Design and Construction of Multi Axes Data Acquisition System for Robot performance Measurement

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Abstract: - At the present time, when technology is capable of offering numerous types of industrial robots, there is a requirement to establish a reliable standard procedure by which the positioning repeatability performance of robots can be assessed.

This paper describes design and construction of multi axes data acquisition and logging system, which could be used to collect a number of parameters from several sources by means of different types of transducers. The design of the system concentrated on the use of both inductive position and platinum film temperature sensors. The series of tests for investigating the robot performance regarding positioning repeatability and their associated results did reveal that the multi axes data acquisition system operated satisfactorily.This work has also demonstrated that thermal expansion plays a significant role invariation of repeatability during warm-up period of the Rediffusion robot.

Key words: - data, acquisition, robot

1 Introduction

One of the most important measures of an industrial robot's ability to perform a given task is positioning repeatability. This feature is often an indicator of whether or not the manipulator is a candidate for the proposed application, particularly when dealing with sophisticated tasks, e.g. an assembly operation.

Introduction of devices such as, Remote Center Compliance (RCC) [1], Instrumented Remote Center Compliance (IRCC) [2] which were designed for aiding assembly insertion operation, can help to overcome the problem of poor repeatability performance to some degree, but still it is just a partial solution and can only be used if this parameter of the robot is examined and well determined.

Unfortunately there is no agreed standard procedure for determining this important parameter. Each manufacturer has tests for its own robots. Therefore, there is an urgent need to develop a reliable method that can be employed by both the user and the manufacturer for the standardization of robot characteristics, thus making it possible to compare data for the various manipulators.

This paper describes the design of a data acquisition system, which can be used to collect a number of parameters from several sources by means of different types of transducer, e.g. position and temperature transducers, thus providing appropriate information for establishing the repeatability performance of the robot.

2 Robot Positioning Errors

By the very nature of the movements expected of them, most robots are very badly designed machines from the point of view of the classical rules of kinematics and the principle of alignment used for machine tools and measuring machines. This is particularly true of those robots with jointed arms whose end effector position is evaluated by the control system from readings of angular transducers mounted on the axes of rotation. While modern robots can operate with precision, the work described here shows that they are subject to loss of positioning repeatability due to mechanical and electrical energy dissipation.

3 Design and construction of Multi Axes Data Acquisition System

This work is concerned with the design and construction of multi axes data acquisition and logging system, which could be used to collect a number of parameters from several sources by means of different types of transducer. The design of the system concentrated on the use of both inductive position and platinum film temperature sensors.

The measurement of the position of a robot end effector with six degrees of freedom in a three dimensional space is not a trivial task when a precision of the order of 0.001 mm within a 2m cube is required. To date most authors have confined their work to measuring the repeatability of positioning at a single point although attempts have been made to track a robot's arm over a range of positions. Measurement techniques have ranged from the use of dial gauges and vernier calipers [1], through non-contacting sensors [2,3] to stereo and 3D vision systems [4,5], and acquiring range images of object techniques[6,7].

For the present work position measurement at a single point was sufficient. The end effector developed for this consisted of a 200 mm across flats octagonal aluminum drum fastened to the end of the robot arm, with a face plate perpendicular to the drum axis which was aligned with the robot hand axis.

For this work two inductive measuring sensors were mounted on a side faceplate, the bottom face and the vertical face of the drum. The inductive sensors where connected via amplifiers to an eight channel, eight-bit analogue to digital converter and conditioning amplifiers which in turn were connected to a computer used for data logging. This arrangement gave a measuring range of 0.25 mm with a one bit resolution of 0.001 mm. In practice the small range, which was determined by the need for high resolution, recorded on an eight-bit system, was only just sufficient for the position change experienced in the experiments.

The two spare A-D channels were either used for temperature recording or for handshaking signals to synchronize data logging with robot position (fig. 1). When the robot arm was in its goal position each sensors face was opposite a pre-adjustable target stud mounted in the three mutually perpendicular surfaces of a corner constructed from steel plates. A number of platinum film temperature sensors were placed inside both inner and outer arms using special adhesive with high thermal conductivity.

The repeatability of an industrial robot may be defined as the expected or observed dispersion on each side of a mean from a series of trials when the end effector approaches a given point under the same conditions. Such dispersion might well be expected to have a distribution and a numerical value be allotted to the term repeatability in terms of the standard deviation of the scatter [8].

Platinum resistance thermometer elements were bonded within the aluminum castings of the inner and outer arms, and also to the points such as the X axis gearbox, drive motor and position encoder. Bridge circuits were constructed so that the A-D converter and associated amplifiers could be used for logging the measured temperatures by the computer. In the later experiments one of the thermometer elements was used with the computer to control the heating system attached to the robot arms.

