IN-LINE MEASUREMENT OF LINER BEARINGS IN AUTOMATED PRODUCTION LINE

НЕПРЕКЪСНАТО ИЗМЕРВАНЕ НА ЛАГЕРИ В АВТОМАТИЗИРАНА ПРОИЗВОДСТВЕНА ЛИНИЯ

Mr. Eng. Skupnjak D. [1], Assoc. Prof. Dr. Eng, Mijanović Markuš M[2],
DAIDO Metal Kotor AD [1], University of Montenegro, Faculty of Mechanical Engineering, Podgorica, Montenegro[2]

Abstract: *This paper offers a brief summary of the liner bearings production for the internal combustion engines and the occurrence of reject materials. Due to the fact that the production is performed on the highly-productive production lines with short work cycle, the frequency of the reject materials occurrence is intolerably high. In order to eliminate rejects or to reduce their occurrence onto the acceptable level, a task has been designed. The task is to plan and realise additional bearing control. The solution to the problem has been found with the development of the original liner bearing control device that is integrated into the production line.*

KEYWORDS: IN-LINE MEASUREMENT, QUALITY ASSURANCE, SENSORS.

1. Introduction – Problem Defining

In DAIDO Metal Kotor, Joint Stock Company, in Montenegro, a liner bearings production for automobile industry is performed. We analysed OEM (Original Engine Manufacturing) production of liner bearings for the internal combustion engines which is performed on automated highly-productive production lines (APL). The production is performed on four production lines and two lines of presses. Cutting, bending and compression of the two liner bearing halves are performed. Then, the production continues on one of the production lines.

Production line Y-01 consists of 12 machines connected in a line through transporters and controllers. Line capacity is 6-8 thousand workpieces per shift (8h); the work cycle is 1.8sec/piece and is defined by the slowest machine (face and chamfering machine). The production line consists of the following machines input unit, face and chamfering, corner chamfering, two piercing machines, nick relieving, nicking, grooving, hole chamfering, brushing, high crush finishing, autochecker, and in the end boring machine. All of these machines are automated and organised into one unit.

During the production, certain parameters of liner bearings are controlled, off-line after the processing on the press, and, in-line on autochecker machine in the production line. Autochecker machine controls certain measures like, height or existence of lubrication or oil hole, but not all. Even though the control is implemented, during the production a reject material will inevitably occur. Because of the automated production and its scale, the reject material should be carefully taken into account and reduced to the lowest possible extent. Causes of the reject material occurrence were analysed with the help of Ishikawa diagram, which was followed by a complete analysis that encompassed place of occurrence of the reject material etc.

Fig. 1. Machine line Y-01

The next step encompassed analysis of the possible ways of how to eliminate or reduce rejects in the OEM production. Each idea was based upon the measuring of key liner bearings parameters which were not controlled up to that point during the production. Prior to the decision of how to measure the key parameters, we analysed the manners and the possibilities of their measuring.

2. Measuring Manner Analysis

2.1. Advantages and disadvantages of Coordinate-Measuring Machines

Mechanical touch probes on CMMs (Coordinate-Measuring Machines) have been, until very recently, the most frequent probes for the control of the parts, especially automobile ones. Significant part of the measuring was performed off-line on a sample.

This trend from the touch trigger probe to a mechanical (analogue) scanning probe was a good manner regarding data collection; however it was limited by some basic characteristics of mechanical (analogue) scanning probe. [1]:

- Mechanical probe has a limited scanning speed,
- The dynamic scope of the touch probe is, by its nature, very small,
- Mechanical probe programming requires know-how and experience,
- Resolution and the dimension of parameters which can be scanned are limited by the size of the probe tip, so, for example, edges cannot be scanned.

So, the application of CMM for the liner bearings control is not convenient because of the aforementioned reasons. Additionally, off-line measuring is not appropriate, because the reject existence data cannot be used for its expulsion from the further production that, due to the short production cycle of APL, could lead to the occurrence of a large number of reject products. So, products control operation should be integrated into the production line, and the control itself should be done as quickly as possible. The need for efficient, precise and fast contactless laser metrological systems for the control of the work pieces is ever more present.

The remaining question is in what manner and to what extent (from the aspect of information exchange) such metrological system should be integrated.

2.2 Modern Metrology Philosophy Consideration

Numerous demands can be set out for the production. Short product life cycles and fast changes of the product features demand flexible production devices. At the same time, demands related to the product quality are increased. These are confronted demands, and one of the key aspects of metrology is to meet them both. Only by measuring relevant data during the production process, can we provide process control and optimisation. [2]. Apart from the provision of the product quality, metrology influences productivity increase as well and become an economic factor of production.

