JOURNAL OF ENGINEERING
annals OF
FACULTY OF ENGINEERING HUNEDOARA
Tome V (year 2007), Fascicole 3, (ISSN 1584 – 2673)

ROBOT BASED QUALITY CONTROL AND TESTING OF FERROMAGNETIC DETAILS

Krassimir GEORGIEV

INSTITUTE OF MECHANICS, DEPARTMENT OF MECHATRONIC SYSTEMS, BULGARIAN ACADEMY OF SCIENCE, SOFIA, BULGARIA

ABSTRACT:
The aim of the study is to present main components of the robotic based system for quality control. A structure of mechatronic system is suggested, used for non-destructive testing and sorting of ferric – magnetic details according to their stiffness qualities. The use of modern computers and robotized technique are mandatory for the correct control of mechanical properties of products fabricated from ferromagnetic materials.
KEYWORDS:
quality control, measurements, robot positioning, mechatronic system, testing , ferromagnetic details

1. INTRODUCTION

The development of modern industry implies the study, design and implementation of various devices and automated systems. Regarding various branches of industry, a large part of those systems are employed for non-destructive testing of the quality of various industrial parts, as well as for assessing material physico-mechanical properties and structure and machine operation. The present study describes an automated mechatronic (robotic) system for positioning, quality control and testing of ferromagnetic details.

2. SYSTEM STRUCTURE AND OPERATION

The goal of this research is to automate all operations from the measurement cycle of the mechatronic system for non-destructive quality control of machine engineering details: transport of details from the feeding and orienting device to the measurement head; insertion of the bolts into the measurement head; transport to position for sorting of ready production. The quality control and measurement is made by a measurement head with a cylindrical opening for insertion of the bolts (2). A 4R structure robot is used for designing the mechatronic system.

During the experiments of the robot was estimated that because of the low positioning accuracy (1,2mm) and repeatability it is impossible to insert the measured detail into the measurement head. This fact insisted on building in a mechatronic adaptive assembly module, (based on the author's method of local dynamic compliance), into the measurement system and putting the measurement head on top of it (3,4). Figuras1,2 present the designed robotic/mechatronic system for quality control of details – bolts .