4 Experimental Procedures

4.1 Position and Temperature Measurements

Platinum resistance thermometer elements were bonded within the aluminum casting of the inner and outer arms. The steel corner target was mounted on a heavy cast iron T-slotted table resting on the concrete floor to which the robot was bolted. A 25 mm diameter steel tie bar was fastened between the table and the robot pedestal to maintain their relative positions. The corner target was oriented so that its planes where parallel to the axes of the robot's global frame of reference. In this position the Z-axis was vertical, the Y-axis essentially radial and the X-axis tangential to a circle centered on the vertical axis of the robot. The target was placed so that it was almost at the limit of the robot's reach (Fig. 2).

The robot was programmed in the high level language "AR-BASIC 2" so that the end effector approached the target along one of the axes at high speed until it was at a point just outside the target of the inductive sensors. From this point the robot slowly approached the goal position at an angle of 45 degrees to all three axes. At the goal position a delay of four minutes was incorporated. At the end of delay the robot sent a synchronizing handshake signal to the computer to record the gap values registered by the sensors. The arm then moved a way from the target at high speed and exercised by a large horizontal (at least 180 degrees) and vertical swing before coming back and approaching for the next four minutes wait in the goal position. In eight hours 99 cycles were completed. A set of experiments consisted of five 8 hours tests.

In the first of the five, the end effector approached the target along the X direction for every cycle in the 8 hour period. For the second and third tests the approach direction was along the Y and then the Z directions respectively. In the fourth test the approach direction alternated sequentially between the three axes throughout the period. The final test used the same alternating approach but with a 4.5 kg weight bolted to the end effector. For each 8 hour test the starting goal position was taught by means of the robot's joystick. Fine mechanical adjustment of the target stud was used to give an initial gap between stud and sensors of between 0.8 and 0.95 mm.

5 RESULTS

From the tests, with X, Y and Z-axes approach directions sequentially; it was found that the largest variation in position occurred on the Y-axis, with the range of 0.176mm (see fig. 3). Gradual change in variation on both X and Y-axes during the early stage of the test was noticed. From the position graph, it can be clearly seen that the repeatability of the robot on Y-axis stabilized after about three hours and thirty minutes from starting the test.

During the above tests, maximum temperature rises of 6.5° C and 12.6° C were measured on the inner and outer arms respectively (fig. 4). The two arms reached their maximum temperature at about the same time of three hours and thirty minutes.

On examination of the variation of the alignments, the smallest overall range was seen to be about the Z-axis, with the range of 0.000238 radian or 0.013 degrees. The spread of the alignment about the Z-axis was found to be consistent throughout the test period (fig. 5). Due to limited space available for publishing this paper only one set of results (i.e. graphs) associated to the test carried out with X, Y and Z axes approach directions sequentially presented.

The results of the test, which was carried out along X-axis approach direction, indicate that the Z-axis variation was the largest, with the range of 0.228mm. This was surprising since it was expected to achieve similar results to those obtained from the previous test. The spread of the position variation on both X and Y-axis revealed a similar pattern to those from the previous test. During the above test, maximum temperature rises of 6.5° C and 11° C were recorded on the inner and outer arms respectively. On examination of the variation of the alignments, the largest variation was noted on the rotation about the Y- axis, with the range of o.oo1264 radian or o.o72 degrees.

From the test with Y- axis approach direction, it was found that the largest variation in position occurred on the X- axis, with range of o.175mm. Variation on both X and Y axis followed almost a similar pattern to those obtained from the previous tests. The maximum temperature rise of 6.1° C and 10.2° C were measured in the inner arm and outer arm respectively. The largest variation throughout the test was noted on the rotation about the X-axis, with range of 0.000592 radian or 0.033 degrees.

From the results of the test which was carried out along Z axis approach direction, the position repeatability of the Z axis showed the largest variation compared to the other two axes, with the range of 0.188mm.During the above test, maximum temperature rises of 6.5° C and 13° C were measured on the inner arm and outer arm respectively. On examination of the variation of the alignments, the largest over all ranges was seen to be about the X-axis, with the range of 0.000672 radian or 0.038 degrees.

From the test carried out with a weight of 4.5kg added to the robot end effector, where approaches were made from different directions sequentially, it was noticed that the largest variation was on the Z-axis with the magnitude of 0.198mm. The maximum temperature rise of 5.3° C and 8.6° C were measured on the inner arm and outer arm respectively. The largest variation of the rotation was about the Y-axis, with the range of 0.00087 radian or 0.049 degrees.

