The 5th International Symposium on Robotics in Construction June 6-8, 1988 Tokyo, Japan

THE DEVELOPMENT AND SOME APPLICATIONS OF THE HEAD BALANCED MANIPULATOR FOR THE CONSTRUCTION INDUSTRY

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Abstract

With balancing functions, the head balanced manipulator enables fine positioning of a heavy object, requiring only a minimal application of force, while fully utilizing the manipulative senses of human hands. Through the application to pin fitting and core insertion work on factory assembly lines, the manipulator has proved its effectiveness.

Application of the head balancing functions is versatile, and the manipulator with these functions is expected to perform effectively in the handling and positioning of construction materials on building construction or civil engineering sites. Thus the importance of the head balanced manipulator as a piece of labor-saving equipment is expected to increase.

1. Definition of Head Balanced Manipulator

A head balanced manipulator must have the dual functions of hoisting and balancing an object. Like a hoist, it must be able to not only hoist or lower an object through the operation of a lever or push button for control, but also keep it in place in a balanced manner. In other words, it is a piece of loading and carrying equipment which can be used for transferring heavy objects as well as for assembly work requiring fine positional adjustments (See Fig.1).

The balanced state for an object implies a state where a hoisted object can be moved upward or downward with the help of human hands and a minimal application of force, and where the object stays where it was positioned even after the hands have been removed.

Any piece of equipment which fails to keep the object where it was positioned, does not qualify as a head balanced manipulator.

2. The Need for Head Balanced Manipulator

In recent years, there has been a growing demand from factory shops as well as building construction and civil engineering sites for something with the ability to assemble or fit heavy components or materials with precision. Since

accurate positioning of an object was beyond the ability of any conventional crane or hoist, the machine now in demand is required to have fine and simple positioning capabilities.

Various studies have led to the conclusion that the ability for fine positioning can be substantially increased if human hands aid the object being handled in order to help it move upward or downward with minimal manual force. It has also been proved that if the position of a hoisted object can be easily changed with the help of human hands, finer positioning will become feasible in a shorter time and without difficulty.

In order to facilitate the lifting or lowering of a hoisted object with the help of human hands, a balancing function for keeping the object in a zero gravity state is indispensable. In this context, the need for the head balanced manipulator is anticipated to increase.

3. Newly Developed Manipulator

With a view to excellent controllability, an electrical driving system was employed to obtain balancing functions, and an articulated arm design ensured a wide range of access (See Table 1, Fig.2).

3.1 Applied Force Control

The load of the hoisted object and the applied human force are directly detected by a highly sensitive force sensor, without involving any play or friction. Since the force control system is structured so that it depends upon the detected forces, minimal human force can cause upward or downward movement of the hoisted object in a balanced state (See Fig.3).

3.2 Accurate and Quick Load Memorizing Method

In order to facilitate the movement of a hoisted object by human force in a balanced state, it is necessary to identify the load of the object as accurately as possible. It is also necessary that detection of the load is performed quickly enough so as not to disrupt the flow of operation.

In order to achieve these ends, this system is designed to obtain the load of the hoisted object by instantly averaging the signals detected by a force sensor, once the object is hoisted from the ground operating a lever or push button system which can control the object's ascending or descending speed.

3.3 Ability to Instantly Deal with Any Load for Hoisting

Since load data re-enter the memory system each time hoisting speeds are controlled through operating a lever, the equipment can deal instantly with the weight of any hoisted object. In addition, the moment load data are re-entered

into the memory system, the hoisted object is automatically put on stand-by in a balanced state, allowing movement by manual force at any time.

3.4 Safety

In case of damage to the hook which is hoisting the object in a balanced state, the arm could suddenly bounce because the hoisted load becomes zero in weight. Likewise, if any part of the equipment catches on to the hook during disassembly, the arm could suddenly fall because the load could become heavier than registered.

In order to prevent these dangerous situations from occurring, the equipment incorporates a system which enables instant detection of any possible falling or bouncing of the arm as well as the retention of its position, through the algorithmic processing of signalled data provided by the force sensor, as well as the revolution of the motor.

These safety measures are reinforced by a built-in safety circuit for preventing the arm falling or bouncing in the event of emergencies involving power, sensors or wire harnesses.

4. Proven Effectiveness of the Balancing Functions

The head balanced manipulator is expected to demonstrate its special effectiveness when applied to such jobs as pin fitting, core inserting, or setting of works on machines, which require fine positioning accuracy as well as swift movement compatible with human senses for actions (See Fig.4).

The cycle time was compared between a head balanced mainpulator and a non-balanced electrical hoist, when applied to a pin fitting job which requires accurate and precise positioning. It shows that overall, the cycle time of the head balanced manipulator is approximately 40% shorter than that of the electrical hoist without balancing functions (See Fig.5).