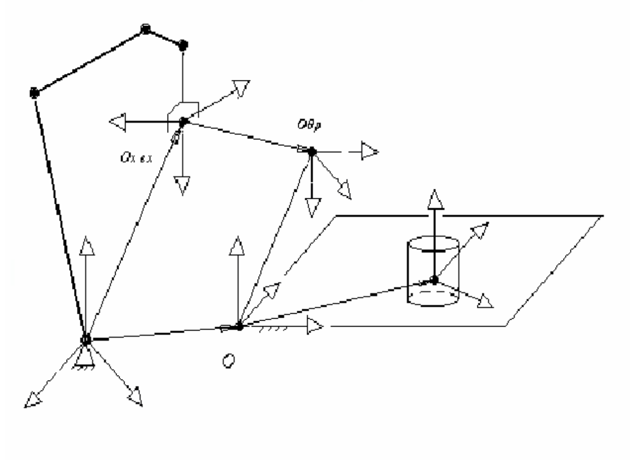

FIGURE1. Robot motion planning at the system design

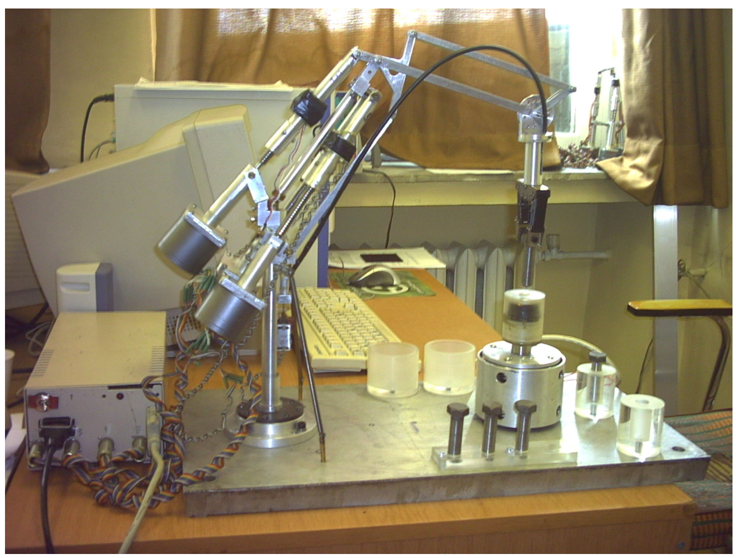

FIGURE 2. General view of the robotized (mechatronical) measuring system

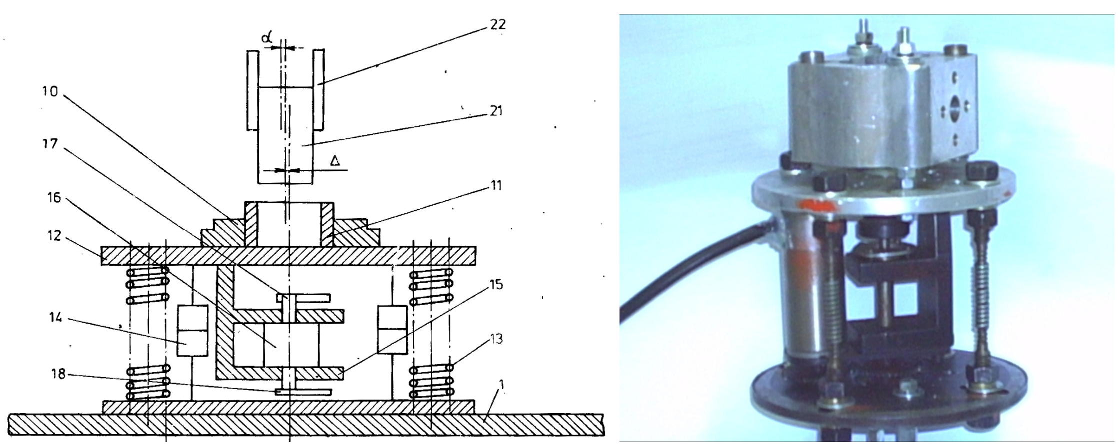

Figure 3. a) – Mechatronic adaptive module(socket) b) Real prototype

It is possible to add several adaptive assembly sockets 10 in the structure of the mechatronic system, placed on an operational table 1, in which the measurement heads 11 are attached firmly (figure 3a). In doing this it is possible to achieve independent quality control of detail on several measuring positions. The adaptive socket 10 is placed on a moving platform 12. The latter is attached via flexible components 13 to the table 1 and can be locked up using the locks 14. The measuring head 11 is attached firmly to the platform 12.

The actuator 16 and the drive shaft 17, with debalances 18 attached to it, are mounted into detail 15. The adaptive assembly socket oscillates (vibrates) together with the measuring head and compensates for the linear and angular errors during the positioning phase of the end effector of the assembly manipulator. For achieving this the drive shaft together with the debalances is actuated by the motor with angular velocity, determined by the control system and realized by the circuit for coordination and gripping force control. The platform of the adaptive assembly socket oscillates depending on the adjustment of the dynamic system with controlled amplitude and frequency (3). The measuring head oscillates too, realizing vibration motion with the corresponding seeking curves or surfaces relative to the assembled detail (bolt), compensating for the linear and angular three dimensional inaccuracies and realizing successful adaptive assembly. The dynamic compliance is understood as the ratio between the resultant displacement and the value of the harmonic disturbing force (moment) for a given geometry and structure of the adaptive assembly module (linear and angular components of the dynamic compliance respectively).