The higher temperature rise in the outer arm was due to the heat generated by the three wrist axes motors, which are located at the end of the outer arm on the robot. Statistical analysis of all recorded point showed strong correlation between temperature and position.

6 COCLUSIONS

This series of tests for investigating the robot performance regarding positioning repeatability and their associated results did reveal that the multi axes data acquisition system operated satisfactorily.

The series of tests showed that the gap on all three axes tended to get smaller with time. Each test was carried out for eight hours. It was noticed that the measured gaps mostly decreased in what approximated to an exponential decay with a time constant of about two and a half hours. This indicated that there is a factor (s) effecting robot performance particularly during the first hours of test periods.

This work has also demonstrated that thermal expansion plays a significant role in variation of repeatability during warm-up period of the robot. A maximum temperature rise of 13° C was measured on the outer arm. This could be due to the heat generated from the three stepper motors, bolted to the end of the outer arm, to drive the three wrist joints.

Since the Rediffusion robot was an electrically driven robot, a long running time was needed by the robot to stabilize. Almost three hours and thirty minutes were taken to stabilize. This was the time required by both inner and outer arms to reach their maximum working temperature.

The results confirmed that the difference in the positioning repeatability were significant when the robot was approaching the same point through different paths, regardless of employing the same speed and the same final approach path.

The designed and manufactured data acquisition system proved to be a very useful tool for assessing the performance of an industrial robot with the required accuracy, also this system enabled automatic recording of end effector position to be achieved.

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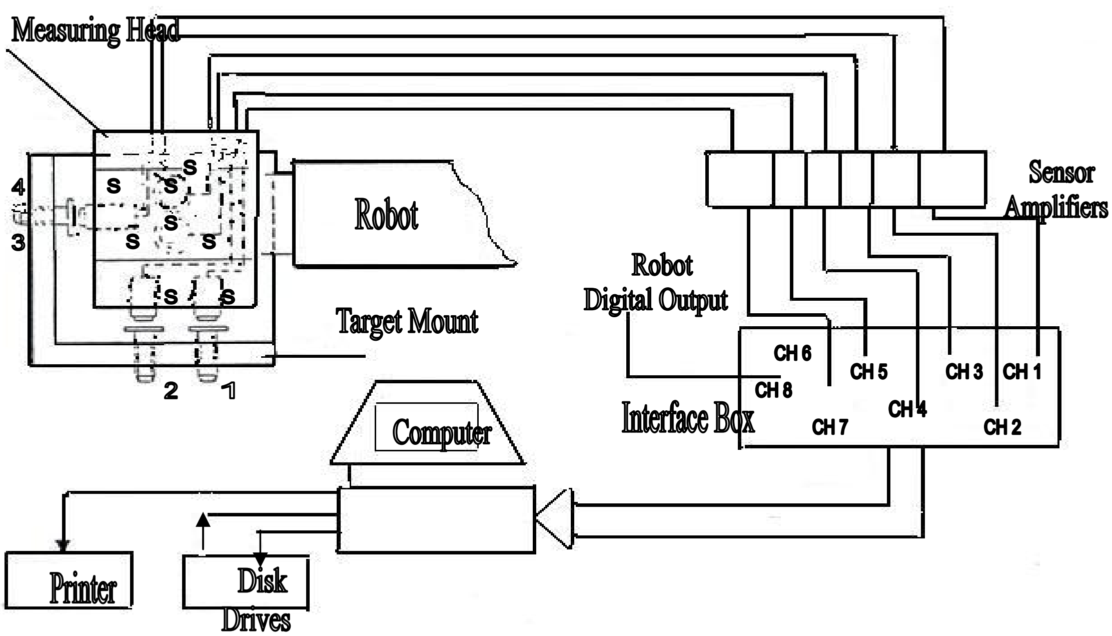

