MECHATRONIC APPROACH FOR QUALITY CONTROL IN MANUFACTURING

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ABSTRACT

Subject of this paper is to analyze the tendencies in approaches and means for quality control in manufacturing. The accent is pointed out to the key elements and crucial problems of mechatronic devices for quality control as part of mechatronic systems and quality control. The main goal and requirements to the devices for quality control in industrial manufacturing are defined and systematized. Mechatronic approach for conceptual design of several quality control devices for unconventional quality control tasks in manufacturing is developed and proposed in this paper. Multidisciplinary fields are investigated as physical systems modeling, sensors and actuators, signals and systems, computers and logic systems, software and data acquisition, user interface and operator control.

KEYWORDS Mechatronic systems, Quality Control

1. INTRODUCTION

One of the most important issues that businesses have focused on in the last 20-30 years has been quality. As markets have become much more competitive - quality has become widely regarded as a key ingredient for success in business.
Quality is first and foremost about meeting the needs and expectations of customers.
Producing products of the required quality does not happen by accident. There has to be a production process which is properly controlled. Ensuring satisfactory quality is a vital part of the production process.
Quality is concerned with controlling activities with the aim of ensuring that products are fit for their requirements and meets the specifications.

1.1 Quality control

Quality control is a way that businesses have used to manage quality. It is concerned with checking and inspecting products and work that has been done.
Under quality control, inspection of products (checking to make sure that what's being produced is meeting the required standard) takes place during and at the end of the operations process.
The assurance of the quality represents an important task in all areas of production.

There are three main points during the production process when inspection is performed:

- When raw materials are received prior to entering production
- Whilst products are going through the production process
- When products are finished - inspection or testing takes place before products are dispatched to customers

There are several problems with inspection under traditional quality control:

- The inspection process is NOT applied to the every work piece. If there were guarantees that no defective work pieces are produced output would be produced, then there would be no defective output at the end of manufacturing process in the first place!
- Inspection is costly, in terms of both tangible and intangible costs. For example, special laboratories, time, employee morale.
- It is sometimes done too late in the production process. This often results in defective or non-acceptable goods actually being received.
- It is usually done by the separate "quality control inspection team"

rather than by mechatronic quality control systems.
- Inspection is often not compatible with more modern production techniques (e.g. "Just in Time Manufacturing") which do not allow time for much (if any) inspection.
- Working capital is tied up in stocks which cannot be sold
- There is often disagreement as to what constitutes a "quality product". For example, to meet quotas, inspectors may approve goods that don't meet 100% conformance, giving the message to workers that it doesn't matter if their work is a bit sloppy. Or one quality control inspector may follow different procedures from another, or use different measurements.

As a result of the above problems, many businesses have focused their efforts on improving quality by implementing unconventional quality control techniques, which emphasize the role of mechatronic systems for quality assurance. Real-time inspection with the aim of finding the defect product with related in-time bad manufacturing process will have big advantage on to affectivity, and cost of the all production flow. Quality comes not from inspection just part of the produced work pieces and using statistical methods at the output of manufacturing flow but from quality control on every work piece which reflects to the improvement of the production process.

1. 2. Mechatronics approach for quality control

Many concepts as well as technologies are used in that field and always improved.
New needs of the quality assurance are raised and have to be better answered; using advantages which are offer by increase of the computing and storage capacity, the development of intelligent algorithms, like Fuzzy, neuro Fuzzy, Neural nets as well as Wavelets.
During measurements for quality control are always introduced sensors which are of high importance.
These developed, lately integrated solutions to be offered, with hardware, software as well as the signal processing, ever more than complete solutions, which perfectly meets requirements of quality control tasks.
A further developments in last years consists of quality of (micro) positioning for the sensors, the position corresponds to the better process control.

1. 3 Mechatronic systems

Mechatronic systems are natural step of evolution process in modern engineer design.
In wide technical areas the integration of products or processes and electronics are observed. This is especially true for mechanical and micromechanical systems. These systems changed from electro-mechanical systems with discrete electrical and mechanical parts to integrated electronic-mechanical systems with sensors, actuators and digital microelectronics. These interdisciplinary systems are called Mechatronic systems.
Evolvement of computers and further to microcomputers, embedded computers and connected with them information technologies and advances in software, takes mechatronic on the front line of design of unconventional systems. The tradition in mechatronic design approach includes complex integration of different scientific and engineering fields, generally defined as mechanics, electronics and information technology.
Due to the multi-functional use and high precision of mechatronic system for dimensional quality control it is necessary to improve their intelligence and capability to accept and to process a large amount of information.

