Introduction of Product

Off-line Teaching System "TCHMORE"

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Teaching of a welding robot in a virtual space on the screen of a personal computer is called "off-line teaching." A new system "TCHMORE" has been developed to combine a personal computer and robot controller as a new form of off-line teaching. This system has been installed in many factories gaining the support of robot operators.

Key Words: *Welding robot, Offline teaching, "TCHMORE", Robot operator, Programming pendant, Robot controller*

1. Background

Welding robots are installed in factories as machines that perform welding work, which is hard work for men. Work programs have to be created to operate industrial robots including welding robots. Generally, a teaching playback system is used with industrial robots, whereby robots are actually operated to perform teaching to create programs, and work is performed by replaying the programs.

In teaching, welding start, end and waiting positions are sequentially stored in a program. A robot has many axes. It takes time to decide the direction of the welding torch at the tip in a position where collision is avoided. Teaching for one piece of work sometimes requires more than one week with construction equipment that has many places to be welded. Production by robots stops during teaching, and the teaching periods pose problems when programs have to be created anew due to model changes.

Off-line teaching is used to solve these problems. Teaching is performed by operating a robot in a virtual space on the screen of a personal computer that displays a robot, peripheral equipment and works. The application of off-line teaching has expanded thanks to the spread of three- dimensional CAD and the enhanced performance of personal computers. In the past, work models have been created for off-line teaching. However, by utilizing the data of designs created by 3D CAD, work models are no longer created, allowing teaching to start with newly designed work models. The enhanced graphics functions of the personal computer enable very real display and fast screen refreshing, allowing checking of collision and the motion of the welding torch while moving at the same speed as that of a real robot.

In 1994, Komatsu started off-line teaching by installing a system sold on the market. This system was useful in studying productivity, but problems remained with off-line teaching, which was the purpose initially intended.

2. Purpose

An operation panel called a programming pendant (teaching box) is used in teaching a robot. The robot operator approaches the robot, and the teaching box has a program display for teaching and operation keys. The key layout and functions have been refined with new ideas, and the teaching box is very easy to use for the robot operator. On the other hand, off-line teaching is performed through the mouse and keyboard of a personal computer. Certainly, the personal computer allows operations that are common to all applications, and it is very easy to operate it by merely clicking the icons and menu using the mouse. However, it is not very easy to operate for robot operators.

Even though off-line teaching is spreading, teaching with the robot is necessary for works with which program checks and modifications cannot be performed and for which there is no 3D CAD design. At Komatsu, robot operators are trained to perform both robot teaching and off-line teaching. Robot operators need to know about the robot and welding when operating a welding robot. It has been a burden on robot operators to learn robot teaching and off-line teaching. Robot teaching and off-line teaching are performed to create robot programs. Almost all robot operators wished to use the programming pendant because it is familiar to them. However, there was no teaching system on the market that allowed

operation by connecting a programming pendant to a personal computer.

The off-line teaching system cannot execute all commands and confirm execution as the robot does. Commands that cannot be confirmed must be added using a robot, and this has been one reason that teaching robot operations has taken a long time.

A new system, "TCHMORE," was planned in an effort to solve these problems by modifying an off-line teaching system sold on the market. The development goal was robot operation using a programming pendant and confirmation of all commands of the robot as illustrated in **Fig. 1**.
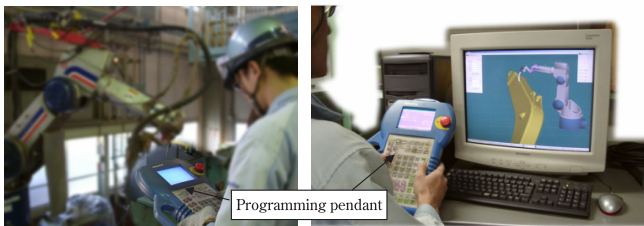

Fig. 1 Teaching to robot (left) and off-line teaching with "TCHMORE" Programming pendant (right)

Functions more than offered by off-line teaching systems sold on the market are needed to accomplish this goal. The new system, "TCHMORE," solved this problem by combining a personal computer and robot controller as shown in **Fig. 2**. The robot controller has a programming pendant, allowing robot operation and program editing. The same programs as those of the robot can be created and the same motions can be replayed. The robot controller drives the motors contained in the robot. However, the robot and the motors can be separated, and the robot on the personal computer can be operated by transmitting the positions of the motors to the personal computer. The personal computer displays the robot, works and peripheral equipment and operates the robot on the display screen when it receives the positions of the robot motors. The robot controller could be made compact containing only the printed circuit boards needed for "TCHMORE," and the software could be developed by modifying it. The software modification could be performed in a short time. The personal computer software was developed in house to quickly meet in-house requests as programming simplified, parallel with enhanced graphics functions, allowing development by parties other than specialized software houses for CAD and game software.
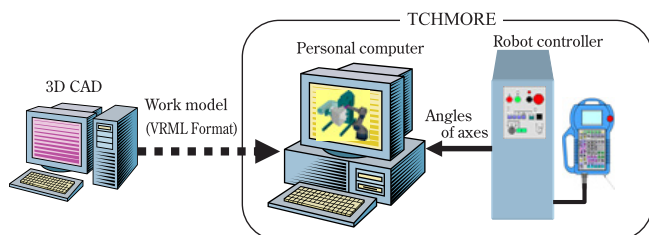