$$g_a^L = \frac{q_i}{F_i(t)}; g_a^\varphi = \frac{q_i}{H_i(t)} \tag{1}$$

q_i - joint variables , $\underline{K}$ - elasticity matrix(elasticity coefficients on coordinates of adaptive device, *M* – mass of dynamic system, *F (t)* – harmonic generating force of adaptive socket, *H (t)* – harmonic generating moment, ω - natural frequency, λ - feedback parameter of the adaptive socket, G –the weight of module, R_T – dry friction radius;

$$\begin{aligned}
X(t) &= \frac{F(t)}{4K_x - M\omega^2}\sin\omega t \mp \frac{\mu\lambda t}{4K_x} \mp \frac{\mu G}{4K_x} \\
Y(t) &= \frac{F(t)}{4K_y - M\omega^2}\cos\omega t \mp \frac{\mu\lambda t}{4K_y} \mp \frac{\mu G}{4K_y} \\
\theta(t) &= \frac{H(t)}{4K_\theta - A\omega^2}\sin\omega t \mp \frac{\mu\lambda t R_T}{4K_\theta} \mp \frac{\mu G R_T}{4K_x} \\
\psi(t) &= \frac{H(t)}{4K_\psi - B\omega^2}\cos\omega t \mp \frac{\mu\lambda t R_T}{4K_\psi} \mp \frac{\mu G R_T}{4K_\psi}
\end{aligned} \tag{2}$$

The equation system (2) describes the fine controllable micromotion of adaptive socket and enable to realize of-line planning and compensation of linear and angular errors at positioning.

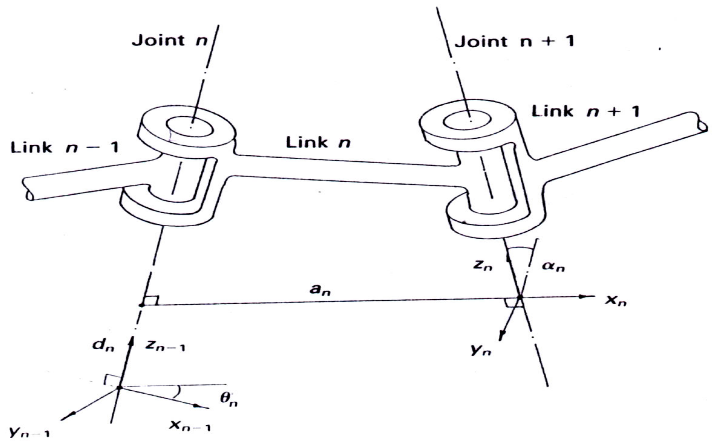

FIGURE 4. Denavit Hartenberg coordinate systems and parameters of the robotic system

Once the robot link frames have been defined (Fig.4) and the corresponding link parameter found, developing the kinematic equations is straightforward. Using the values of the link parameters the individual link transformation matrices can be computed. Then we have for the global transformation matrix:

$$A_n = \begin{bmatrix} C\theta_n C\beta_n - S\theta_n S\alpha_n S\beta_n & -S\theta_n C\alpha_n & C\theta_n S\beta_n + S\theta_n S\alpha_n C\beta_n & a_n C\theta_n \\ S\theta_n C\beta_n + C\theta_n S\alpha_n S\beta_n & C\theta_n C\alpha_n & S\theta_n S\beta_n - C\theta_n S\alpha_n C\beta_n & a_n S\theta_n \\ -C\alpha_n S\beta_n & S\alpha_n & C\alpha_n C\beta_n & d_n \\ 0 & 0 & 0 & 1 \end{bmatrix} \quad (3)$$

where the following parameters are valid: the distance d_n, length of the link a_n, joint angle deflection a_n, angle β_n, joint variable θ_n.

After that we have developed the full kinematics model for the 4R kinematical robotic structure.