2. OVERVIEW QUALITY CONTROL TASKS

Here we investigate the cases of quality control tasks, which are characterized with motion in principle of sensing or with motion requirements to the object to be controlled or to the sensor, as follows:

2.1 Sensing principle:

- vibration or acoustic principle used for sensing of the process or detail to be under control;
- detection of the sensitivity part motion;

2. 2 Actuator performing the motion requirements:

- fine positioning of the sensor to the object to be controlled;
- fine feeding operation of the sensor or the object to be controlled;
- amplitude/frequency controlled impact and excitation;

2. 3 Requirements to the sensors and actuators

Common performance requirements to the sensors and actuators to be integrated in the Mechatronic System for autonomous Quality Control are:

- reliable and fast algorithms for real time sensing and actuating;
- fast algorithms for DSP;
- control of dynamic interaction;
- high dynamic range of sensing;
- controlled range of dynamic impact and excitation;
- free error fast communication;
- motion control and positioning;
- work in an environment with high level of uncertainty and in unpredictable circumstances;

The common requirement to the sensor and actuator is to be intelligent and autonomous. Definition for the intelligence implies the ability to operate and control in a reliable and robust manner under high level of uncertainly and in unpredictable circumstances without human assistance. Intelligent Sensor is sensing unit having a data processing function, automatic calibration/compensation function, in which the unit itself detects and eliminates abnormal or exceptional values. It incorporates algorithm capable of being altered and has a certain degree of memory function by (NASA Definition).

Some of the Intelligent Sensor's desirable characteristics are:

- neutral communication interface for integration;
- adaptation of changes in environmental conditions;
- discrimination function;

Intelligent Actuator has to be complete actuation unit that integrates into the unit the servo actuator, the software and hardware for control and sensing and communication.

Its capabilities are as follows:

- neutral communication interface;
- on-board digital subsystems with memory for control;
- performance supervision;
- fault detection and logging of measured states during the operation;

3. CASE STUDY

Let's consider shortly some partial case of quality control tasks, which put special problems and requirements to be decided:

3.1 Quality control of accumulator electrolytes

It becomes one of most important problems, those the function of a battery or battery systems marks is the quality of the electrolyte as well as their behavior during the loading and/or unloading phase. Sensors for experimental plants are applied, the exactly as to be examined possible this behavior. An indirect characteristic and estimation parameter in this direction are represented by the gas out-blown during the function. Their measurement precisely defines the quality of the electrolytes under developing. This control process is undertaken in a highly aggressive environment, where is necessary to keep the experiment precision and objectivity. In this way the control process of new electrolytes and accumulators needs easy to use and reliable tool for measurement of the gas quantities produced during the charge/discharge process. Especially this is a problem in the cases of a large number of accumulator's cells to be controlled, and the information to be analyzed. Hence, the development of an intelligent gas micro-flow meter system for quality control of accumulator electrolytes on the principle of bubbles registration is an approach to overcome the problems of multiple channel registration and control, working in high aggressive environment high sensitivity effectiveness and objectivity of the control process.

3. 2 Deposition process quality;

The transfer of insoluble mono-layers spread on an aqueous phase at the surface of solid

substrate by dipping technique of Langmuir-Blodgett is performed by means of Langmuir troughs. A great number of experimental conditions affect the transfer ratio. The influence of some of them, i.e. surface pressure of the monolayer, time calibration of the surface pressure sensor used and the temperature, defines the deposition process quality. Instruments which measure the differences in the interfacial tension between two air-water interfaces are widely used to study the physical behavior of insoluble molecules in monomolecular layers. The most commonly measured property of an insoluble monolayer is its surface pressure. In this way to control its quality the surface pressure sensor has to measure the surface pressure and to form a feedback signal to the control system in order to maintain a constant surface pressure during the film deposition process, avoiding the disadvantages of the Wilhelmy method and necessity of corrections and additional adjustments. In this way the quality of the deposition process is defined by the obtained conditions. The problems here are high sensitivity and dynamic range of measurement, development of self corrections and self adjusting procedures.

3. 3 Quality control of deposited layers

For many cases for quality control of deposited layers is necessary to measure the surface layer energy. First is necessary to define the interface between the surface layer and the substrate. There are different interfaces liquid-gas, liquid-liquid, solid-gas, solid-liquid and solid-solid.