Fig. 2 System configuration of "TCHMORE"

3. Features of "TCHMORE"

3.1 Fast drawing and crash detection by DirectX

DirectX that is mainly used in game machines is used in the 3D graphic processing of "TCHMORE." A personal computer with the latest functions even if it is low priced can display equal to that in 3D CAD by installing a graphics board. Display of more than 20 fps (number of cycles to refresh the screen per second) is possible with almost all robot systems, and even weaving of swinging the welding torch at the tip of the robot left and right at several Hz can be confirmed.

Even though robot motion can be viewed on the personal computer screen as if an actual robot in motion is being viewed, a robot crash cannot be confirmed visually on the personal computer screen, and a function to detect a robot crash and to notify the operator by personal computer processing is needed. Processing to detect the crash of objects is used in games and other applications[1]. However, this increases the load to the CPU, and screen refreshing is greatly delayed. In many cases, crash detection enable and disable is switched by the operator, and detection is enabled only when it is necessary. "TCHMORE" detects crashes by a unique method using a graphics board, and screen refreshing is not delayed even if collision detection is always enabled. Near crashes between a robot and piece of work can also be detected (**Fig. 3**).
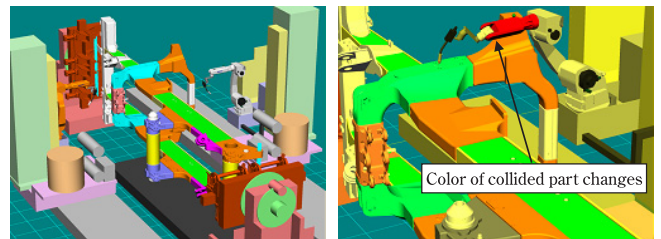

Fig. 3 Display of normal operation (left) and display of robot crash (right) Color of collided part changes

3.2 Simulation of wire touch sensor

The joint position deviates in the welding of thick plates as in construction machinery due to the thermal distortion of welding, and a wire touch sensor is used to detect joint positions. The wire touch sensor is operated by moving the robot as voltage is impressed to the welding wire. The robot motion is stopped when the wire detects contact with a piece of work. As shown in **Fig. 4**, in "TCHMORE," a detection signal is output to the robot controller when contact with a piece of work by the welding wire in the display is detected by graphic processing. The robot controller stops robot motion as in robot operation when it receives a detection signal. This enables confirmation of operation of the wire touch sensor as in actual robot operation. The wire touch sensor can be made to approach or leave the work surface by a specified distance to input wire touch sensor commands.
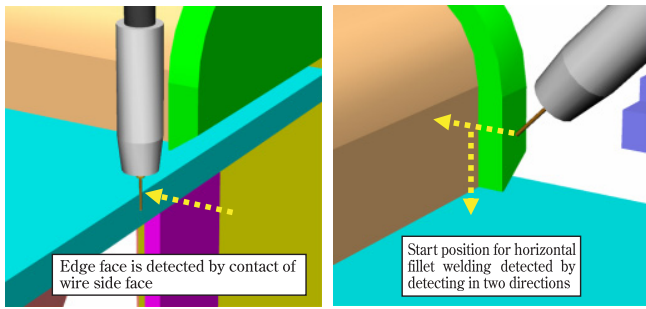
Fig. 4 Usage of wire touch sensor

3.3 Teaching correct welding posture

The joint posture and welding torch direction can be decided as follows in teaching welding work. The angles are specified by numeric values, and a correct posture can be accomplished (**Fig. 5**).
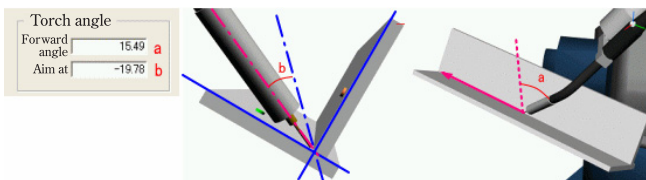

Fig. 5 Welding torch posture is specified

(1) A command is given to face the work joint down or horizontally, and the positioner with the piece of work on it is turned. A position to make the surface of a weld bead horizontal can also be specified by specifying a downward angle or upward angle and the unequal leg length of a fillet.
(2) The welding torch is moved by moving the cursor to the welding start position.
(3) The direction of the welding torch is decided by specifying the forward angle and aim angle of the welding torch.

