

Remotely Controlled Manipulators Using Telerobotic Software Provide Enhanced Efficiency and Ergonomy for Work in Hot Cells – 15101

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ABSTRACT

Computer aid and electrical assistance have been applied to remote manipulation inside hostile environments. A heavy duty master/slave manipulator system, the MT200, has been updated with the addition of an electronic bay with specialized software, a motion module and a poly-articulated master arm. This is the result of an ambitious 20-year continuous improvement program undertaken by the French nuclear institutions, CEA LIST Interactive Robotics Unit and AREVA in order to improve ergonomics, safety and efficiency at the AREVA La Hague nuclear plant.

The new manipulator system, named MT200 TAO, uses telerobotics to improve ergonomics by literally lightening the workload transmitted to operators. The link between the master and slave arms is electrical rather than mechanical. The poly-articulated master arm uses haptic (force feedback) technology, so the operator effort is multiplied by a homothetic coefficient in the slave arm. Simplification of the offset function, now integrated into the master arm, means that the operator can be correctly positioned for each task. Some repetitive tasks can be carried out with great precision in playback (robotic mode). In addition, this technology contributes to better efficiency, higher availability rate, lower maintenance costs with increased MTBF (Mean Time Between Failures), reduced waste, improved performance and safer use (remote workstations are feasible).

INTRODUCTION

AREVA La Hague nuclear plant in the north-west of France uses around 8 hundred manipulators, enabling over 150 operators to carry out a variety of jobs inside hot cells. The large majority of these units are La Calhène's MT200 manipulator, a mechanical master-slave system with an arm extension up to 4.5 meters and a maximum load at tongs of 20 kg. [1] Research was conducted by CEA LIST and AREVA to alleviate the fatigue and effort imposed on the operators working on heavy tasks with the traditional heavy-duty system. This resulted in the MT200 TAO concept, and the realization of a first prototype.

A methodical test program (involving the medical department for the ergonomic aspects) took place over a long period of time, with a panel of operators, in order to validate the concept and establish the requirements that were most useful for the operators

As of this early testing stage, gains were demonstrated in:

- Higher availability rate, better reliability
- Lower maintenance cost
- Lower workers dose (ALARA)
- Better performance (load and work area)
- Safer and more ergonomic use (human factor)

Following this highly successful testing campaign, AREVA decided to proceed with the development of the system, incorporating the lessons learnt and operator feedback. The system was then industrialized by La Calhène with the first standard manipulator installed in September 2014 in La Hague plant.



Fig. 1. MT200-TAO System Showing Sub-Systems

DESCRIPTION

The new system concept uses the existing MT200 slave arm and its through-tube, while the standard master arm is replaced by a new electrical one, together with the motion module fitted on the through-tube, the electronic bay, the HMI (Human Machine Interface) and a set of cables.

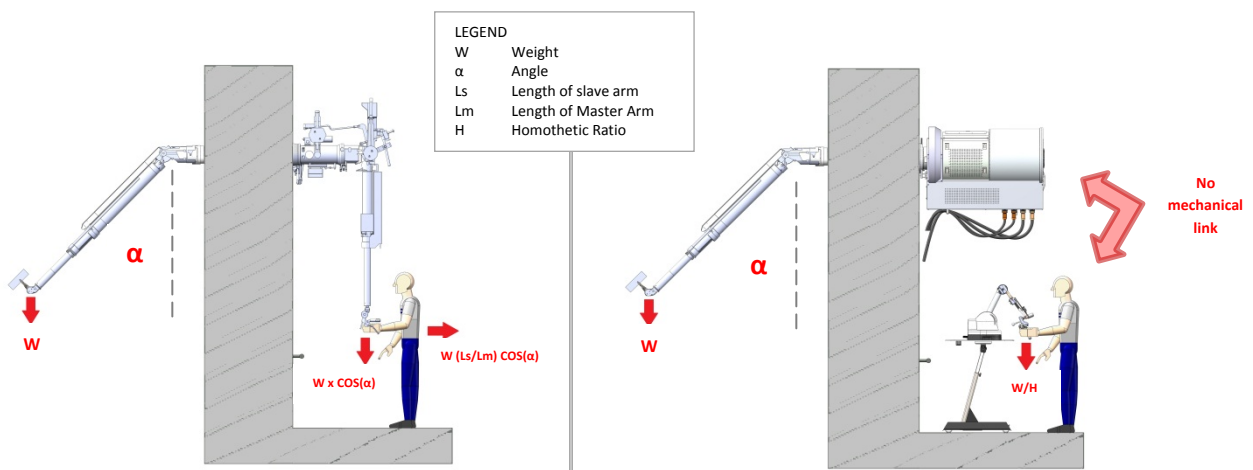


Fig. 2. MT200 and MT200-TAO Systems

TAO Concept

TAO (“Telesmanipulation Assistée par Ordinateur” or Computer-Assisted Telesmanipulation) is the same technology as the “fly by wire” technology now in use in modern aircraft [3]. Its main features are:

- Integrating a high speed computer in the loop which analyzes the operator’s orders and transforms them into orders for the motor.
- Replacing human energy by electricity, the slave arm movements being powered by an electric motion module (motor).
- The software protects mechanical and electrical parts from exceeding performances hence reducing the number of failures.
- Advanced functions including vibration filtering, passive anti-collision and force feedback management.
- No need for a mechanical link between operator and slave arm.
- Repetitive tasks can be performed very precisely in playback (robotic mode).

