“QUALITY CONTROL FOR SPRINGS DURING THE PRODUCTION PROCESS BASED ON IMAGE PROCESSING TECHNOLOGIES”

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ABSTRACT

The stability of the production process and whose control technologies, is one of the major topics for the quality of the product. Therefore fast measurement technique plays an important role. One of the best ways, depending on the application and the required accuracy, is an inline measurement system. The optical quality control of springs is one of many applications for inline measurement. For the quality control of springs fast two-dimensional image processing technologies are well suited. In combination with the methods of quality assurance a powerful inline measurement is possible. In the application presented in this paper for a production process of springs a small quality control loop is used. The novel approach in this application is that the ranges of the quality control chart directly controls the spring forming process. Therefore an upper warning limit and a lower warning limit were defined. Also an upper action limit and a lower action limit were to be used for the control of the process. The second focus in the paper lies on the realization of an image processing system. It is divided in Software and Hardware solution.

Keywords: quality loop, quality assurance of springs, quality control chart, image processing, camera system, optical measurements

1. INTRODUCTION

The optical quality control of springs is one of many applications for inline measurement. Springs are used in a wide range of technical applications. For example a private car contains on the average more than 8000 springs. For the quality control of springs image processing technologies are well suitable, since all nominal dimensions are in two dimensions detectable. Beyond that the image processing offers the advantage to capture all measuring points with a single picture acquisition. Machine-integrated quality techniques in the work cycle make 100% inspection possible to quality control. The present paper describes machine-integrated quality techniques with image processing technologies for the quality control of springs.

2. QUALITY CONTROL LOOPS FOR PRODUCTION CONTROL

Quality assurance means to manufacture material and immaterial products and processes in specified quality, to control and constantly improve processes in specified quality [1, 2, 3]. In analogy to technical control loops therefore quality control loops with Quality Controlled System, Quality Controller and Quality Control Element must be developed.

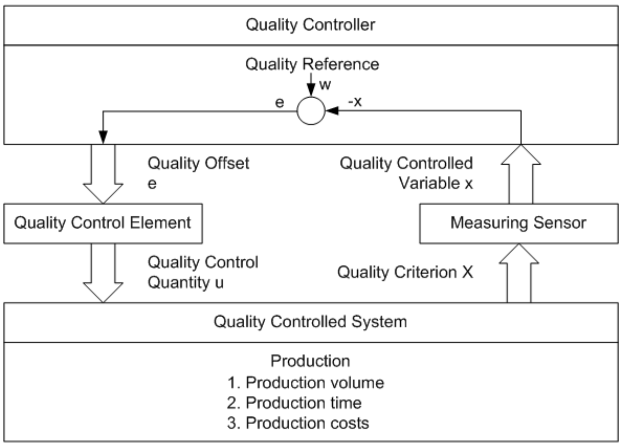

Fig. 1 Components and structure of quality control loops [1]

Quality control loops (Fig. 1) are defined as closed technological-organizational action sequence in a process for the production of a quality product. With view on the whole production process, quality control loops must be divided into small quality control loops and large quality control loops [1, 4].

Small quality control loops are used for current control in the production process by instantaneous influencing control on the individual manufacturing steps. They exert direct influence on quality criteria during their production. They include direct statistical process control (SPC) units in the form of quality control charts. As quality reference for example the desired value and the range of tolerance of a quality criterion are consulted.

The overall quality control loop includes all activities from the idea of the product up to the line production process. They are used for subsequent inspection and quality confirmation of the production process by delayed influence. In the application, presented in this paper, the small quality control loop is applied.

3. STATISTICAL PROCESS CONTROL WITH QUALITY CONTROL CHARTS

Statistic process control is a continuous accompanying monitoring of the manufacturing processes by collection of all characteristic numbers relevant for the product quality. SPC supplies the base data for the recognition of weak points and thus the condition for the constant improvement of the respective processes. SPC developed from the quality control charts technique.

Quality control charts are one of the oldest tools in the quality management and an important aid to the quality control. The quality control chart is a form for graphically representing of measured values taken up by sequential samples. They are used for the purpose of the quality control in comparison with warning and/or control limits [5]. The main objective is to recognize promptly error developments for regulative intervention. Examples of quality control charts are shewhart quality control chart, average value quality control chart and median quality control chart.

