Proceedings of the 2009 IEEE International Conference on Systems, Man, and Cybernetics
San Antonio, TX, USA - October 2009

A Monocular Video See-through Head Mounted Display for Interactive Support System

- Instruction of 3-dimensional Position, Posture and Speed -

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***Abstract*— We are advancing to research an interactive support technology that assists a worker to do a task by presenting the working procedure with Image Capture Display Device. It is expected that an unskilled worker can do various tasks using this technology. We work on applying this technology to the plate bending by line heating. In order to realize it, we have developed an Image Capture Display Device, which consists of a monocular head mounted display and a camera as a human interface. In this paper, the interactive support technology and plate bending by line heating as an industrial application are explained. A method of instructing 3-dimensional position, posture and speed of burner by monocular video see-through head mounted display is described and the evaluation experiments are reported.**

***Keywords*— interactive support, plate bending, line heating, ARToolKit, HMD, mixed reality, augmented reality**

I. Introduction

Recently, shortage of expert persons for manufacturing has become a problem and development of the technology for solving the problem is needed. We are therefore advancing the research of the interactive support technology that interactively supports worker's activity [1][2]. This technology provides the support by presenting the worker the processing method and the procedure according to the situation at that time through an image display device such as a head mounted display (HMD). In order to obtain the information that should be shown, for example, a shape and temperature of a working object are measured, and based on the measurement information, a simulation and database access are performed. It aims to be able to do tasks that require advanced skill even if he/she is not an expert, and to improve the worker's skill by using this technology. In order to apply the interactive support technology, a plate bending work by line heating is chosen as an industrial application, and the examination for the practical use is advanced now. This is a task that heats the iron plate etc. using a burner and requires a lot of skill. Thus, interactive support technology consists of measurement technology, simulation technology, database search technique, and presentation technology of task instruction. The instruction presentation technology is the key in these technologies, which should be developed. In order to realize this presentation technology, a monocular video see-through HMD was developed as a device for capturing and presenting image for a worker. Up to now, it has been verified how to present the heating position on an iron plate correctly and whether a worker can recognize the heating line drawn by Computer Graphics (CG) on the iron plate with high accuracy using this device. However, in order to do the plate bending by line heating using an image capture display device, the problems which should be solved still remains. For example, it is necessary to study how to teach a worker to control 3-dimensional burner's position, posture and movement speed etc. In this paper, the interactive support system and the plate bending work by line heating are introduced. Next, the image capture display device which is made experimentally as a human interface for interactive support system, is introduced. In addition, a method, which teaches 3-dimensional position, posture and a speed required for burner operation is proposed, and the evaluation experimental results to confirm the effectiveness are reported.

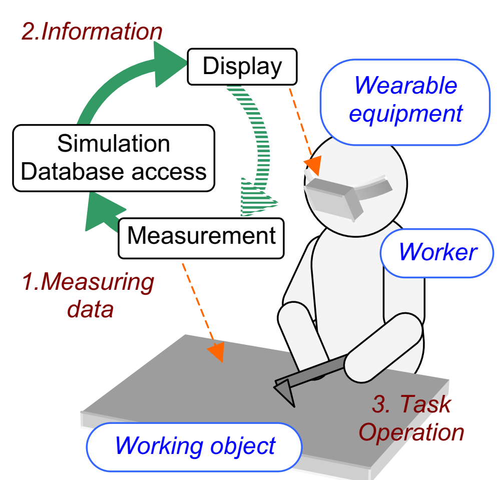

Figure 1. Outline of interactive support system

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II. Interactive Support System

Fig. 1 shows the outline of the interactive support system. A worker is equipped with the wearable apparatus that consists of various measuring instruments, such as HMD and camera. For instance, shape and temperature of working object are measured by measuring instruments. Based on such a working object's information that is obtained through the measuring instruments, an appropriate work procedure and a method are provided after analysis by the simulator and the processing database. And those information are presented to the worker through the image capture display device included a HMD and a camera etc. As the result of using this technology, it is expected that even an unskilled worker can perform a task required advanced skills and the worker's skill can be improved. As the similar research, there are systems of the wearable apparatus that combined HMD and a camera [3][4], some of them are used for welding operation training [5][6], and some are actually used at the site of circulation and production factory [7][8]. However, these researches are different from the interactive support technology that we propose, because the shape or temperature of a working object is not measured by measuring instruments. On the other hand, the interactive support technology not only presents the work procedure decided beforehand but also presents work information corresponding to the situation based on the result of measuring the work object.