Of particular note is the fact that the cycle time for a pin fitting job where the head balanced manipulator was supposed to be at its optimum performance level, was almost halved, confirming the effectiveness of the equipment.

5. Applicational Examples

Several cases of applications to actual jobs in our plant will be presented below:

5.1 The Positioning of Engine cylinder Head to Position Fixing Pins

On an automated sub-assembly line for engine cylinder heads, multiple robots mount parts on each cylinder head placed on a

pallet. For these robots to perform the fitting of parts accurately, the cylinder head itself must be accurately positioned on the pallet.

To ensure such accuracy, each cylinder head is palletized by fitting a number of pins provided on the pallet to the matching holes on its bottom (See Fig.6). This particular job used to be assisted by a hoist. However, since the holes on the bottom of the cylinder head are hidden to the attending worker, the pin-and-hole matching job used to consume a considerable amount of time when handled by a hoist, and often tended to damage both pallets and cylinder heads.

The application of the head balanced manipulator enabled the job to be completed quickly, without spoiling the cylinder heads since it facilitated the pin fitting by feeling for the positions.

5.2 Core Insertion on Casting Line

The job involved is positioning a core with utmost care so as not to let it hit against a mold with which it has only a 0.5~0.8mm clearance (See Fig.7). Because a collision tended to result in demage to the core or the mold, attending workers used to spend a lot of time ensuring careful insertion of the core by operating the hoist's pendant.

Use of the head balanced manipulator enabled the worker to carry out the insertion job while feeling the force of both hands lent to the hoisted core, and this ability resulted in reduced worker fatigue and an approximately 20% shorter cycle time.

5.3 Fitting of Bushes to Construction Equipment Axle

The clearance between a bush and an axle is approximately 0.15mm. Initially, attempts were made to facilitate their fitting by hoisting the bush by a crane, but they did not work because the cranes performed poorly in positioning work. Thus, the job needed two workers to uphold the bush and fit it to the axle (See Fig.8).

Application of the head balanced manipulator not only enabled only one worker to complete the job with a minimal amount of labor but also improved worker's environment.

As these examples illustrate, the abilities of a head balanced manipulator to save labor, reduce the cycle time and avoid spoiling any work involved, while quickly and accurately positioning any heavy object with a minimal amount of manual force and exploiting the advantages of the sensitivities of human hands, have been highly commended among shop workers.

6. Application to Construction Sites

Diminishing availability and aging of construction workers have brought about an increased mechanization of jobs as well

as the removal of workers from undesirable jobs. Nevertheless, commercial application of fully automated equipment to construction sites is by no means an easy thing to introduce because of an extensive variety of jobs and the complexity of the site environments involved.

Indeed, various robots for application to building construction were developed in the past as semi-automated, labor-saving equipment. However, few could demonstrate a practical use on sites.

As is the case with factories, building construction and civil engineering sites involved many jobs which call for fine positioning. Among others, the handling and positioning of flat materials for interior construction work is expected to offer many opportunities for effective use of the head balanced manipulator.

The board handling manipulator is one conceptual answer to the call (See Fig.9). The equipment is projected to have the abilities to suck up each wall board stacked on the floor with its sucking pads, hoist the board in a vertical position, and keep it hoisted in a zero gravity state to allow for placement at any desired position by manual force.

It would also be possible to apply Fig.9 to such equipment as that used for fitting heavy plate glasses to their frames or for piling up blocks to form partitioning walls.

The use of this kind of equipment developed with an aim to make jobs easier, and at the same time save labor, would turn these undesirable jobs which hitherto required many workers, to jobs which could be handled by a single worker and with minimal operating labor.

7. Conclusion

It is considered that the basic functions enabling a worker to handle, with a minimal amount of force, any heavy object hoisted in a state of zero gravity will become increasingly significant because of their potentioal application to building construction and civil engineering sites. However, in view of various restrictive conditions peculiar to construction sites, we would like to pursue our research and development effort for the kind of labor-saving equipment which can earn immediate acceptance on sites, through the cooperation of both construction companies and contractors.

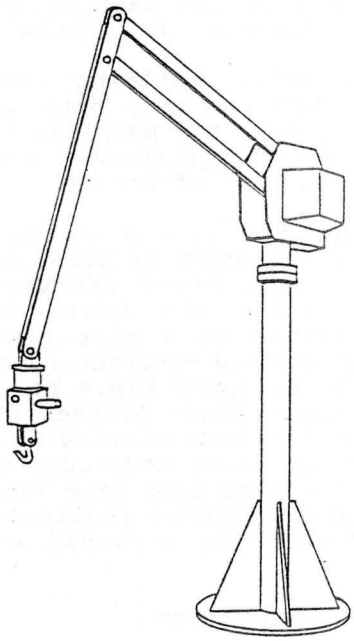

Fig. 1 Arm type balancer

Payload	100 Kg
Required human force at 100Kg load	1 Kg
Speed at 100Kg load	20m/min
Weight of manipulator	200 Kg
Power source	AC 200V

