Intelligent Modular Design of Automatic Dimensional Inspection Systems

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Abstract: The new production has to undertake a continuous quality improvement due to its major economic involvement; the consequence consists in high performances in the quality assurance. Therefore the author of this work wants to present some concerns in the automatic dimensional inspection systems field. The new production has to undertake a continuous quality improvement due to its major economic involvement; the consequence consists in high performances in the quality assurance. Therefore the author of this work wants to present some concerns in the automatic control system field.
This paper presents aspects of the design for an intelligent modular inspection system. The performed researches aimed at an original method of grouping the parts based on the relation between dimensional inspection process characteristics and modular design of all inspection equipments with a high universality and flexibility degree.

Keywords: Inspection, mechatronics, modular design, automation, dimension.

1. Introduction

Automation plays an increasingly important role in the global economy and in daily experience. Engineers strive to combine automated devices with mathematical and organizational tools to create complex systems for a rapidly expanding range of applications and human activities [1].

Mechatronics comprises today almost any field of instrumentation, from optical and medical technology through to domestic appliances, metrology, automatic control engineering, office automation and systems engineering.

An Automated mechatronic system is capable of handling materials and energy, communicating with its environment and is characterised by self-regulation, which enables it to respond to predictable changes in its environment in a pre-programmed fashion.

Starting at design and continuing through manufacture, mechatronic designs optimize the available mix of technologies to produce quality precision products and systems in a timely manner with features the customer wants.

The real benefits to industry of a mechatronic approach to design are shorter development cycles, lower costs, and increased quality, reliability, and performance.

Traditional automated systems are rigid and are not capable of responding rapidly to changes in demand and supply. An *Intelligent* mechatronic system is capable of achieving given goals under conditions of uncertainty. In contrast to automated systems, which are, by definition, pre-programmed to deliver given behaviour and are therefore predictable, intelligent systems may arrive at specified goals in an unpredictable manner. They are endowed with flexibility, which means they are capable of responding to frequent changes in their environments without being re-programmed. This qualitative difference in their behaviour is a result of the separation of the domain knowledge from the mechanism for problem solving Intelligence can be designed into a system using traditional

AI methods such as expert systems, fuzzy logic or neural networks, but the most cost-effective and powerful implementation is through the use of distributed artificial intelligence, where a community of intelligent agents decides on the optimal or near-optimal action through a process of negotiation. [4].

The recent manufacturing trends aim at delivering wide variety of products with short lifetime and increasing complexity. The goal that the modern production system must achieve is the production with expected quality and characteristics, as well as small expenses. That tendency is visible on production systems that modified their own internal structure as well as their activities as a series of procedures aimed at defining new production systems with high performances. This task requires high flexibility and modularization in production planning and manufacturing.

The literature on modular design suggests that the modular design approach is deemed to be applicable across different sectors. Little attention has been paid to the different product characteristics and the way they can shape its implementation.

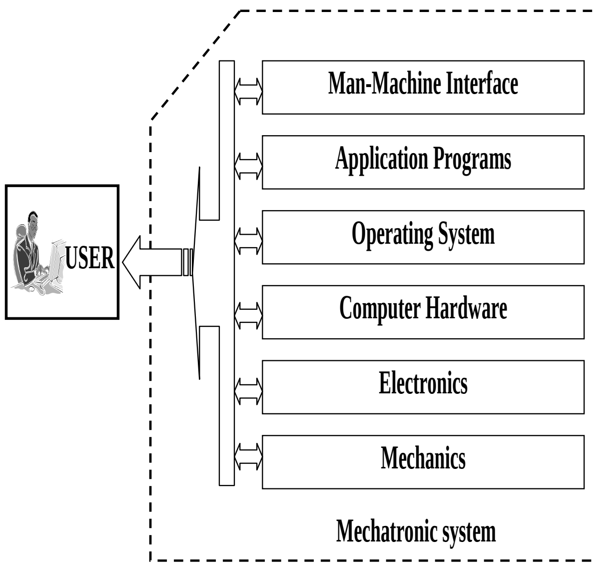


Fig. 1. Components of a mechatronic system.

A typical type of problem in Mechatronics combines precision mechanics, optics, electro-mechanics, electronics, data processing and applied computer science and requires a very high standard of precision, reliability and miniaturization.

Generally speaking, a mechatronic system consists of several layers (fig. 1), where each layer is able to perform correctly only when the underlying one is behaving correctly, too.

The number of interfaces between layers leads to an explosion of the overall complexity of the system, thus rendering the development error prone, and the testing extremely difficult.