III. Applying to Plate Bending by Line Heating

A. *Plate Bending by Line Heating*

We propose to apply this interactive support technology for plate bending by line heating as an industrial application. The plate bending by line heating is a processing method using the principle of the thermal deformation generated by heating the iron plate with the burner and cooling. This method is widely used in bend processing of ship shells for instance. In the conventional work procedure, wooden models are used for measurement of the difference in the shapes of the wooden models and the iron plate shown in Fig. 2. The position that should be heated is decided based on the experience and intuition of the expert person (skilful technician). After drawing a heating line with chalk, the line heating work is performed with the burner along the heating line as shown in Fig.3. As a result, the iron plate is formed in the target shape.

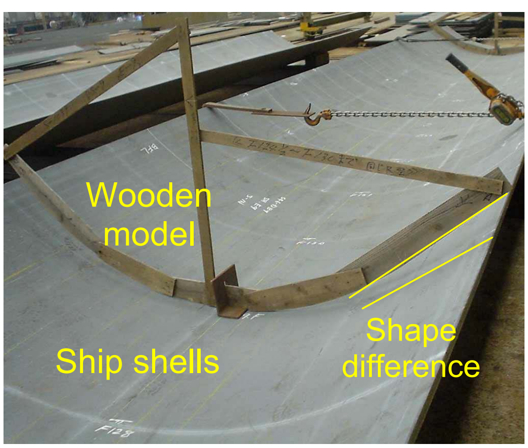

Figure 2. An example of shape mesurement
(Courtesy Ishikawajima Ship & Chemical Plant Co., Ltd.)

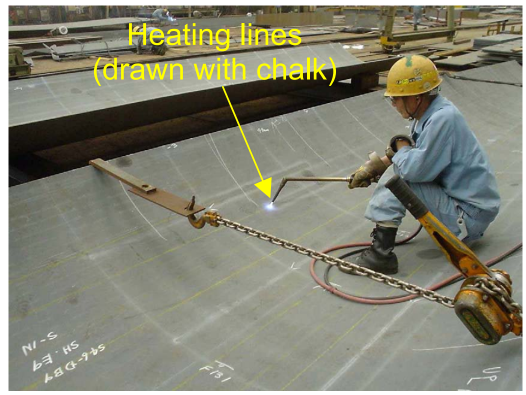

Figure 3. An example of plate bending by line heating
(Courtesy Ishikawajima Ship & Chemical Plant Co., Ltd.)

B. *How to Apply to Plate Bending by Line Heating*

In this chapter, application of interactive support technology to the line heating work is examined. Fig. 4 shows a flow chart of process for plate bending work using interactive support technology. When the interactive support technology is

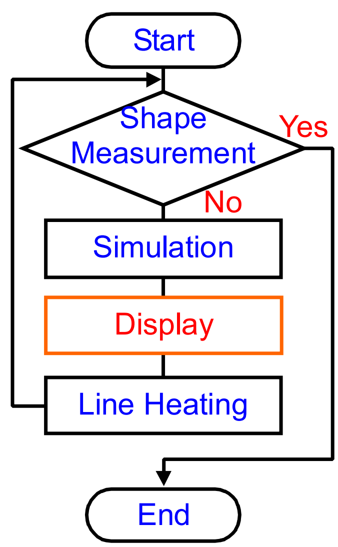

Figure 4. Proceedure of plate bending
using interactive support system

applied, the procedure consists of the shape measurement by the measuring instrument, the decision of the heating positions by the thermal deformation simulation, the presentation of the heating position with HMD, the heating along the recommended line. Fig. 5 shows the goal image that should be displayed by the image capture display device. The heating position is calculated based on the shape measurement result of the iron plate. Then, a heating point is presented by CG on the iron plate. A worker can heat the iron plate with a burner while watching through the CG. In order to develop the system, there are various research elements that should be solved. In this paper, a device for capture and display images shown in Fig. 6 is developed, and an instruction method of working procedure using CG is examined. In order to perform the plate bending task by unskilled worker, it is necessary to provide the following information.