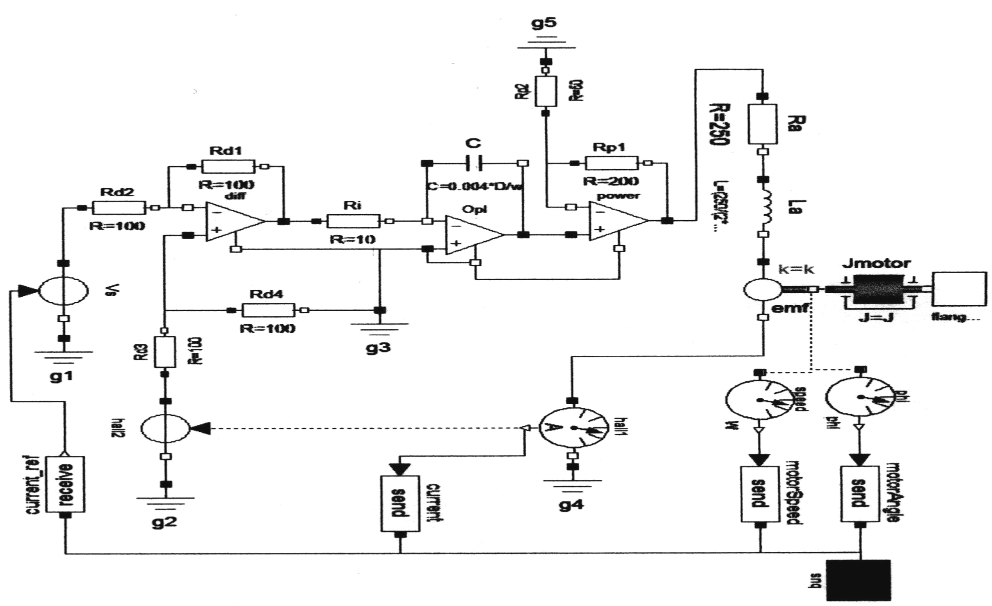

FIGURE 5. Circuit diagram of the controller

3. CONTROLLER DESIGN

The goal is to design a cheap, reliable and fast controller, which can operate as intelligent interface in a PC based research system for gathering data and other real time tasks. The controller circuit consists of current, position and speed parts and we choose the single chip microcontroller PIC16F 877A with high performance, digital, analog and special purpose IO pins. General purpose digital inputs block provides limit switches level conversation and data acquisition. (Figure 5)

4. MOTION PLANNING AND VIRTUAL SIMULATIONS

For designing appropriate program control of the assembly robot it is necessary to perform a motion planning process. To do this it is necessary to prepare a scheme of the assembly scene.

The first step of the motion planning process is to create a Denavit – Hartenberg kinematics model of the robot. Then the position and orientation of the joint coordinate systems is determined. All of the motions of the end effector of the robot are done using straight-line trajectories while maintaining vertical orientation along axis Z of the global coordinate system.

The inverse kinematics is solved, using Robotics toolbox software for Matlab 6.0, given the initial global coordinates of the end effector for every step of the motion plan. This is done by accounting the matrix of joint degrees of freedom for achieving synonymy of the obtained solutions.

A 3D solid body virtual model is designed for investigating the operation of the second module of the mechatronic system – adaptive assembly socket. All components of the module are correctly reproduced with the corresponding metrics, mass and inertial parameters. The assembled model is built in Solid Works software environment. The model is exported and animated in Cosmos Motion software environment (3,4). A number of simulations are made to investigate the dynamic response of the adaptive socket to various input drive torques. The oscillation amplitudes are measured virtually. The results of the simulations are presented on figure 6.