As an integrated field, the automatic inspection devices include the classic mechanic engineering, electronics and computer field in designing, control and evaluation for these systems.

The quality assurance achieved in our country special results in the field of devices used in the automatic dimensional control of the parts. The currently used automatic drive systems are manufactured for concrete service and are equipped with elementary components. The flexible and modular dimensional control systems are based on highly automated control systems managed and aided by computers, consisting of modular devices for feeding, transport, measuring and classification for a wide range of products (fig.2).

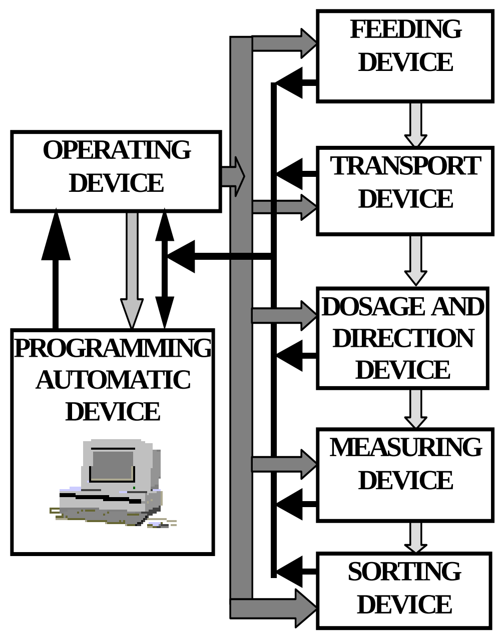


Fig. 2 The block chart of automatic dimensional inspection system.

2. The modular concept

Modular systems are more difficult to design than integral one as designers need a deep understanding of the ‘inner workings’ of the product, in order to partition and decouple design tasks. From a technical viewpoint, a modular architecture implies a clear division, or more precisely decoupling, between ‘visible and hidden design parameters.

Modular design allows for 'loose coupling' components interactions at the design level which is different from 'tight or loose' in an actual product.

By modulating the component subassemblies and using microelectronic systems with the worldwide highest performances for control and drive and based on a detailed analysis of the automatic control systems, we consider as necessary the improvement of the modular control devices for all kinds of parts.

This goal is possible by applying adequate methodology of planning that can enlarge the quality of project solutions, shorten planning time and costs, generate different variants of flexible solutions. Because of the dynamics and complexity of the specified tasks, the successful quality is possible only by applying the computers and adequate software and database.

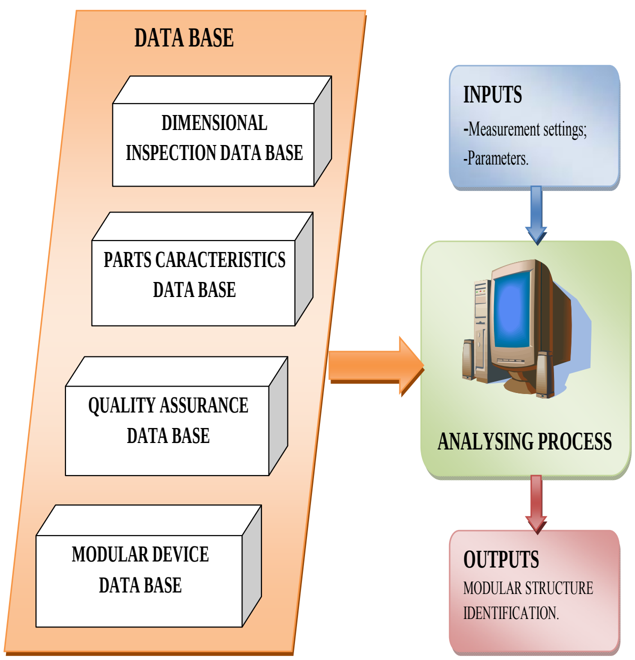


Fig. 3. The block chart of information system

The design of improved inspection systems for the control automatic device has taken into account the following issues: the configuration of an automatic device with a certain number of mechanic modules - for supplying, distribution, sorting, etc, depending on the user's needs; it makes possible the checking of a larger product range from the same class or similar ones; it makes possible the checking according to one single parameter or a multi-parameter one, with many sorting possibilities of the codes, such as, the classification and the sorting in N dimensional classes according to the control criteria.

The performed researches aimed at an original method of grouping the parts based on the relation between dimensional control process characteristics and modular design of all control equipments with a high universality and flexibility degree.

In designing the process, we emphasize that the modular control station could be organized as follows:

- All modularly and flexibly organized devices;
- Modular device designed in the most propitious way for each families of parts;
- Measuring and automation checked by an electric computer controlled device;
- High accuracy of operating;
- Interchangeable modulus;
- Different measuring and control transducers and sensors to be used;
- High productivity and efficiency.