This discussion Schmitt [2] shows on Picture 2 where the production parameters for four production steps are considered in two different cases. In the first case, metrology is used for the quality provision after all four production steps have been accomplished. In the second case the in-line metrology has been used after each step.

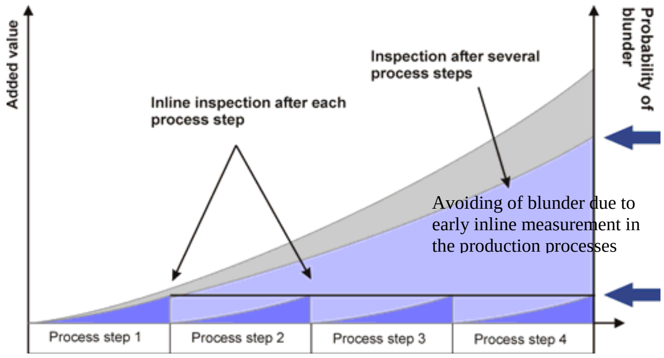

Fig. 2 The behalf of inline-metrology [2].

During the production process, metrology can be applied:

1) After each step in the process,
2) At predefined production process spots, and
3) After the finishing production steps.

If there is a mistake related to a workpiece (process), defective workpieces are immediately eliminated from the production. The production process is continuous until all of the workpieces are within the tolerance limits. This simple analysis will show that metrology has an economic aspect as well.

Goal of in-line metrology is to obtain measured data during the production, and later on to use them for production management and quality provision. In such a manner the existence of changes in the production process can be quickly detected. Timely reaction enables for this process to be corrected and this leads to the increased product quality.

Off-line metrology is conducted in ideal conditions. Contrary to this, in-line metrology is conducted in the real working conditions which are far from ideal and it depends on the production processes. With advanced processes in-line metrology can be used for reversible control loops, thus enabling direct process management, statistical process control and process stabilisation. In order to achieve that, in-line metrological concept should be integrated into the process in the early phase of product and layout planning. This implies analysis and keeping of measured data, existence of appropriate software and interface solutions in order to connect metrology with production and CAM [2, 3].

When the in-line metrology technique is used for direct process management during the work, that process is called in-process measurement.

3. Problem Solution

If we want to install in-line measurement on the existing production lines and devices, it is very hard to maintain direct process control on the basis of measured data from the process, unless we make substantial changes on both controlling hardware and software. As a rule, there is no financial justification for such modifications. So, what can be done regarding in-line metrology when it comes to the existing production lines and devices?

3.1. What Requirements The Device For In-Line Measurement Should Meet?

The solution should be economically acceptable and meet the following requirements:

1. All of the defined bearing parameters should be measured on one sport, i.e. the device,
2. The device should perform liner bearing control during the production process itself.
3. The measuring time should be shorter from the production cycle,
4. The device should be integrated into APL on the most convenient spot,
5. On the basis of information from the device regarding the existence of a critical number of rejects, the production line should be stopped and an operator should be notified about the existence of an error. The operator, then, takes necessary steps in order to remove the source of the error.

It should be measured three aspects of each workpiece: position of the lubrication hole in relation to the angle and width of the bearing, width of the bearing and free spread. It should also enable the control of the bearings (diameter 30-80 mm), (width 13-30 mm), and the control of up to 3 lubrication holes (diameter 2-8 mm).

Work cycle is conditioned by the production line cycle, i.e. by the work cycle of the slowest machine in the line, and should amount to 1.8 sec.

The device should be installed into the production line after the autochecker machine and the size of the device should correspond to the installation place.

The device should be ergonomically adapted i.e. operator-friendly. The device should be programmed to stop the production line after it has detected three rejects. Prior to installation this device should be tested.

3.2. Concept Of The Liner Bearings Control Device

Liner bearing control device consists of: control unit with sensors (and amplifiers), transporter, electro-pneumatic system for bearing fixation and expulsion, control case, PLC for controlling functions and stand [4].