- Heating point in real time and heating line
- Burner position and posture in 3-dimension
- Burner moving speed

It is necessary to verify whether these informations can be presented with sufficient accuracy by CG and recognized correctly by the worker.

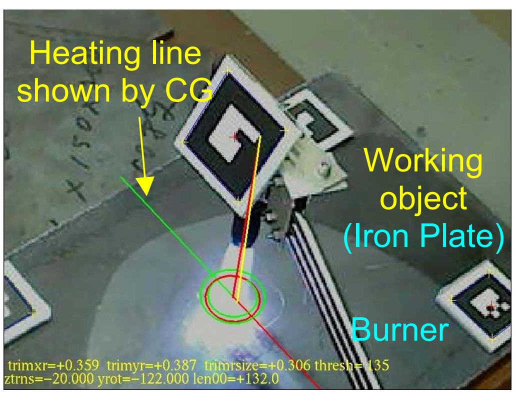

Figure 5. An example of goal image

IV. IMAGE CAPTURE DISPLAY DEVICE

In the interactive support system, it is assumed that visual information can be presented while a worker moves at the working site. In order to achieve it, a human interface device is preferable to capture the real image, to present the image that overlaps CG and a real background video image, to be wearable. Furthermore, it is better, if information can be seen while a worker works with both hands, if the image is seen clearly even in the environment with a bright background. And it is also important that it is safe even when an image disappears by the power failure under work. In addition, compact composition of a camera and an image display was studied. As candidates, a PDA with a camera, a cellular phone, the combination of small camera and HMD etc. were considered. Furthermore, there are some kinds of HMD. For instance, there are optical see-through type, video see-through type, binocular type and monocular type. In consideration of the above-mentioned conditions, the composition of a monocular video see-through type HMD and a small camera was selected [9][10]. Fig. 6 shows the appearance of the image capture display device made for experiment. This device is composed of DataGlass3/A of Shimadzu Corporation and Qcam Pro for Notebooks (two million pixels) of the Logicool Corporation. In this system, the left eye can see the image captured with the camera through HMD as shown in Fig.6. As a result, an operator can see an object with both eyes.

Figure 6. Overview of the image capture display system

V. INSTRUCTION METHOD WITH MONOCULAR VIDEO SEE-THROUGH DISPLAY

In order to perform burner heating according to the result of the thermal deformation simulation in the procedure shown in Fig. 4, the heating position, the three-dimensional position posture and the moving speed of a burner should be instructed at least. However, a monocular video see-through HMD adopted as an image capture display device, can not present 3-dimensional images theoretically. Therefore, using a monocular video see-through HMD, we tried to instruct three-dimensional position posture and the speed with the following methods. A principle of instructions is explained using Figs. 7 and 8. A desk surface imitates the iron plate, and a black stick imitates the burner. The markers for position posture recognition are stuck on a stick tip and a desk surface. When the markers are detected from the captured image by a camera of the image capture display device, those position and posture can be calculated. The ARToolkit was used for position posture detection of a marker [11][12][13]. As shown in Figs. 7 and 8, based on the position posture detection result of the markers, CG figures are drawn for the instruction to an operator. The red line imitates the axis of the burner flame. A red circle is orthogonal to the red line. The center of a red circle is an intersection on the red line and the desk surface. When a stick is brought close, the red circular diameter will be large, and when it keeps away, it becomes small. When the stick is tilted, a red circle will change into an ellipse. A blue line in the figure means a perpendicular line taken down from a stick tip to a desk surface. By drawing of these simple CG figures, the worker can recognize three-dimensional position and posture of the stick. Moreover, a green line and a double circle are drawn by CG on the desk surface. A green line means a line that should be heated with the burner. When the instruction starts, the double circles move. A worker operates the stick so that the red circle may place between the double circles. As a result, 3-dimensional position, posture and a passing speed of the stick can be instructed. In order to perform such an instruction, there are various ways of CG drawing style. In this paper, the instruction way that uses simple figures as much as possible was selected.