All modular devices are defined in order to execute the control operations in correlation with all parts in group.

By correlating the influential factors of parts assortment and measuring and control equipments, suitable for computer implementing, the results necessary for a modular designing are obtained.

Based on these analyses, the authors build the information system (fig. 3) dedicated to design the modular and flexible dimensional control systems.

This system is based on client – server concept. By means of the user's interface, the client (user) gives inputs of de information system.

The user has the possibility to input data concerning his/her own application (part, measuring and process characteristics). After that, the main menu of the system works with data bases of parts, measuring and automation process, modular device projects and gives the process results for the most propitious dimensional control structure.

3. Experimental aspects

The interactive work between user and server assures the possibility for varied analysis and changes of the inputs. By analyzing the different conditions and by adequately assessing and selecting correlation factors inside the goal, the computer chooses the best solution of modular automation. This new method was tested in the bearing and assembling component production.

The main purpose of this research is to generate optimised feeding, transport, and proportioning and alignment systems for more mechanical efficiency. Because of that, the whole mechanical and electronic structure of the analysed automata is based on a modular concept. Each important component of the automata control system has a modular structure, which ensures a very large working flexibility.

Through the modulating of the component subassemblies and the using of microelectronic systems with the world wide highest performances for control and drive and based on a detailed analysis of the automate control systems, we consider as necessary the improvement of the control devices for the thrust bearings.

The inspection automatic device makes possible the measuring head positioning, depending on the measuring variant, using an electric computer controlled device, which is built up of a step by step motor and a rack. The computer processes all the information, testing the analysed system and setting the working parameters to obtain an optimised mechanical system (fig. 3).

The characteristics of signals are described as objects, their control and interconnection as rules and goal specifies the actual purpose of dimensional inspection.

The command program has been structured in 4 phases: initialisation phase, parameter input/ calibration phase, run phase and stand-by phase. The initialisation phase has the following effects: all mobile elements move to their initial position; all initial positions are verified through the configuration of the signals from corresponding binary sensors; presence of controlled parts in feeders and on the conveyor is verified.

Parameter Input/calibration phase consists of displaying of suitable messages, telling the operator the type and sequence of necessary parameters and input of these parameters, input of the number of classes, the parts are classified in; measure of the standard part with tolerance zero; measure of the standard parts for - and + limits, or input of the deviation values for these parts, expressed in µm and input of number of cycles. Run phase consists of repeated cycles of feeding, measuring and sorting.

In the stand-by phase the energy consumption is minimised and the command system waits for pressing a suitable key to activate again. Due to the complexity of the program, the main frame of the program has been elaborated in C+ and only the most important routines have been in the Assembly language, including routines for solving the input and output of signals of different types interrupts, serial communication; different routines for controlling the input of data from the keyboard and different routines for controlling the display of data.