Fig. 1 Data Logging Instrumentation

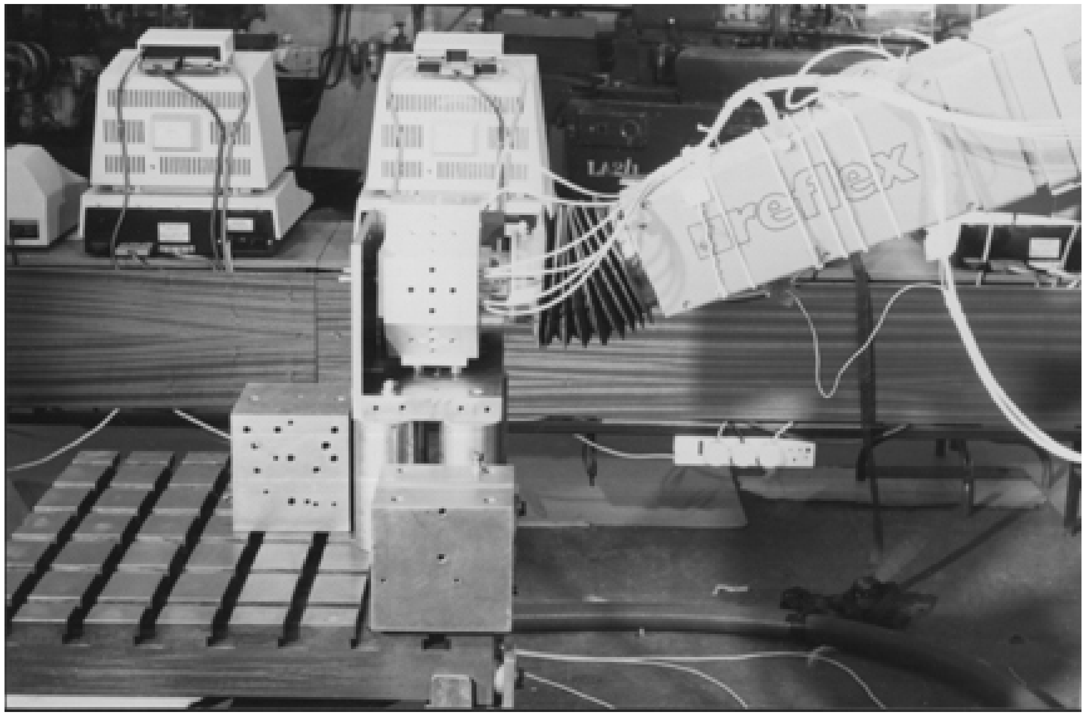

Fig. 2. Robot in Goal Position

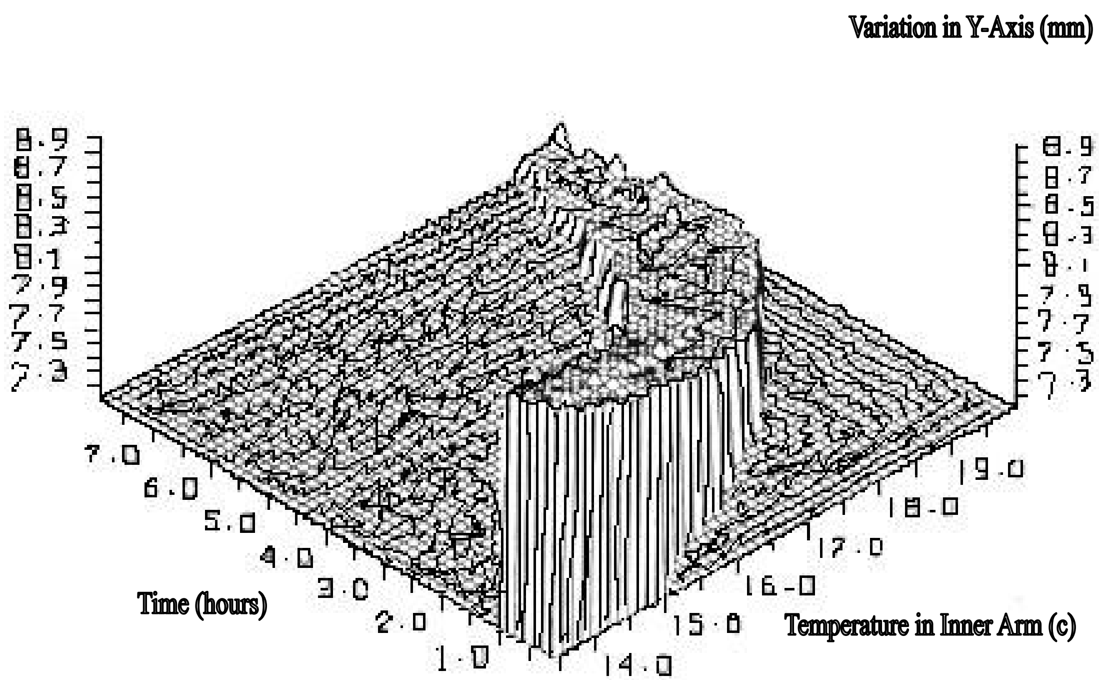

Fig. 3. Variation in Y-Axis with to Time and Inner Arm Temperature.
X, Y and Z-Axis Approach Direction Sequentially, No Temperature Control.