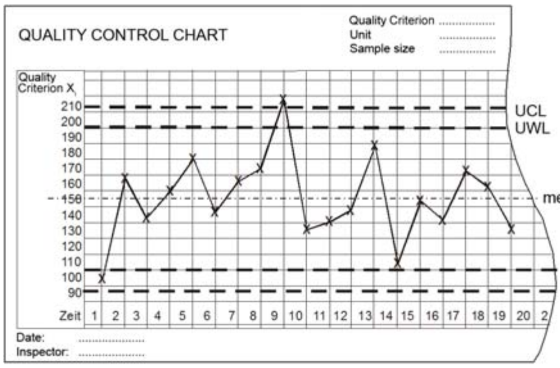

Fig. 2: Structure of a quality control chart (UCL = Upper Control Limit (or Upper Action Limit); LCL = Lower Control Limit (or Lower Action Limit); UWL = Upper Warning Limit; LWL = Lower Warning Limit)

For the definition of the interference and warning limits of quality rule maps the following error bands are used:

- α = 1% → 99% error band → control limit
- α = 5% → 95% error band → warning limit

In the 99% error band covers at least 99% of the values of the characteristic. With the fact it is improbable that with an unchanged process values arise, which lie outside of this range. That means, if the values lie within the control and warning limits, the process can be continued without intervention. A Violation of the warning limits leads to a monitoring of the process with increased attention. If the values fall outside the control borders, intervention must take place into the process, in order to guarantee quality of the product. In addition the causes for the change of the process must be examined.

For the successful implementation of SPC four conditions must be fulfilled: data integrity, data traceability, identify critical process parameters and real-time capability [6]. Data integrity means that the measurements must be accurate, so that fluctuations during the process are recognized surely. The traceability to the respective process and product must be secured, so that interferences in the correct place are accomplished. Beyond that the production steps must be recognized, which have a significant influence on product quality. Each intervention into a current process means a interference. The reduction of unnecessary interventions into the process is a goal of the SPC. The presented Inline measuring system on basis of image processing technology fulfils all these conditions.

4. NOVEL STATISTICAL PROCESS CONTROL SOFTWARE FOR QUALITY CONTROL OF SPRINGS

In the presented application, the quality control chart represents the quality controller in the quality control loop (Fig. 3). The set points for the spring production are the length and the diameter. The drives of the production machine and its mechanic system represent the control path. The entry values for the quality control chart deliver an image processing system. So the control loop is closed. Troubles during the control path can be, for example, defective wire or abrasion of the mechanical forming tools.

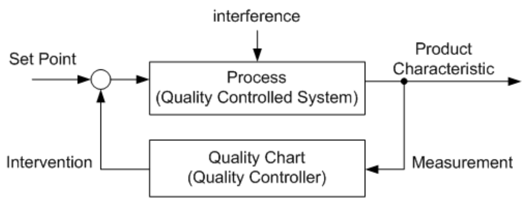

Fig. 3: Small quality control loop using quality control charts for SPC [1]

The novel approach in this application is that the ranges of the quality control chart directly controls the spring forming process. Therefore an upper warning limit and a lower warning limit were defined. Also an upper control limit and a lower control limit were to be used for the control of the process.

Beyond that, the software offers additional support to the operator. In a typical measuring scenario is assumed humans know the item under test and its situation exactly. In the field of technical recognition the algorithm must be able to detect type and orientation of the unit under test.

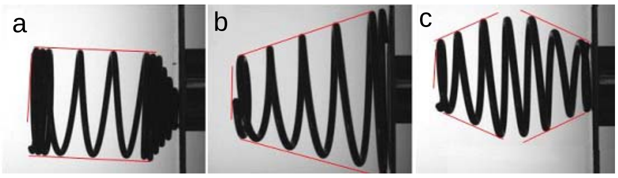

Fig. 4: Different spring types (a: cylindrical spring; b: single-conical spring; c: double-conical spring)

For humans it is relatively easy to differentiate on a single view cylindrical, single-conical or double-conical springs. The different spring types cover different geometrical boundary conditions, which must be monitored during the production process. The teach-in process of these conditions for inspection is however more difficult for the operator to realize. That leads to the fact, that a manual setting-up of the individual values, depending on the type of spring, increases the danger of operator errors.

In this new approach of software the detection and the classification of the spring type works automatically. The operator only has a one button solution to set up the whole production system. The manual configuration of area of interest (AOI) for the measurement is replaced by the new algorithm. So the operator errors and the teach-in time for new geometric spring forms can be minimized.

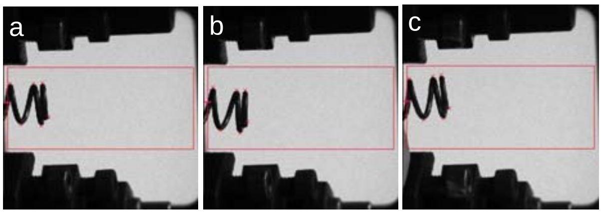

Fig. 5: Images of swinging springs (a: horizontally; b: downward swinging; c: upward swinging)

Another novel algorithm in the software realizes automatic tracking of the measuring points. That means, during the production process the spring can begin to swing and has different orientations. This leads to not deterministically assignable deviations of the spring position of two following springs during the production process (Fig. 5). From it results, that the use of static AOI is not possible in such high-dynamic processes. After the machine configuration the software is able to make a good or bad divisor identification based on the set points from the small quality loop. Furthermore the software generates new setup values for the forming tools during the runtime of the machine. In case of a bad divisor identification a sorting device is steered, in order to segregate the incorrect spring.