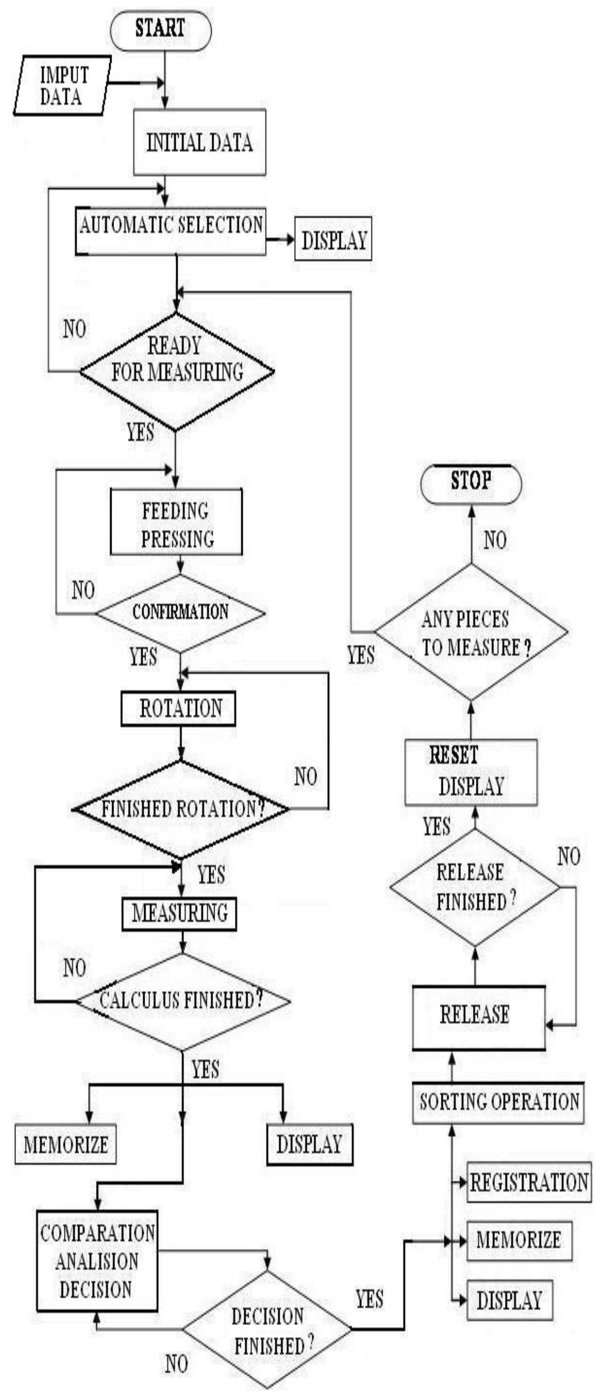
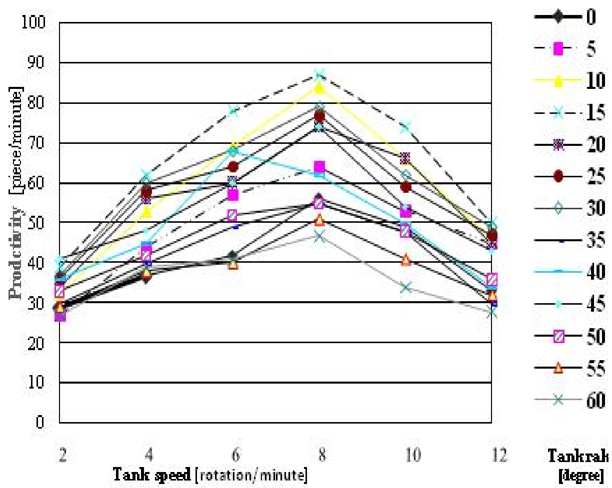


Fig. 4. Logical diagram of inspection process.

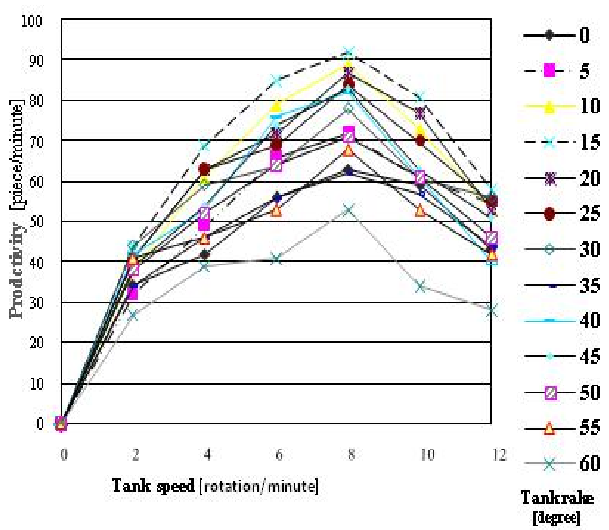
The testing plant reproduces the mechanical structure of some topes of feeding and transport systems in varied operating characteristics (hooked disks, carved disks and catch pin disks).

The computer traces the whole process of deposition, catching, handling, transport and exhaust of the parts from the tank, analysing the necessary information and signals from the sensors and generates the decisions on the optimised conditions of the feeding system.

The handling, catching and transporting elements must turn round with a rotation speed with a variation range between 1 and 18 rotations per minute.



a)



b)

Fig.5. Feeding testing chart.

The tank rake must vary between 0 and 90 degrees, namely from horizontal position to vertical position. The primary data that will be processed by the computer are: the speed of the manipulation elements, the tank rake, the time, the working productivity and the part characteristics (shape, dimensions, appearance and material, inspection characteristics). The general structure of the testing plant routine is presented in figure 4.

The primary data that will be processed by the computer are the speed of the manipulation elements, the tank rake, the time, the working productivity and the part's characteristics (shape, dimensions, appearance and material). The computer processes the information about the experiment and presents the optimal parameters of the inspection systems analysed.

Figure 5, a presents an example of a chart generated inside the experimental process for the tapered rollers. The chart underlines the tank rake and the speed values for which the analysed system has a maximal range for productivity.

Figure 5, b presents an example of a chart generated inside the experimental process for the spherical parts. It also presents the correlation among the static, dynamic behaviour and the specific functional characteristics.