For investigation the sensing process a prototype of the dV-sensor for the surface energy measurement for the interface liquid-gas now is developed. It measures the dipole moment of the molecules. This is so called delta V potential. The sensing principle in this case is based on vibration electrode. It can be considered as a piezo actuator to be controlled by the sensor and vice versa. To be more precise measurement of the surface energy of the substances (not liquid) is necessary environment with suppressed convection and controlled temperature (e.g. in volume up to 30 litters in the temperature range of 22-32 Celsius degree) which arises the task complexity for quality control of layers.

3. 4 Dimensional quality control of manufactured parts

Large amounts of dimensional information must be collected quickly in order to provide the dimensional quality control of manufactured parts. High speed data gathering necessary to define work piece which requires a co-ordinate measuring machine (CMM) capable of scanning. Until recently those machines and the software to run them, were expensive and not readily available. They also required extensive programming expertise to achieve the best results from the inspection routine. CMM and software manufacturers have refined and simplified scanning technology so that today the cost of scanning machines has dropped to the point where small to medium sized shops can take advantage of this technology. However, the dimensional quality control requires more simple and effective means to qualify the dimensional parameters of the all manufactured parts and select them eventually. We design r a mechatronic system performing dimensional quality control on cylinder parts using single point and continuous techniques. It has to deal with gathering of large amounts of data, quickly processing for quality control and for accurate selection. The relative measuring instrument of cylinder shape for its dimensional quality control could be used installing a sensor, which can measure a distance to the cylinder surface. This means that the work piece has to rotational and translational movements to the sensor. The distance to the cylinder surface is measured continuously while the cylinder is rotating trough its axis and the sensor is moved translational along the cylinder axis. The continuous scanning of the cylinder surface can be used to reduce the noise and to improve the measurement accuracy due to self organized procedure for calibration and verification. Since some shafts as in the worst case are not with fixed centers the cylinder axis is not determined by fixing on the translational module. Hence, it is determined analytically and virtually presented in the control algorithm. The cylinder shape dimensional control mode

could be chosen by an operator as spiral or multiple slices scanning.

3. 5 Control and detection of failures in structures

A mechatronic system for quality control of laminate and composite structures is developed to detect the possible failures into them. It is consisted of an electromagnetic actuator as exciter to generate low frequency elastic waves, accelerometer and acoustic sensor, one micro-computer and system software. The acoustic sensor captures the generated by the electromagnetic actuator waves along the structure studied. The obtained information for different basic model laminate and composite structures with defined failures are analyzed in order to determine the optimal excitation and rules for failure detection and algorithms for fast control of structures with high reliability subject to permanent exciting.

Hence, the special requirements could be summarized:

- special working environment and control of its conditions;
- collecting information from large number of channels;
- disturbances free sensing of large number of channels;
- self calibration procedures
- control of high frequency vibration electrode by piezo actuator
- frequency/ magnitude control of the impact/excitation;
- reducing the noise of measurement;
- development of approaches for reliable collecting of information;
- obtaining information, which could not be measured directly;

Here some quality control task are studied, but they show enough the complexity of the quality control tasks autonomous to be performed by mechatronic systems, uncertainty of the environment, disturbances, means for acquisition and signal processing. Hence, it is necessary to develop intelligent mechatronic system performing such complex and difficult problem as quality control. The subject of the project will be intelligent sensor and actuator subsystems and their communication and interaction with the mechatronic system for quality control they involved into.

4. CONCLUSION - INTEGRATED DESIGN APPROACH

A design process generally is consisted of iterative procedures between reference task function analysis, conceptual design and embodiment design. Reference task function is considered as an area in the manifold of the possible functions, which describes the state of the mechatronic system to be designed including the motions, qualitative parameters, constraints (e.g. force, space, design etc.). At this stage the reference task function is considered as integral function of the mechatronic system which has to be developed and designed. There exist a lot of variants the reference task function to be fulfilled by the subsystems: (1) mechanics, (2) actuators, (3) sensors, and (4) controls.

Conceptual framework for integrated design of mechatronic system (MS) based on optimal trade-off relations between task function realization, features of the sensor and actuator subsystems, the information has to be dealt with, degree of uncertainty, bounds of disturbances, performance accuracy and control force limits.

The integrated design approach for the development of new sensors and actuators as intelligent autonomous systems for mechatronic systems performing quality control tasks is very promising as regards MS with complex structure topology.

Fundamental methods and means will be developed for optimization and experimental investigation of the mechatronic systems for quality control dynamic interacting with their environment during the rapidly changing conditions, references and big capacity sensor information.

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