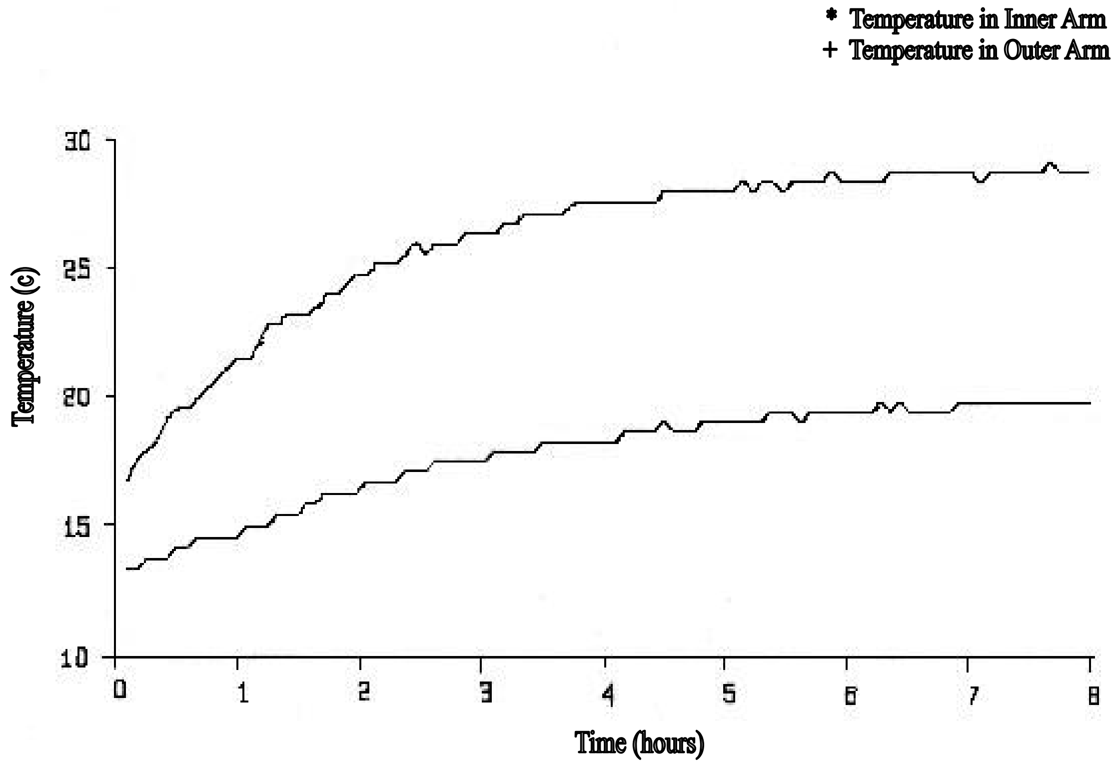

Fig. 4. Temperature Change on Robot Arms.
X, Y and Z-Axis Approach Direction Sequentially.

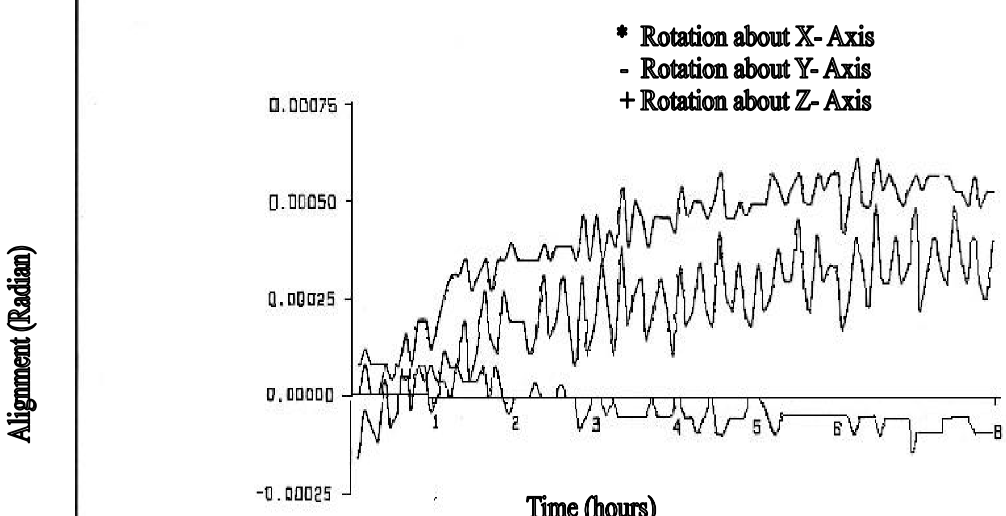

Fig. 5. Alignment Change, No Temperature Control.
X, Y and Z-Axis Approach Direction Sequentially.