Control unit contains:

- 3 high-power digital laser optic sensors KEYENCE LV-H32 with Amplifiers LV-21 A, for the control of the opening [6],
- 1 laser measurement sensor OMRON ZX series for the bearing width control, ZX-LD40L (diffuse reflective sensor head, line beam), amplifier ZX-LDA11 [5],
- 1 dual digital fibre sensor KEYENCE FS-V2 [6], and
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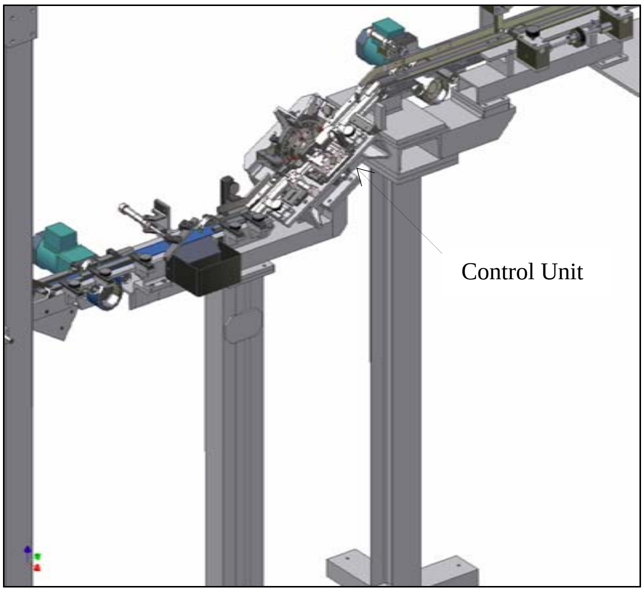

Fig. 3. New control device.

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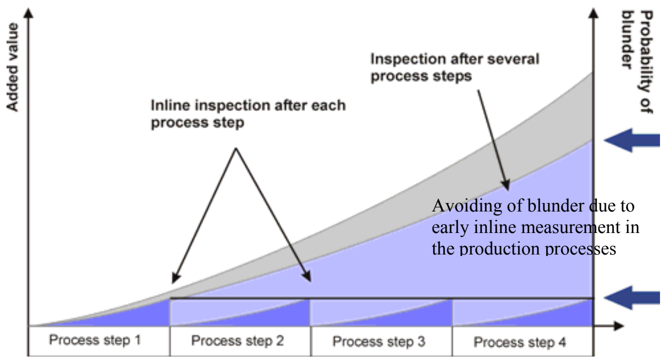

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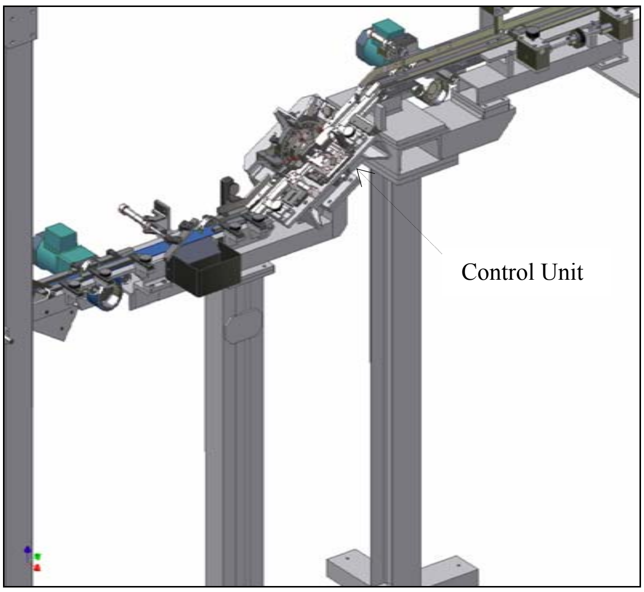

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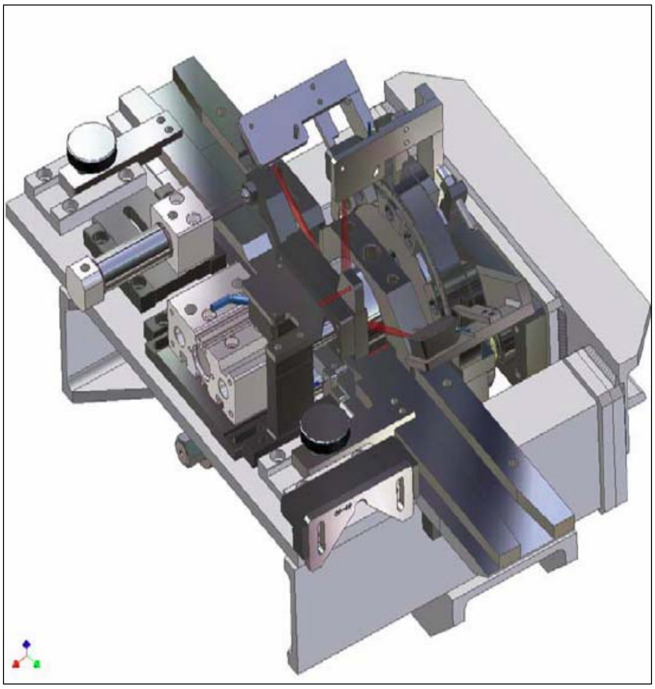

Fig. 4. Control unit of the device.