Analysing this chart, the author can remark the tank rakes and the speeds that assure a high productivity for each of part types. The main purpose of this research is to generate optimised feeding, transport, proportioning, measuring and alignment systems for more mechanical efficiency. The computer processes all the information, testes the analysed system and sets the working parameters to obtain an optimised mechanical system.

The vibrating dosing system uses an electromagnet to produce the vibrations on the conveying vibration chute. Depending on the value of the vibration parameters (amplitude and frequency) the bulk solids will flow accordingly. An important advantage of this dosing method is that material is fed in the weight cell 1 uniformly and with smaller impact on the weight scale.

The principle of this dosing system is that the flow speed of the material is given by the vibration and the angle of the chute. These two parameters are set by microcontroller depending on material dosed.

The regime process that I propose includes 2 steps: one to dosing 80% of material and another for the rest of 20 % of process.

The first step that represent 80% of dosing process is made with DC vibrator motor at 100% maximum voltage. In this time the angle of the chute is modified according to the dosed material from a big angle to a normal angle.

At the second step that represents the end of dosing process the angle of the chute remains constantly at a normal position. In this time the voltage of vibrating DC motor is changed depending on dosing material that is dosed. In figure 1 is represented the running scheme of this automatic dosing system.

For the automatic monitoring of the dosing process in the case of a volumetric dosing system with vibrator slot, it was built an automatic dosing system using the system presented in figure 6.

For automatic system an 8 bit microcontroller with RISC architecture is used.

The reasons for this chooses are: It has 4 input/ output ports. On these ports can be connected a keyboard and a led's display

The maximum speed is 16 MHz and can execute 1 instruction per clock cycle.