Table. 1 Specifications of developed manipulator

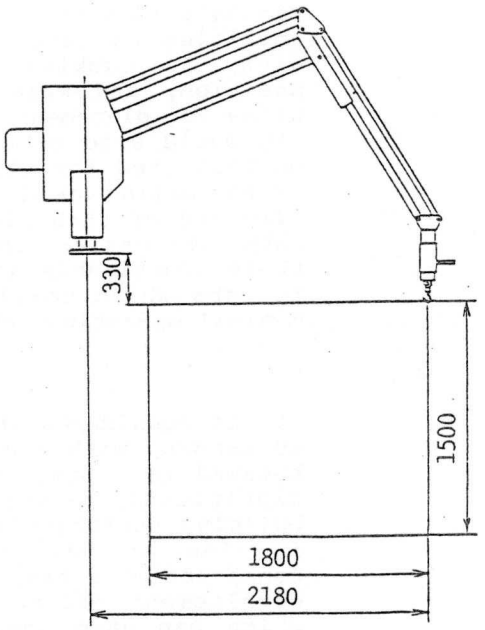

Fig. 2 Working area of developed manipulator

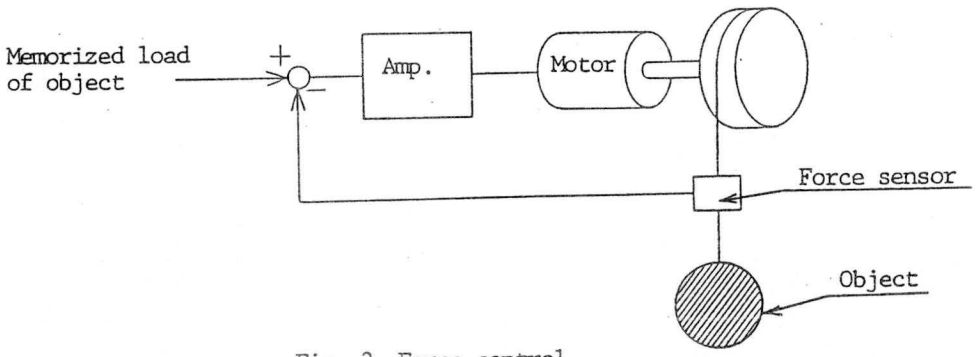

Fig. 3 Force control

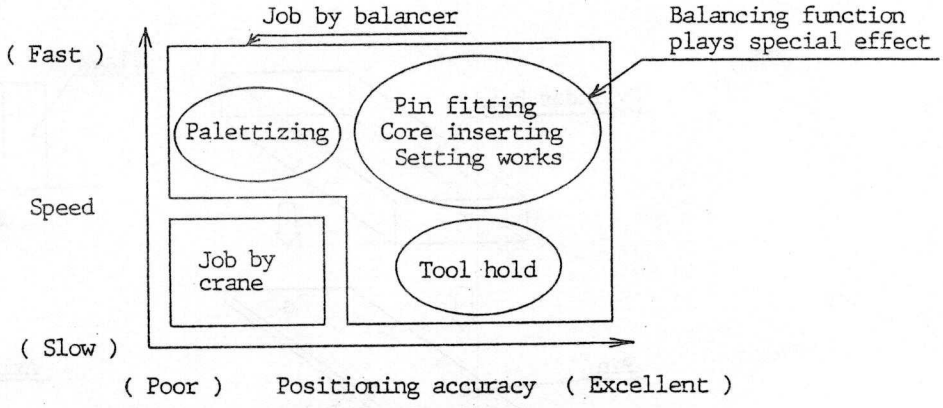

Fig. 4 Effectiveness of balancer

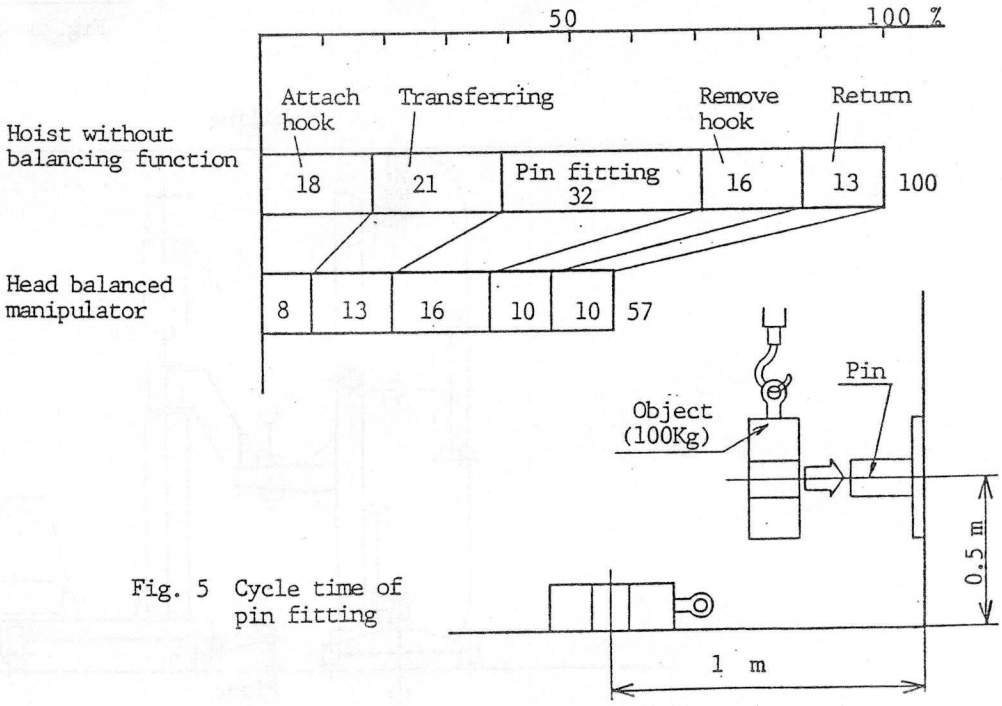