The software for statistical process control was integrated directly into the machine control software (Fig. 6). An algorithm compares the quality controlled variable determined by the measuring system (geometrical dimension) with the quality reference (nominal dimension and tolerance). In the case of a quality offset the drive control is readjusted. Different control algorithms can be realized.

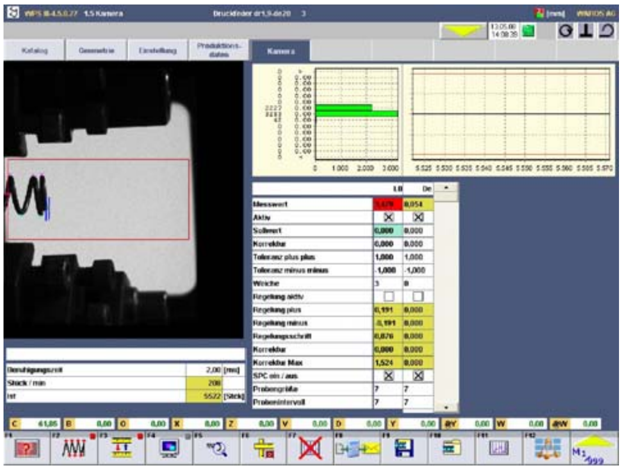

Fig. 6: Machine-integrated image processing software with analyzed spring and quality control plan

5. IMAGE PROCESSING HARDWARE

As mentioned the image processing system works as the feedback control system. The user defines in the application software the set points like diameter and length. Furthermore a maximum speed of up to 600 springs per minute must be analyzed in the fastest machine.

The image processing hardware is structured in three parts: the charge coupled device (CCD) - camera, the illumination with illumination controller and, in this special case, also the communication cable plays an important role.

The CCD - camera

Within the machine housing the camera system was integrated. The camera is based on a scalable hardware platform. It is divided in image acquisition board, power supply board and the data transfer board.

Task of the image acquisition board is the timing of the CCD sensor, exposure control, gain control and the analogue to digital conversion (ADC). The digital output from the ADC is presented on an 8-bit wide data bus interface and the image synchronous signals. Beyond that a bi-directional serial bus is used for parameterization and control.

The data transfer in the presented application is realized by a Universal Serial Bus (USB) 2.0 controller. The controller is located on the exchangeable data transfer board. Data is buffered in first in first out (FIFO) line buffers before it will be transfered to the host computer as uncompressed packages. For special applications a power source and a bus entry for a field programmable gate array (FPGA) board is ready for use.

With a 640 x 480 pixel resolution and the external asynchronous trigger option, a frame period of 33 ms is possible. In continuous capturing mode the image frequency is 60 frames per second (fps). In asynchronous trigger mode image frequencies up to 30 fps are possible.

The housing for the camera was designed in such a way that it can be positioned as near as possible at the forming tool. Beyond that the environmental conditions, dominant in the manufacturing machine, had to be considered. The meant, the camera electronics must be protected from electromagnetic interference by the drives. In addition, lubrication and cleaning agents may not damage the system.

The illumination system with illumination controller

To get best results for the measurement task a stable and homogeneous illumination is needed. In dependence of the size of the spring, four different sizes of backlight illumination were developed. The biggest one contains up to 1400 LED. The dominant wavelength was aligned with the maximum sensitivity of the CCD chip. To eliminate scattered light from the surroundings, an aligned filter was additionally mounted on the lens housing.

Depending on the high vibration level inside the machine, a flash illumination is needed to guarantee motion blur less than 10 µm. Therefore the drive control unit triggering the camera and the illumination controller. After the trigger the camera transfers the picture via USB to the central procession unit.

Communication cable

Because of the high electromagnetic influence level within the production machine also the data line was particularly isolated. In particular the wiring of the communication line parallel to power lines of the drives led to interferences, whereby the condition of an accurate measurement was injured. This problem could be solved by an intensified shielding in connection with additional filter assembly.

6. CONCLUSIONS

Industrial image processing in combination of the small quality loop is a powerful method to ensure a good spring quality in the production process. As machine-integrated measuring instrument instantaneously influence on the production process can be exerted, if variations in quality arise. Quality control chats are used thereby as quality controllers and secure beyond that a good documentation of the measured values. In the presented application this function is extended additionally by operator supporting algorithms. Automatic spring recognition and the dynamic AOI help to teach-in new production processes fast and ensure a continuous quality assurance. After image analysis, measurement and evaluation of the quality control chart, the requirement for a 100 % inspection of 600 springs per minute can be fulfilled.

In addition, the realization as inline measurement system means special requirements to the hardware. These concern in particular the protection from electromagnetic interferences, the compensation of vibrations during image acquisition and the reaching of the speed requirements.

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