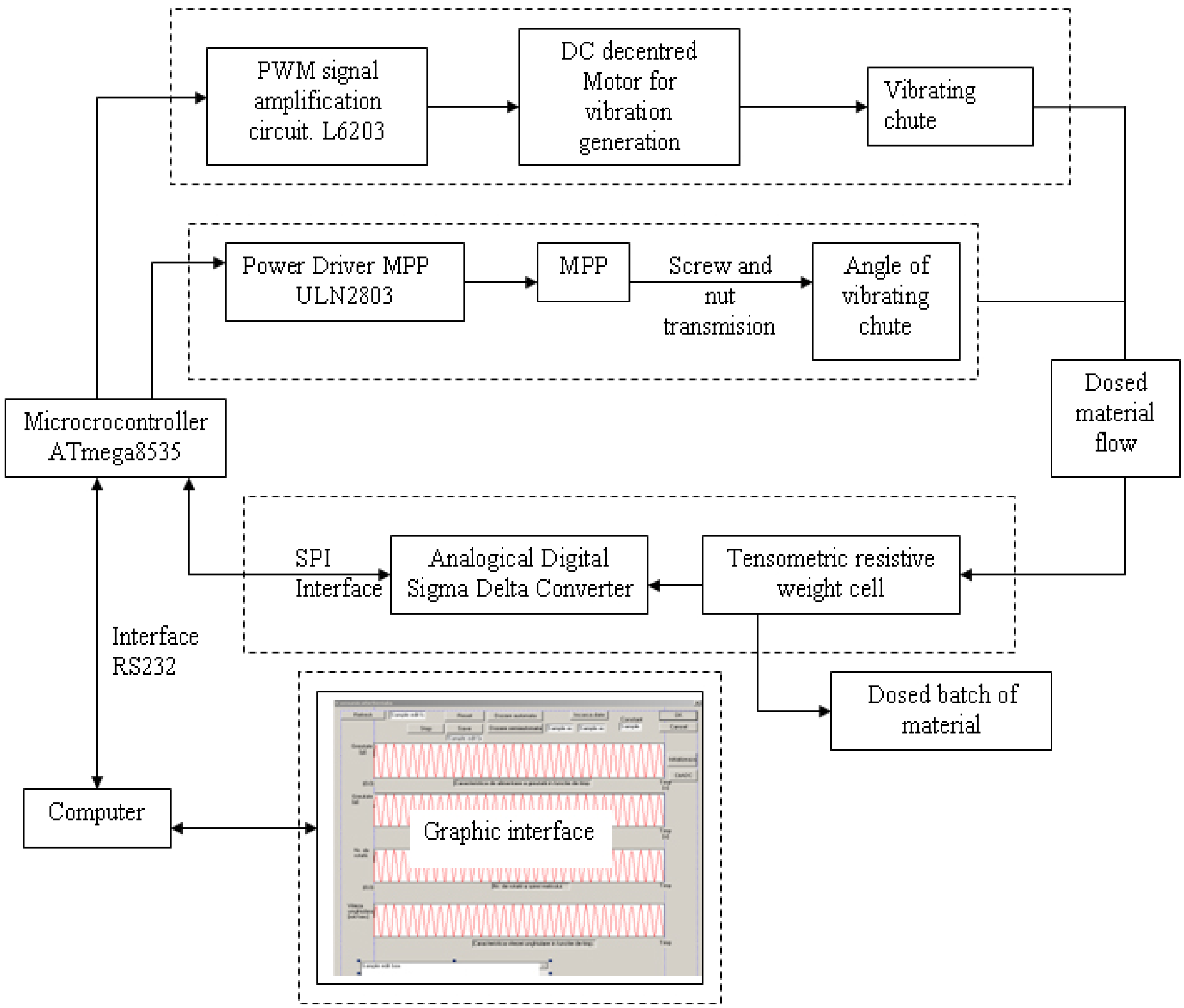


Fig. 6. Schematic representation of the automatic control of the vibrating dosing system.

It has an internal ADC multiplexed on 8 channels.

This ADC makes this system to be very flexible (easily upgradeable), because the special IC AD7730 can be replaced easily with a potentiometer.

In future, the system can process information from other sensors like piezoelectric sensors to measure the vibration, humidity.

For the data processing of the control unit it was used a microcontroller produced by Atmel Atmega 8535

The Atmega 8535 flexible serial interface allows an easy interface to most microcomputers and microprocessors.

The serial interface on the AD7730 has the capability of operating from just three wires and it is compatible with SPI interface protocols. The three-wire operation makes the part ideal for isolated systems where minimizing the number of interface lines minimizes the number of opto-isolators required in the system. Register lengths of the AD7730 vary from 8 to 16 to 24 bits. The 8-bit serial ports of most microcontrollers can handle communication with any of these registers, two or three 8-bit transfers.

The microcontroller communicates with the AD7730BN integrate through a Serial Peripheral Interface (SPI) that uses the following three connections from the microcontroller: data receiving connection (MISO), data transmission connection (MOSI) and one connection for the synchronization of the data (SCK).

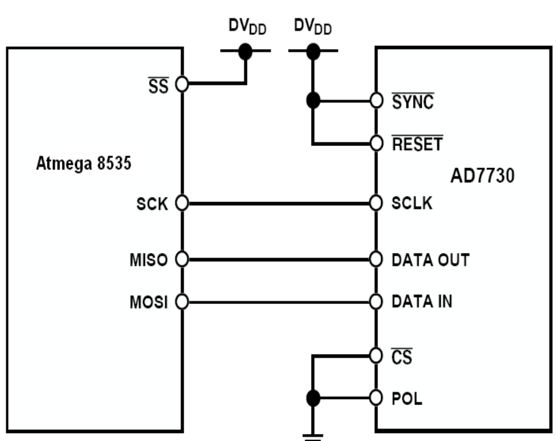


Fig.7.Serial peripheral interface between the microcontroller Atmega 8535 and weight conversion integrated circuit AD7730.

The microcontroller receives trough the SPI (Serial Peripheral Interface) interface the results of the analogue-digital conversion (ADC) and the integrated circuit that realizes the conversion (AD7730) is made by Analogue Devices and is responsible with the processing of the information collected from the weight resistive transducer.

Figure 7 shows an interface between the AD7730 and the ATmega8535 microcontroller. The diagram shows the minimum (three-wire) interface with CS on the AD7730 hardwired low. In this scheme, the RDY bit of the Status Register is monitorized to determine when the Data Register is updated.

An alternative scheme, which increases the number of interface lines to four, is to monitor the RDY output line from the AD7730. For interfaces that require control of the CS input on the AD7730, one of the port bits of the Atmega8535, which is configured as an output, can be used to drive the CS input.

The ATmega8535 is configured in the master mode with its CPOL bit set to a logic zero and its CPHA bit set to logic one. When the ATmega8535 is configured like this, its SCLK line idles low between data transfers.

The bulk solid material is conveyed by the vibrator chute into the weighing vat that is placed upon a weighing cell that continuously monitors the added weight of material.

The weight cell is working on the tensometric principle that modifies the value of the resistance of the Tensometric Bridge with the variation of the vat's weight.

The analogical value of the tension from the Tensometric Bridge is converted then into a discrete value by the analogical digital converter, which is built inside the integrated circuit AD7730BN specialized for weighing applications.

The weighing cell is connected directly to AD7730BN integrate without any prior amplification; because the processing of the analogical signal is processed completely by the AD7730BN integrate through the specialized components from it.