A sophisticated HMI (Human Machine Interface) was specifically developed for the application to provide more options and improve ergonomics. The CYXPro software from Cybernetix includes:

- Virtual reality: off-line used to create, simulate and train
- Personalized HMI
- Real-time display and importing of the 3D environment during execution

Master Arm Sub-System

For the operator, the main difference between the two systems lies in the master arm sub-system [2], a small poly-articulated master arm embarking force feedback technology which gives the operator exceptional feedback (real time, 6 axes).

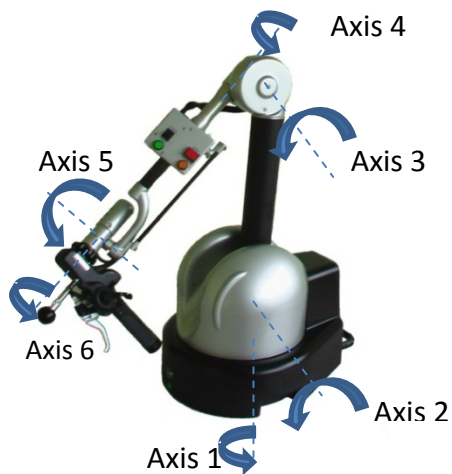


Fig. 3. Haptic Master Arm

The operator moves the handle in the direction of the required movement and the slave arm movement follows the same path (both cartesian and articular modes are available), with respect to a homothetic ratio. The force feedback [1] [4] on both master and slave sides is transparent, i.e. the operator never feels the weight of the slave arm. This does not vary with the slave arm position (see Fig. 1).

The offset function has been greatly optimized by integration into the haptic master arm, resulting in the operator being able to adopt the appropriate position required for each ongoing task. Body posture is improved and physical movements more specific, while vision of the job in hand is facilitated by the “disconnection” between master and slave arms. [1]

Safety/Dosimetry Features

The electrical connection allows the operator to work remotely since the operator station can be located up to 200 m from the hot-cell (using cameras), which is beneficial for the ALARA aspect.

In addition, use of the MT200 TAO decreases working time for a defined operation.

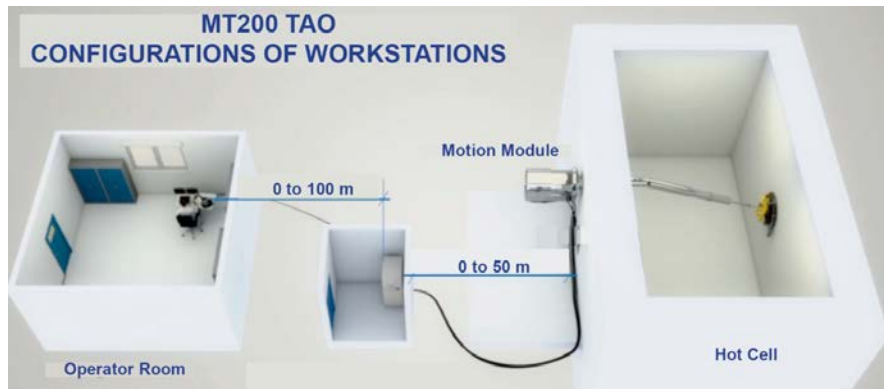


Fig. 4 Remote Workstation Configuration

Sensors located inside the motion module detect and send information to the HMI about the actual slave arm locking status and the actual type of slave arm (length)

Operational Gains

In terms of efficiency (i.e. time related to a specific work), the testing program has proved that the operational gain is: [1]

- 60% minimum through the increase of the working time duration, thanks to the significant decrease of the tiredness of the operators
- 20% thanks to greater accuracy in the movements

Moreover the working life of the slave arm is increased by a factor of 5, as compared to standard MT200 manipulators. [1]

Area Coverage

Compared to the standard MT200, the MT200 TAO provides a working volume 3 to 4 times greater, since there is no limitation to work through the full hemisphere on the hot side (full capacity right, left and up).

A System of Systems

In parallel, industrialization is under way on a new telerobotic manipulator, the TERMAN TAO, featuring (in addition to the improvements incorporated in the MT200 TAO) a cable-less slave arm operated by drive shafts and gears for improved rigidity and precision. This TERMAN TAO system will offer heavy duty performances, so will be particularly useful for dismantling operations.

The TAO family of manipulators have been designed for a maximum of flexibility, interchangeability and modularity. It only takes 2 hours to change from an existing MT200 to an MT200 TAO.

- The throughtube and the slave arm do not need to be removed
- The Master Arm is replaced by the Motion Module (simple unbolting/bolting, same interfaces)
- The electronic bay, HMI, cables and the haptic Master Arm are added.

Going back to the standard MT200 configuration is the same job, in reverse.

Moving up to the TERMAN configuration will be done by changing only the slave arm, all other components being fully compatible by design with this new slave arm. This completely interchangeable system provides versatility, another major benefit which adds to the efficiency of the tool.

CONCLUSION

The MT200 TAO is now opening a new era in telemanipulation. Immediate benefits are now being demonstrated, and we can contemplate wider and far more benefits for cells and building designs.

The list below contains current ideas and impacts for the future installations

- Capacity to fix the system to the ceiling (vertical throughtube)
- Capacity to fix the system under a mobile gantry or telescopic mast, inside the hot cell
- Capacity to embark the system on a remote vehicle
- Larger/wider/higher cells
- Larger distances between wall sleeves
- Totally remote operation, through the use of cameras, thus allowing for cells without shielded glass windows.

AREVA La Hague has now commenced daily use of the first five systems which are being installed so the wide-reaching experience already accumulated during the prototype phase is now being further enlarged.

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