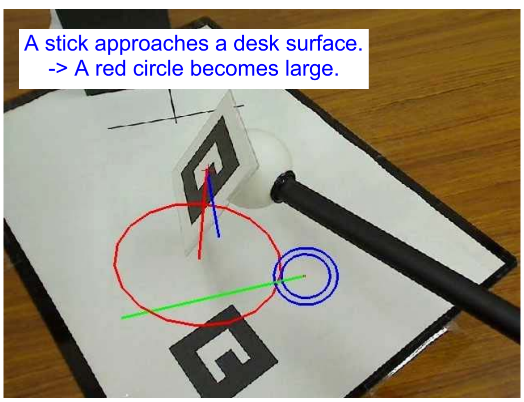

Figure 7. Instruction of 3-dimensional position and posture

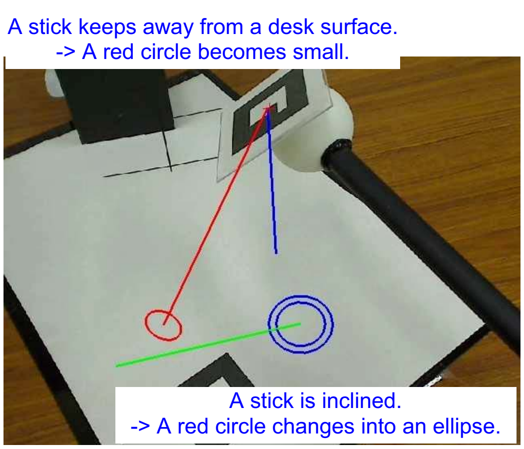

Figure 8. Instruction of 3-dimensional Position and Posture

VI. EVALUATION EXPERIMENTS

In order to confirm whether 3-dimensional position of the stick could be controlled with high accuracy according to the proposed instruction method in the foregoing paragraph, the following evaluation experiments were conducted.

A. *Experimental Method*

The experimental set up and the composition of the system are shown in Fig. 9. A worker equipped with an image capture display device, has a stick which imitates a burner in his / her hand. A marker is stuck on tip of a stick. Real image is captured by camera of the image capture display device. 3-dimensional position posture of the stick is detected by carrying out image processing of the captured image. And captured image and CG image are presented to the operator through an HMD. Fig. 10 shows an example of the presented image by monocular HMD during the experiment. Orange lines and blue texts (Target Orbit etc.) are for explanation of this figure, are not drawn during the experiment. Start Point and Goal Point are set as a height of 120mm from desk surface. In

