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# Reliability of large sized FPD panel handling robot

**Kiyoshi Kanitani***

**R&D Department, Robot Division, Nachi-Fujikoshi corp. Toyama, Japan,
(e-mail: kanitani@nachi-fujikoshi.co.jp*

**Abstract:** For large sized glass handling robot, reliability improving activity increases the importance. The activity is divided into two phases of design phase and line usage phase. At the design phase, accurate simulation for keeping the limitation of material or gear strength and accurate torque control are the key. At the line usage phase, supporting tool for preventive maintenance activity is the key. As the maintenance work itself is a hard work for large sized robot, a preventive maintenance is useful.

## 1. INTRODUCTION

Fig. 1 shows typical Nachi's vertical articulated glass handling robot (SC400LC) which can carry up to G10 glass. Payload is 400kgf and vertical stroke reaches around 5000mm. Wrist axis torque of joint 5$^{th}$ is 1,960Nm which torque enables to carry large PDP panel (for example: 2300mm x 2000mm size and 2.8mm thickness panel with 700mm offset condition) .

Mother glass size of FPD panel becomes bigger and bigger through G6 to G8, glass handling robot also becomes bigger. Each mechanical parts consisting robot are heavy, maintenance work or replacing work itself becomes hard, once failure happens.

As production equipment, reliability is important. At the design phase, reliability is embedded into the product. At the line usage phase, supplying supporting tool for customer's preventive maintenance activity works well.

Fig. 1 External view of glass handling robot SC400LC

## 2. RELIABILITY IMPLEMENTATION

### 2.1 Key factors affecting on the reliability

Factors affecting on the reliability is listed in Fig.2. When reduction gear or motor rotates, generated heat affects lubrication. Under determined application motion, generated heat is proportional to mean torque. Therefore applied torque or stress (peak torque and mean torque) is a key factor on the reliability.

| part \ factor | | Torque | Lubrication | Heat |
|---|---|---|---|---|
| Robot arm | Casting parts Machined parts | X | | |
| | Bearings | X | X | |
| | Reduction gears | X | X | X |
| | Motors | | | X |

Fig.2 Reliability factors

### 2.2 Accurate simulation

Even though glass size becomes bigger, requested cycle time is unchanged. It means robot should move faster. In order to move robot faster, the robot mass is lighter, the casting of robot arm is thinner. Bigger acceleration/deceleration increases gear load. Thus we have to pay attention to the material strength or gear strength which is normally not required to the small sized robot at the design phase.

More accurate simulation work is necessary. The simulation work is divided into two aspect: static analysis and dynamic analysis.

There are several view points for static analysis. One is FEM analysis for the mechanism which has redundant constraint like parallel link type robot. Repeated verification between analysis model and analyzed accuracy was made. The other is fatigue life evaluation applying rain-flow-counting method. The frequency of stress amplitude in a motion cycle is evaluated.

For dynamic analysis, non-linear spring model is defined in reduction gear model. Thus hysteresis characteristics of reduction gear system is considered into simulation.

Combined with static stress analysis and dynamic motion analysis, simulation accuracy is around 30% error. During robot motion, dynamic stress applied to each mechanical elements defined by the dedicated mechanism is analysed, and it is confirmed that the stress does not exceed material strength or permissible torque of reduction gear system.

When mechanical analysis and control analysis are combined, simulation accuracy will be around 20% error.

### *2.3 Accurate motion torque control*

Motion controller keeps the permissible torque of the reduction gear system, not only radial torque but also moment torque which is the inclination torque to the rotation axis of reduction gear system. Based on motion equation, applied torque to reduction gear is calculated in real time and acceleration/deceleration is controlled in order not to exceed permissible torque of the reduction gear. Moment of inertia, Coriolis force and mutual interference torque between axes are also considered. Torque is controlled under around 5% error.

## 3. SUPPORTING PREVENTIVE MAINTENANCE

### *3.1 Life time prediction*

At the design phase, the life time of the drive system is simulated based on application work. But in an actual application work, the simulation condition might not be maintained. Operation sequence, hand/fork or work piece differs.

In order to adjust to this situation, when actual operation program is operated, mean value of applied torque is summed up. Based on bearing's life time calculation formula, life time of reduction gear system is calculated.

Calculated life time is shown on teach pendant screen as an overhaul interval. Customer can make his own adequate maintenance plan according to this information. If calculated life time is too short, alert message is shown on teach pendant screen which requests to modify the operation program.

### *3.2 Remote maintenance*

Life time prediction function described above is utilized just before actual production start. It supplies the information whether actual operation program meets the robot specification or not. On the other hand, remote maintenance function supplies useful information after production start.

Each robot is connected to the computer in maintenance office via network like Ethernet. The computer monitors the mean value of applied torque or cycle time variation from time to time. From the observed data, we can derive the sign of deterioration of the drive system. The information will be useful for preventive maintenance activity.

### *3.3 System approach*

After robot reliability approach is covered, next step is a cell system design including robot. Nachi's robot controller AX model has a function of built in Programmable Logic Controller (PLC) which can control peripheral equipment around robot. It is software PLC which means no additional hardware and hard wiring for higher reliability.

PLC program status can be monitored on teach pendant screen, both PLC program status and robot program status can be monitored via only one display terminal of teach pendant.

Also Nachi supplies monitoring unit which monitors robot trajectory in the rectangular coordinate. By any reason, once robot follows wrong trajectory and interference happens with peripheral equipment, as large sized robot causes heavy impact, both robot and peripheral equipment will be damaged. Down time will be considerable time. The monitoring unit detect wrong trajectory and generates emergency stop signal to the robot. The monitoring unit uses optical encoder signal from servo motor. (The certainty of the information is confirmed by the rotor position of the motor.)

Customer can define polygon area in X-Y plane where robot can operate. During automatic operation, when robot tries to exceed the polygon area, robot is stopped in emergency. Thus the damage will be minimized.

The abovementioned monitoring unit has been safety approved by German safety approving organization of TUEV at the Safety Integrity Level 2 (SIL2) or Category 3.

## 4. SUPPORTING MAINTENANCE WORK

At the maintenance work phase, built-in electronic manual (paperless system) is useful in clean room circumstances. In Nachi's robot controller AX, electronic manual is built in and shown on teach pendant screen.

Trouble shooting process is also included with colour digital photo images. When defect part is identified, parts replacement process is shown in teach pendant screen.

Combined with built in oscilloscope function which shows internal status like robot speed or motor current in visible analogue wave shape, these function will assist actual maintenance work greatly.

Maintenance supporting function will be the issue of availability. But in broad sense, to shorten the downtime is a factor of reliable equipment.

Implementing robot reliability at design phase, confirming that the simulated condition is kept during line usage phase and shortening the downtime at maintenance phase; reliability approach through life cycle is an effective approach to the large sized FPD panel handling robot.