Fig. 5 Cycle time of pin fitting

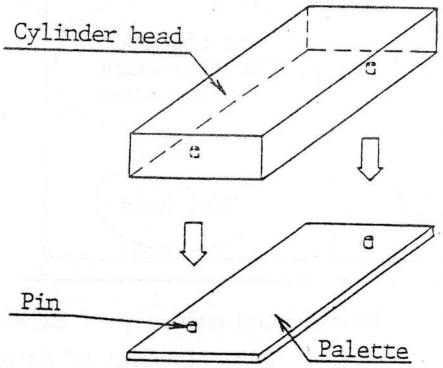

Fig. 6 Positioning of Cylinder head

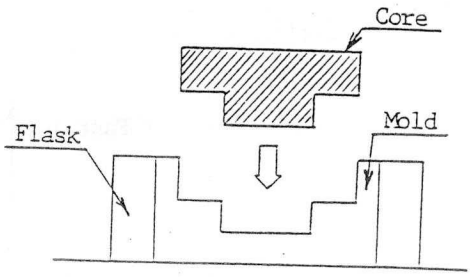

Fig. 7 Core inserting

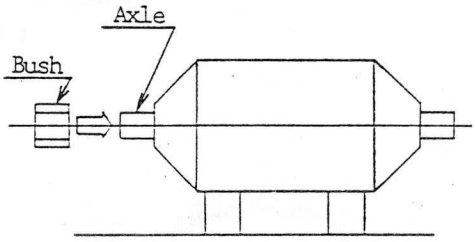

Fig. 8 Fitting bushes to axle

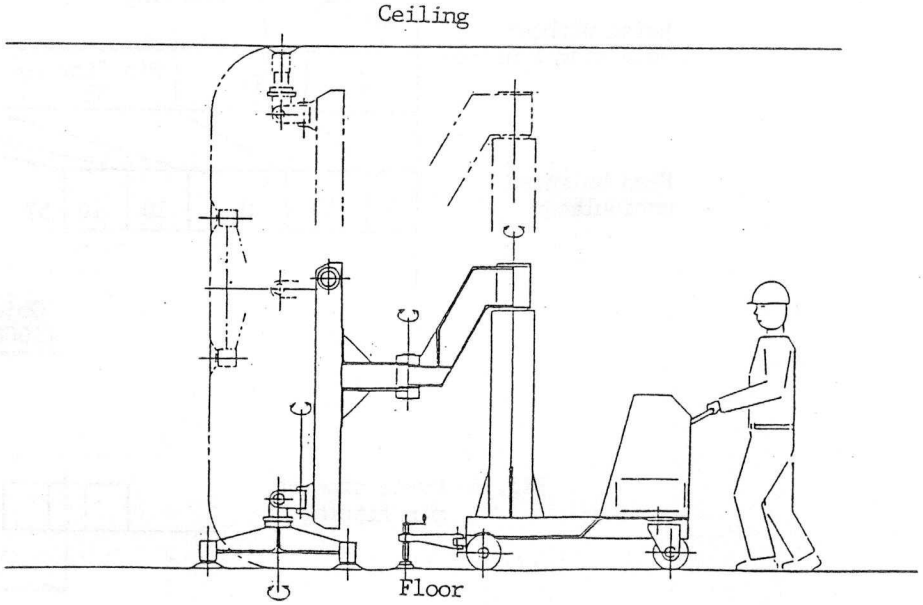

Fig. 9 Boad handling manipulator