The result of one conversion represents a numerical value of 24 bits and resolution of the conversion will be of 230.000 units for in tensions for the interval -40mV and + 40mV.

Connections between the AD7730 and the bridge are very straightforward in this type of application as illustrated in figure 8.

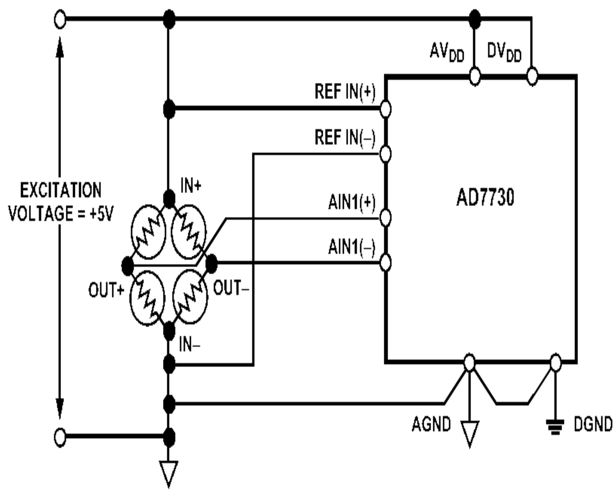


Fig. 8. Sketch representing the connections of the weight cell with the weight monitoring integrate AD7730BN.

The vibrating dosing system uses a DC motor to produce the vibrations on the conveying vibration chute. Depending on the value of the vibration parameters the bulk solids will flow accordingly. An important advantage of this dosing method is that material is fed in the weight cell uniformly and with smaller impact on the weight scale.

The dosing system is periodically fed with material from hopper, and will be refilled at the moment when the minimum level of material in the hopper is reached.

The command block for the control of the vibrating dosing system works with the microcontroller that sends PWM signals on the data in TTL gates of the power integrate L6203, which is capable to command an output tension of maximum 42V and electric current up to 4A. Through the control of the voltage of DC motor can be adjusted in real time the vibration frequency of the chute result in controlling the material flow [4].

For the dosing process optimization it is used a step motor, which allows the gradual change of the chute angle. This angle determines the speed and precision of dosing process.

The angle chute is set with unipolar stepper motor with four phases (MPP) that is powered through amplified signals by the ULN2803 power integrate that receives data in signals from the microcontroller. The ULN2803 is foreseen with 8 levels of Darlington amplification that can command the phases of stepper motor with a tension equal with 50V and an intensity of 500 mA.

The principal aim of this study consists in the conception of an algorithm that makes the dosing process faster with the maximum precision. We tried to do this optimization though having a fast flow of material at the start and a good precision at the end of the process. That is the motivation that made me to divide the process in two parts.

One part where that the angle is graduate change depending on the dosing material. And in the last part the angle remains constant and the power of the chute vibration depend on the rest of the material that remains to be dosed.

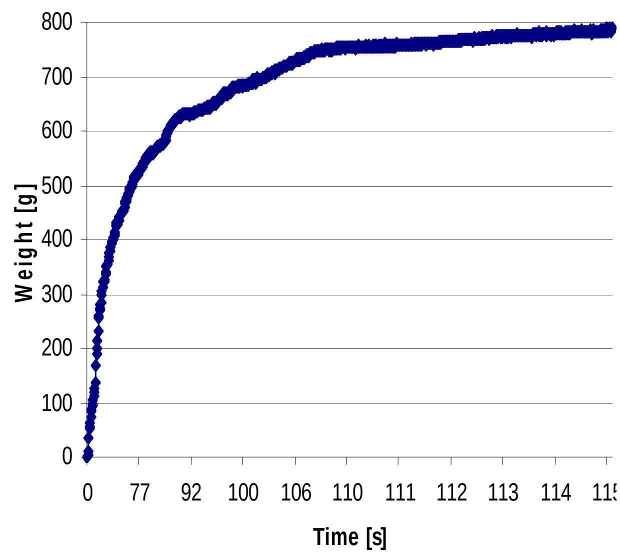


Fig.9. Real time graphic that displays the dosing weight realized for weight batches of 800 g - optimum proportional value based on the material properties;

The algorithm calculates in real time the proportional error. This is obtained from the difference of the value of the material that must be dosed and the material that was dosed.

This error is multiplicated with a constant and the result is proportional error. This proportional error is applied on the actuator. In this way is obtained a feedback and a good optimization of process.

To tune the optimization, the parameters: the percentage of the 2 parts, angle maxim and minimum of the chute, limits of voltage for vibrating motor can be switched for different material.