If the robot cannot move to the target position in 2), "TCHMORE" moves the traveling axes that slides the robot to automatically allow the robot to move. Similarly, if the robot cannot move in 3), the welding torch is twisted.

3.4 Display of welding torch cable

The welding torch cable attached to the robot sometimes curls around the robot depending on the robot posture. A program taught with the cable curled around the arm can be executed on a personal computer. However, when executed with a robot, feeding of the welding wire deteriorates, sometimes damaging the cable. Therefore, this program cannot be executed with a robot. Displaying a moving cable requires a large volume of calculations and is not practical. As shown in **Fig. 6**, "TCHMORE" displays a ring around the arm to simply show curling of the cable around the robot arm. A program without cable curling can be created by teaching a welding robot while checking the ring.
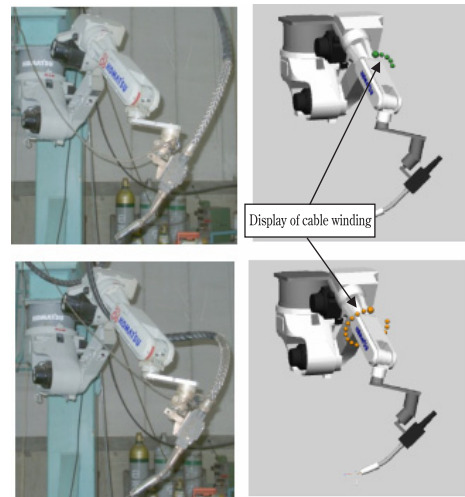

Fig. 6 Cable not wound around the arm (top) and cable wound around arm (bottom) Display of cable winding

3.5 Confirmation of program created

All motions of a robot during execution of a program can be recorded using the capture function. The program step No. is also recorded in the case of a robot collision. After a program ends, the motion during the collision can be played back to confirm the motion and to modify the program (**Fig. 7**). A program whose execution time is long can be executed unattended during the night, and scenes can be checked the following morning using the capture function. Robot positions and program step Nos. are recorded, and records of about one hour can be saved in a small file of several MBytes by compressing data.
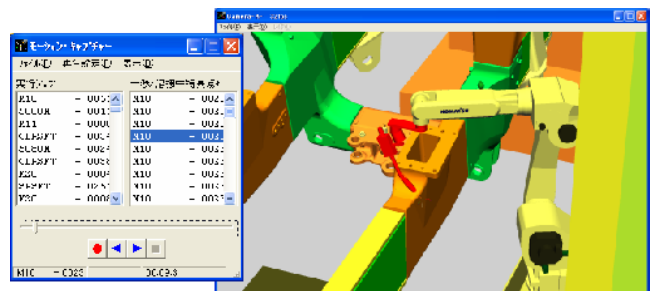

**Fig. 7** Scene of collision replayed by capture function

A saved file can be fast replayed without connecting the robot controller. Files are used when studying program improvement in a group or when explaining the welding procedures of robots to Komatsu-affiliated plants outside Japan.

3.6 Correction of machine errors

The robot and positioner positions of old equipment often differ from the layout drawings due to a poor accuracy at the time of installation. "TCHMORE" is equipped with a function to correct machine errors by storing several reference positions of the positioner and jig in the robot through teaching.

This program is executed by "TCHMORE," and positions are corrected by calculating differences. A special function to match the moving direction of the traveling axes and positioner revolution shaft is also provided (**Fig. 8**).

Shifts in moving direction of traveling axes are corrected
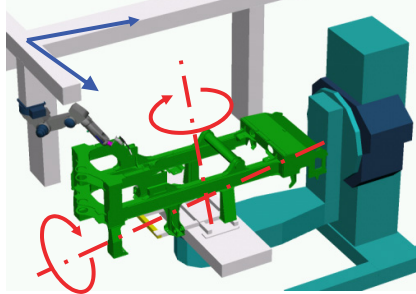
Position and axial direction of revolution center are corrected

Fig. 8 Rotary axes of traveling axes and positioner are corrected

3.7 Layout examination

"Layout study" means studying the layout of a robot, positioner and works and is performed before installing new equipment or welding new works. In a layout study of "TCHMORE," a robot controller does not have to be connected, and another personal computer can be used. The following functions have been added for layout study.