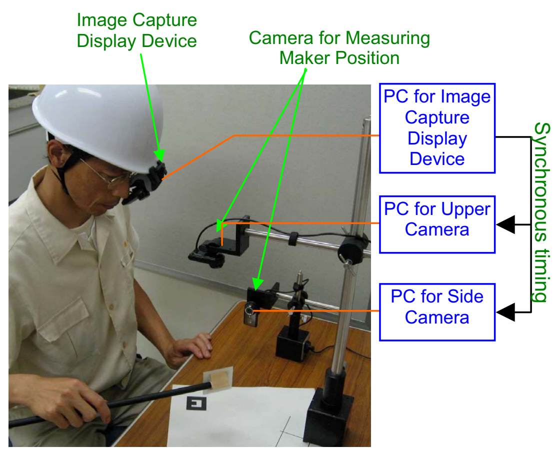

Figure 9. Structure of experimental setup

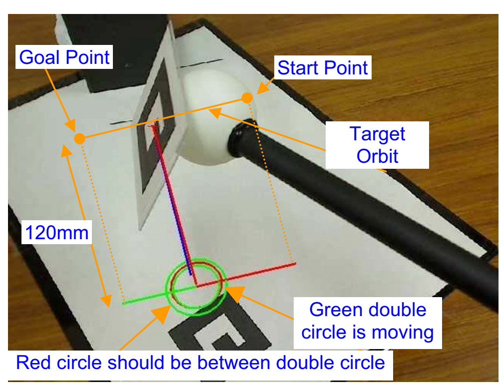

Figure 10. Instruction Experiment

this experiment, the tip of the stick is moved about 100mm from Start Point to Goal Point with the movement speed of 5mm/second. In other words, when the instruction experiment starts, the double circle begins to move from Start Point at the speed of 5mm/second along the green line on the desk surface.

Operator is requested to control the stick so that the red circle is placed between the double circles as precise as possible. The part of green line that the double circle passed changes to red color. Moreover, in order to measure the marker position at the stick tip, two cameras are arranged above the marker and in the side of marker, as shown in Fig. 9. The marker size is 40mm square. The marker posture at the stick tip was chosen so that a marker could be detected from three cameras, an image capture display device, an upper camera, and a side camera. The distance from an upper part camera to a target orbit is about 250mm, and the distance from a side camera is about 200mm - 300 mm. Qcam Pro for NoteBooks (2 million pixels) of Logicool was used for the upper and side cameras. And they captured images in 960*720 resolution dots. Three operators were selected and they repeated the operation 5 times respectively after sufficient practice.

B. *Experimental Result*

The coordinate is defined for the experiments as shown in fig. 11. X-Y plane is defined as the parallel and above 120mm from the desk surface. Z-axis is upward taken from the X-Y plane, and the origin of the coordinates assumed to be Start Point. An example of an experimental result is shown in Figs. 12-17. Figs. 12 and 15 show the locus at the tip of the stick calculated from images captured by the upper camera and Figs. 13 and 16 show the locus from images captured by the side camera. Table I shows the average values for five experiments. Standard deviations in Y-direction were calculated from the stick tip locus from the upper camera as shown in Figs. 12 and 15 on the average of five experiments. Moreover, the standard deviations in Z-direction were calculated from the stick tip locus from a side camera as shown in Figs. 13 and 16. Figs. 14 and 17 show the relation between the elapsed time and X-position captured from the upper camera. The inclination of the approximation straight line is regarded as average moving speed of the marker, which values are shown in Table I. From

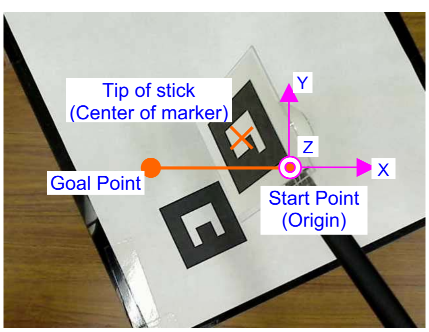

Figure 11. Coordinates for trace experiments

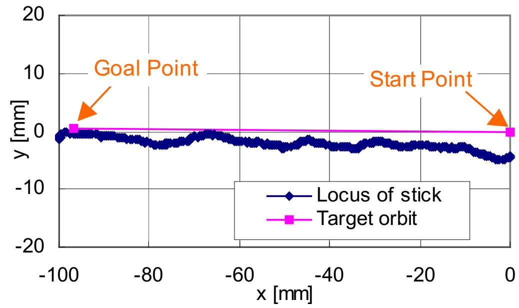

Figure 12. Experimental Result (Locus of Stick Tip) (Operator A)