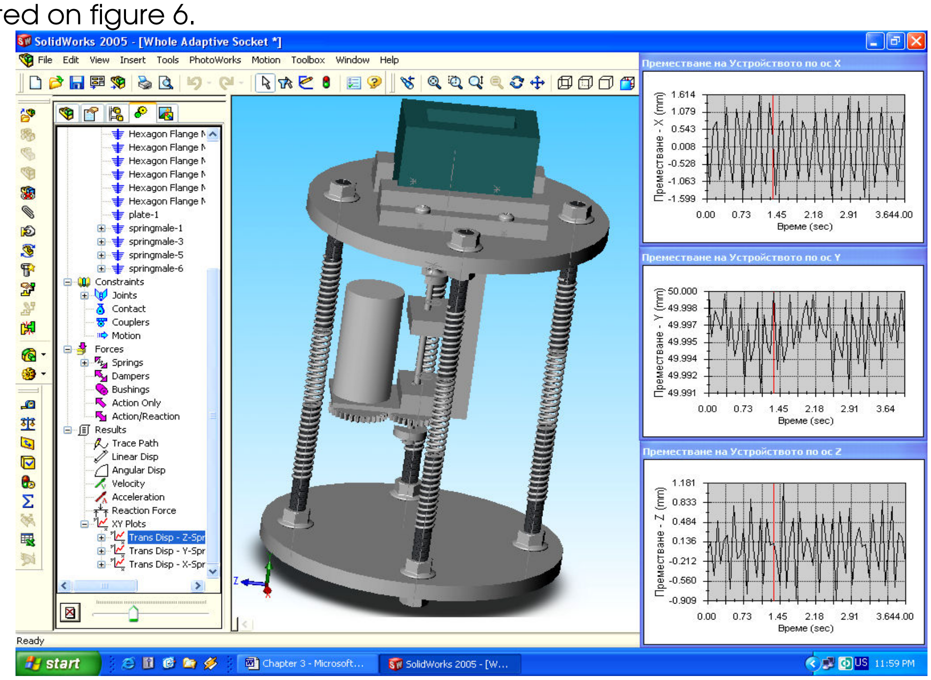

Figure 6. Dynamic model and simulation of the operation of adaptive socket

5. MEASUREMENTS & TESTING (Robot based quality control)

- Objects of testing are supporting elements – anchor bolts fabricated from structural steel 40X with dimensions 12x50x22;
- Measuring equipment is MULTITEST–MC04 apparatus with a set of magnetic-noise transducers;
- There are comparative specimens involved in the study, 6 pieces per each group, which have undergone different thermal treatment – hardness of Rockwell -HRC;
- The mean HRC hardness is also determinate by performing three independent hardness measurements;
- having specified the classification criterion and the characteristic interval for the groups of standard specimens one should start with measurements over real parts;
- the controllable part should be automatically inserted into the aperture of the magnetic – noise transducer by means of a robot-arm and the non-destructive parameter is found on the basis of three independent measurement over each controllable part. Then apparatus should transfer an input signal to the robot specifying where the controllable part should be sorted.
- Controllable parts should be classified with a specific degree of probability into groups of parts with identical mechanical properties-hardness. After that the robotic (mechatronic) system should be prepared for the next measurements.
- The software is written in a MATLAB environment using author's data aggregation principle the subsequent incorporated graphic editor. A possibility for online data acquisition is foreseen in the future, using the computer serial port. The output data can be saved in a file in the form of tables.

6. CONCLUSIONS

- A successful robotic measuring system was realized of the quality controlled details with the measuring head, during the experiments, in spite the presence of positional and orientation errors of the bolts grasped in the end effector gripper.
- These results confirm the efficiency of adaptive sockets when they are installed in mechatronic systems together with manipulators with lowered accuracy parameters. The use of modern robotic systems and PC equipment are mandatory for the efficient control of the mechanical properties of ferromagnetic materials and details (parts)
- This robot based quality control systems have reached a level of complexity that can only be mastered by an integrated system design strategy, using the combined knowledge from mechanics, electronics and software development.

REFERENCES / BIBLIOGRAPHY

(1) ANGELES J., Fundamentals of robotic mechanical systems: Theory, methods and algorithms, 2002, Springer, 520 p.,

(2) VELEV G., LATKOVSKI V., ILIEVA L., Non destructive analysis of ferromagnetic materials by means of Berkhausen effect methods, proc. of 10th International Scientific Conference "Academick Dubnica 2004", Dubnica nad Vahom, p.635-638., 2004 .

(3) GEORGIEV K., KAMENOV V. "Mechatronic modules for precise assembly of non-rotational details", Научна конференция "Роботика и Мехатроника'2004" 06-08.10.2004г., Дряновски Манастир, p.2.42-47.

(4) GEORGIEV K., Robotic adaptive assembly systems, D.Sc.Thesis, Sofia, BAS, 2004, 278p.