(1) Moving the cursor to the welding torch and dragging it moves the welding torch in the dragging direction (**Fig. 9**). Using this function, the area in which the robot moves can be checked.
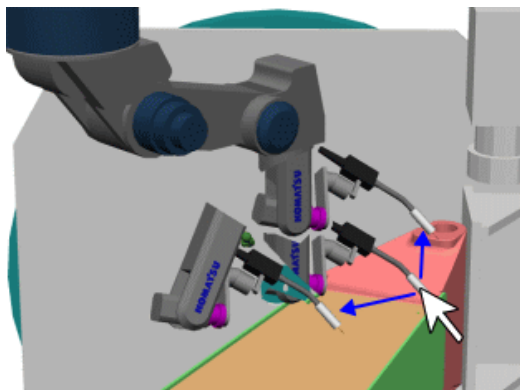

Fig. 9 Robot operation by mouse

(2) The robotization rate fluctuates depending on the shape of the welding torch. "TCHMORE" can create the welding torch to select the optimum torch and to study the torch mounting position (**Fig. 10**). Several torch types can be selected, and the torch size and mounting position can be changed through numeric input.

Water cooled torch   Offset torch
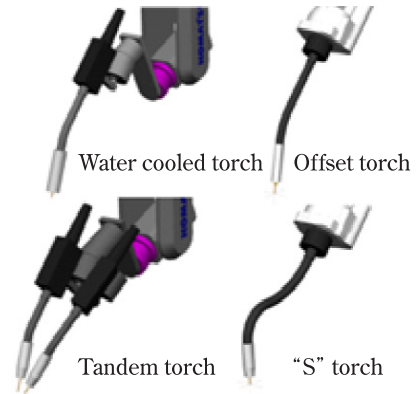
Tandem torch   "S" torch

Fig. 10 Torches fabricated

(3) Whether or not welding is possible is checked by operating the robot. Positions of the robot can be recorded and played back. The position data can be saved in a file and can be played back during teaching.

4. Principal specifications

"TCHMORE" is compatible with robots manufactured by Komatsu and Yaskawa Electric Co. (**Fig. 11**). The "TCHMORE" specifications are presented in **Table 1**.

Fig. 11 "TCHMORE" compatible with KXRC (XRC)

Table 1 Specification of "TCHMORE"

Item		CXX	KXRC
Controller		CXX manufactured by Komatsu	KXRC manufactured by Yaskawa Electric (MOTOMAN XRC)
Robot		Floor mounted/ceiling mounted type	Floor mounted/ceiling mounted type Cable embedded
Personal Computer	Hardware	Intel Pentium IV 2GHz or its equivalent, or higher Memory capacity 128MB or more Graphics board compatible to DirectX8 or newer	
	System software	Windows Me/2000/XP DirectX9 or higher	
	I/F	RS232C×2 Parallel I/O 8 points or more	
	Software protection	Aladdin HASP（USB key）	
Controller	Configuration	Servo amplifier not installed yet Printed circuit board interchangeable with robot installed Programming pendant installed	
	Housing	Special box (manufactured by Komatsu Engineering)	
Compatibility		Komatsu CX （converter software）	MOTOMAN NX
Seller		Komatsu Engineering Co.	

5. Delivery records of "TCHMORE"

All the main plants of Komatsu in Japan use "TCHMORE" for the off-line teaching of welding robots. "TCHMORE" is being installed at Komatsu group companies and local corporations of Komatsu outside Japan.   At present, the following units of "TCHMORE" are installed.

- Komatsu plants in Japan   11 units
- Komatsu plants outside Japan   3 units

6. Future plan

"TCHMORE" was readily accepted by robot operators because the same programming pendant as that used in robot teaching and off-line teaching can be used.   "TCHMORE" is intended for teaching, but also enjoys a high reputation as a training tool for robot operators.

Komatsu plans to construct a database for welding conditions and program standardization in cooperation with the plants of Komatsu.   Technical problems such as creating loci to avoid collisions will be solved to create automatic programming that requires no teaching, as has been accomplished in other industries[2].

References:
1) ABC of 3D Game Programming, Impress, 2000.
2) J. of Japan Welding Society, Vol. 74, No. 5 (2005) pp. 372 - 382

Introduction of the writer

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Entered Komatsu in 1983.   Currently belongs to Manufacturing Engineering Development Center, Production Division

[A few words from the writer]

Almost all the features described above have been realized by listening to the wishes of the robot operators in the Komatsu plants. The writer thanks these robot operators in the plants who have contributed their wishes and improvement suggestions to the initial version of "TCHMORE," which had no plausible functions except allowing robot operation by a programming pendant, without giving up "TCHMORE."