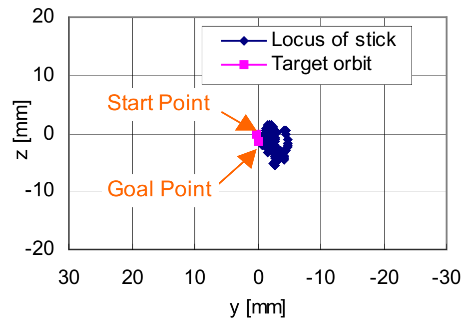

Figure 13. Experimental Result (Locus of Stick Tip) (Operator A)

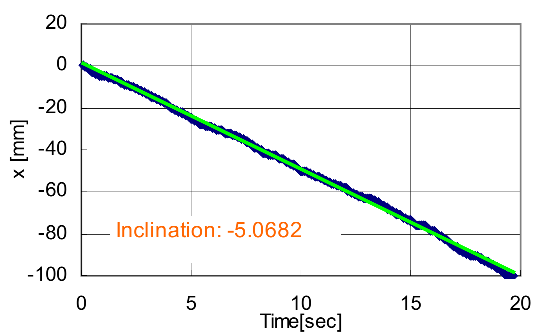

Figure 14. Relation Between Time and x- position (Operator A)

TABLE I. AVERAGE VALUES OF EXPERIMENTAL RESULTS

	Operator A	**Operator B**	**Operator C**
standard deviation in y-direction	0.80	0.86	0.94
standard deviation in z-direction	1.36	1.58	1.63
movement speed	5.08	4.97	5.11

these results, it was confirmed that it could trace the target orbit with sufficient accuracy and the moving speed of 5mm/sec was instructed well when image capture display device is used.

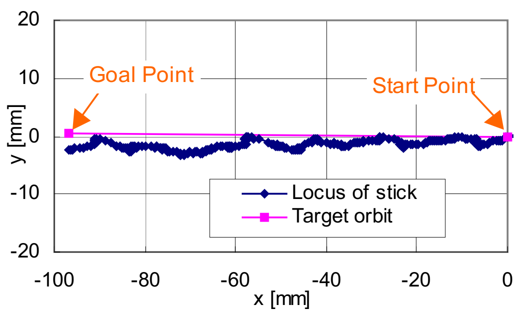

Figure 15. Experimental Result (Locus of Stick Tip) (Operator B)

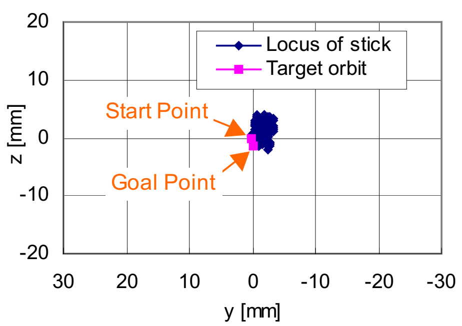

Figure 16. Experimental Result (Locus of Stick Tip) (Operator B)

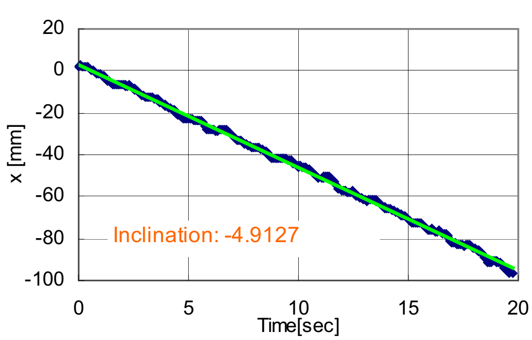

Figure 17. Relation Between Time and x- position (Operator B)

VII. Conclusion

An interactive support system and its application to the plate bending by line heating were introduced. The image capture display system was considered and a monocular video see-through HMD was selected as a result. It was confirmed that operators could trace with sufficient accuracy along with the target orbit using the prototype that we constructed. Therefore, it was confirmed that instruction of a three-dimensional position and speed could be performed using the monocular display and basic effectiveness of the prototype was confirmed. The improvement for higher accuracy of the instruction will be done and the line heating experiments using a real burner will be performed in the future.

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