In Figure 9 and 10 are presented two graphics for optimized (fig. 9) and standard dosing process (fig. 10)

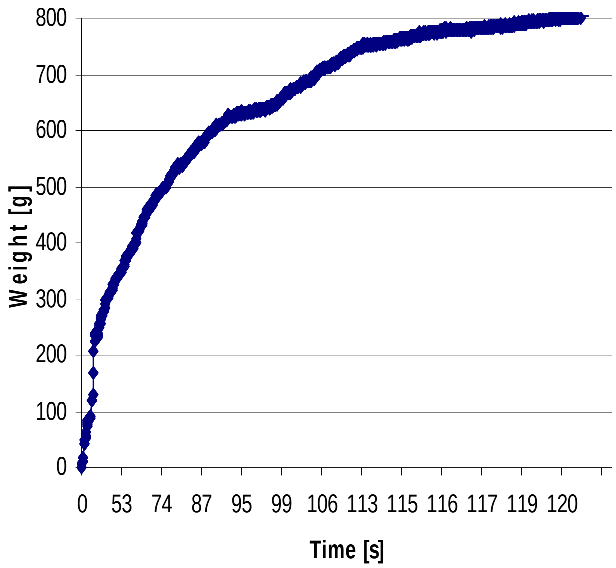


Fig.10. Real time graphic that displays the dosing weight realized for weight batches of 800 g- standard dosing process.

4. Conclusion

The development of smarter control algorithms, microprocessor design, and analysis of environmental systems also come within the purview of systems engineering. Systems engineering encourages the use of tools and methods to better comprehend and manage complexity in systems.

Defining and characterizing such systems and subsystems and the interactions among them is one of the goals of systems engineering.

Modular design has been regarded as the new logic for product and organisation design as it helps firms cope with nowadays turbulent environment. The promise is that by conceiving products in terms of modules, firms can take responsibility for the design and development of separate modules.

Modular Design requires up front planning to ensure that the design is partitioned properly. It also requires communication among team members to ensure that partitions work together during the Final Assembly phase. The number of modules should be kept to a minimum. Modular Design is best used for large designs that can easily be partitioned into self-contained modules

The basic idea underlying modular design is to organize a complex system (such as a large program, an electronic circuit, or a mechanical device) as a set of distinct components that can be developed independently and then plugged together. Although this may appear a simple idea, experience shows that the effectiveness of the technique depends critically on the manner in which systems are divided into components and the mechanisms used to plug components together.

All these studies are very important in the field of precision mechanics and mechatronics systems. The main purpose of this research is to generate optimised feeding and transport systems for more mechanical efficiency.

The modular systems designed in this way are part of the global tendency to achieve the automatic control systems. This system is reorganized to meet the international trends in achieving the automatic control systems [6].

They exclude the subjectivism of the measuring, ensure a dynamic control of the analysed parameter and the plain modular constitution allows the rapid integration in the execution technology of the rings and could be used for any cylindrical surfaces.

In the most quality problems during the manufacturing process, the solution has been set up accordingly to the multicriterial analysis concerning: the necessary measuring accuracy for the tolerance size of the checked parameter, taking in account the increased uncertainty of a sufficient measuring accuracy on the acceptance-rejection decision with the respective involvement; the cost of the checking on a minimal reasonable level.

They have the advantage to eliminate the subjectivity of the measurement operation, assure the dynamic control of the analysed parameter, and the simple modular construction allows the rapid and flexible integration within the manufacturing technological lines and may have as destination any surfaces designated to the control.

In relation to the requirements of the manufacturing automation, the fabrication methods have to meet a series of conditions in order to become adjustable for this type of manufacturing from both the technical and economic point of view. In other words, the fabrication methods will be flexible unless they address the principles of automatic manufacturing.

This method provide an automatic optimised process for dimensional inspection as well as an important data base for selecting the optimal working parameters that can assure the most efficient mechanical structure used in automation of dimensional control systems.

Automatic control has been an essential part of primary processing elements. Computer-based control systems permitted the coordination of machines and production lines, and have enabled management information to be made available from directly from the dosing systems.

The automatic control interface of the realized stand can offer a high precision of the dosing of each batch and can help in the understanding of the material behaviour during the transport process.

This system used in industrial applications assures a large potential for improving the product quality and increasing the efficiency in the automation system and the control techniques used. This contribution is concerned with different control strategies for mechatronic systems.

In the near future models of the micro inspection will be added to the methodology. This will enable optimisation of all vital parts of the structure of a mechatronic module. Later on, dynamic properties and controller design will be included into the methodology, which will allow for integrated design and optimisation of structure and control properties.

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