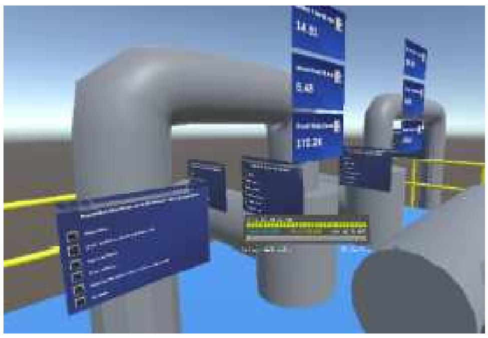

Fig. 2. Virtual mode display on the rooftop gas removal system

Fig. 3. Virtual mode display on checklist feature maintenance

Fig. 4. Steam jet ejector in local mode

In this study, a local mode is also introduced (see Figure 4), a 3D mode that shares 3D scenes using static 3D models reconstructed from the local host user's environment. Unity software is utilized to process photogrammetry from 2D digital camera images, generating 3D spatial data to accomplish this. The use of static 3D scenes can reduce the data bandwidth requirement. To aid 3D perception and enhance the connection between the virtual and physical worlds, Head-Mounted Displays (HMDs) that support position tracking are used to enable natural walking as a navigation method within the 3D scenes. Unlike the 360 mode, where visual cues and interaction methods are in a first-person view shared between two users, in 3D mode, users see each other from a second-person perspective within the 3D scene. This local mode is designed to perform a tracking system between the conditions in the field and those created in Unity 3D. The display can be observed in several subsequent images.

Here is a view of a user utilizing a mixed-reality device while operating their equipment as shown in Figure 6 and Figure 7. Furthermore, the user is able to read Computational Fluid Dynamics data in the workspace, which facilitates the user's conduct of maintenance processes as shown in Figure 5.

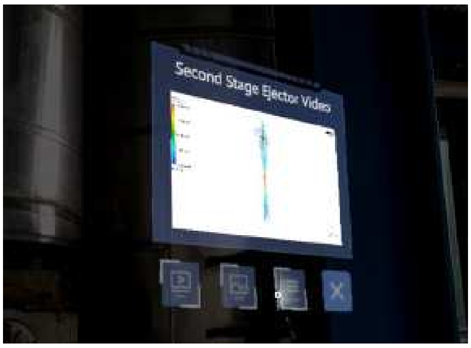

Fig. 5. CFD Display on Steam Jet Ejector

Fig. 6. User using Hololens 2 in opearation area.

Fig. 7. The user is operating the equipment.

B. Computational Fluid Dynamics

This CFD analysis is utilized for a 5 kW steam ejector with a primary nozzle geometry in the GRS. Variable geometry is achieved by employing a moving spindle in the primary nozzle inlet. Operational conditions are suitable for air conditioning applications, with thermal energy supplied by a vacuum tube solar collector. The CFD model is based on an axisymmetric experimental representation of the ejector, using water as the working fluid. The experimental entrainment ratio varies in the range of 0.1 to 0.5 depending on operational conditions and the position of the spindle tip. It was found that the spindle can successfully adjust the primary flow rate. Both CFD and experimental primary flow rates show good agreement. CFD predicts the secondary flow rate and entrainment ratio with reasonable accuracy.

The results of the Computational Fluid Dynamics (CFD) analysis on the Gas Removal System (GRS) of the geothermal power plant exhibit constant values that align with the existing database because the CFD in this study focuses solely on visual data to demonstrate the flow characteristics occurring within the closed system. The parameters used in the computational fluid dynamics process include speed, pressure, turbulence, and cavitation. The results of the CFD analysis on the steam jet ejector and condenser can be seen in Figure 8 and Figure 9.

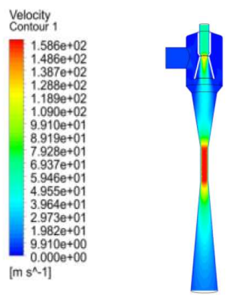

Fig. 8. Profile velocity in steam jet ejector.

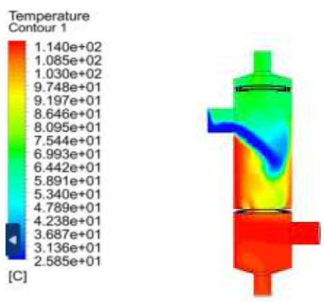

Fig. 9. Profile temperature mid pada GRS condensor

IV. DISCUSSION

Respondents were asked to sign a consent form and complete a biometric questionnaire for this test. After this initial phase, they were introduced to the experiment and the research objectives. Once ready, they were instructed to wear the Microsoft HoloLens 2. Respondents were then familiarized with the MR UI so that they could adjust to the Microsoft HoloLens 2 comfortably. Respondents were informed about the selection method that would be used, starting with air tap hand gestures to initiate the experiment. All trials were conducted in sequence from the main menu. Upon completing the trials, respondents were given a Software Evaluation Form (SEF) to complete using Google Forms. Figure 10 displays the evaluation results from five categories assessed after using the MR machine for GRS.

Ten respondents evaluated the MR software for the GRS machine based on their direct usage experience. As shown in Figure 10, five evaluation categories were assessed by expert respondents. These five evaluation categories were coded as Q1, Q2, Q3, Q4, and Q5, each representing specific aspects: whether the CFD information could be viewed completely and accurately (Q1), whether the checklist could be completed effectively (Q2), whether the eye-tracking system functioned properly (Q3), whether the UI/UX was user-friendly (Q4), and whether the 3D model could be viewed effectively (Q5). The scores for these categories were compared and presented in a graph, as shown in Figure 10. Based on the graph, it is evident that the five categories have similar scores, ranging from 4 to 4.5. This indicates a high level of respondent satisfaction with the MR application for the GRS machine in the field.

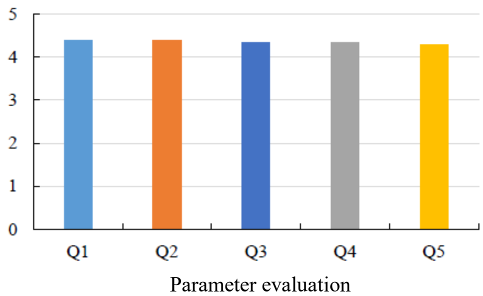

Fig. 10. Evaluation results of respondents towards MR

V. CONCLUSION

The conclusions of the research conducted can be outlined as follows: The integration between Mixed Reality (MR) and Computational Fluid Dynamics (CFD) can be achieved by synchronizing the gap between ideal and existing conditions, with CFD integrated using photo and video formats from CFD ANSYS simulations. The MR system evaluation in user activity received an overall rating of 4.40/5.00, with specific scores for the career development process, user interaction, technical aspects of software and materials, and support services.

The system that displays the results from the CFD analysis has proven to significantly ease the workload for workers by enabling direct analysis of equipment. It has also been shown to be effective in assisting workers with real-time inspections, as they can directly interact with the equipment through the MR system. However, to fully utilize this system, it is essential to provide proper training for workers so they can operate it efficiently.

Although the MR system has reached an intermediate level capable of implementing visualization, manual procedures, and condition monitoring, it still needs to become real-time and fully interactive. This is evident from features like an internet-connected dashboard and machine learning for predictive maintenance. It is hoped that future research will implement real-time data processed using machine learning to support predictive maintenance.

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