Control of the liner bearing control device is preformed via microcontroller PLC MITSUBISHI Fxon-60MR [7]. Positioning of the bearing into the device is electro-pneumatic. Transporter uses electromotor as its drive.

4. Results

4.1. Functioning Of The Device

After the control on the autochecker machine in the production line, liner bearings are transported to the separator (that is moved by electro-pneumatic cylinder), which stops the bearings and makes sets of 2 – 8 bearings. After the PLC command, the separator allows the bearings to pass through, down the perpendicular surface (between the guidelines) one by one into the control device, where it controls the position of the lubrication hole in relation to angle and width of the bearing and free spread of every bearing being machined on the line.

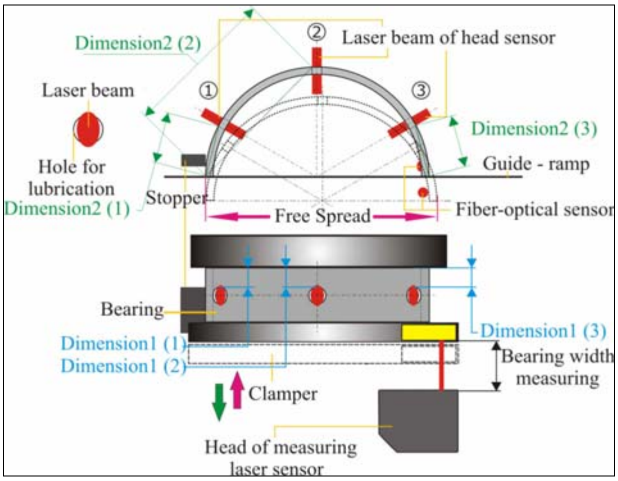

Fig. 5. Dimensions to be measured.

Position for the control is provided by stopper. Inductive proximity sensor detects the presence of the bearing ready for the control and that information is sent to the PLC. PLC sends exit signal that activates the electro-pneumatic valve and the cylinder. Then, the control is performed, i.e. the values (and the respective tolerances) are compared to those found on the bearing. If the controlled values are out of limits, PLC lights up the signal bulb and, after the bearing has passed under the second inductive sensor, gives the command for the vent to push the bearing into the box for rejected bearings. If the bearing is good it will be sent to the next machine or device by the transporter.

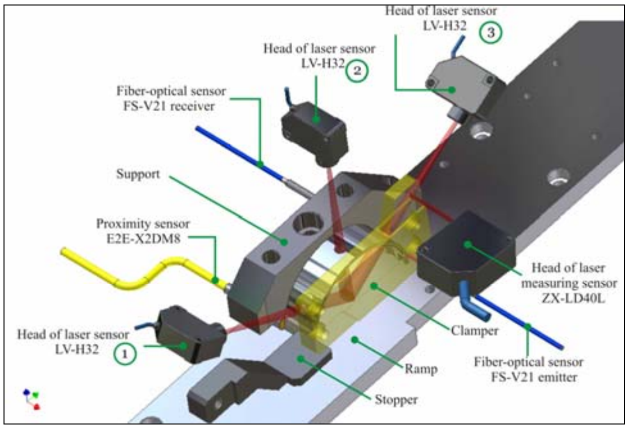

Fig. 6. A liner bearing in the control device

The next bearing goes into the device in the moment when the reed sensor on the stopper cylinder is activated, i.e. when the stopper cylinder piston is in the front position (position for new control). PLC gives the exit signal, that is, activates electro-pneumatic separator cylinder vent and this movement enables for the next nearing to go through. This starts a new liner bearing control cycle in the device.

4.2. Testing Device

For device testing purpose were prepared 40 parts for measuring of position of the lubrication hole in relation to the angle and width of the bearing, 10 parts for measuring of width of the bearing, and 10 parts for measuring of free spread of every bearing being machined on the line. Amplifiers response was tested too.

Measured parts were tested at the device separately first, and than mixed in the sequence. The device always was rejected false parts outside tolerances without mistakes.

Testing device confirmed operation stability, and provided expected checking results. This device detected every bearing (for which it was previously adjusted) whose measures of parameters being controlled are out of tolerance. In the same time the device sent STOP signal to the production line and stoped false liner bearing producing.

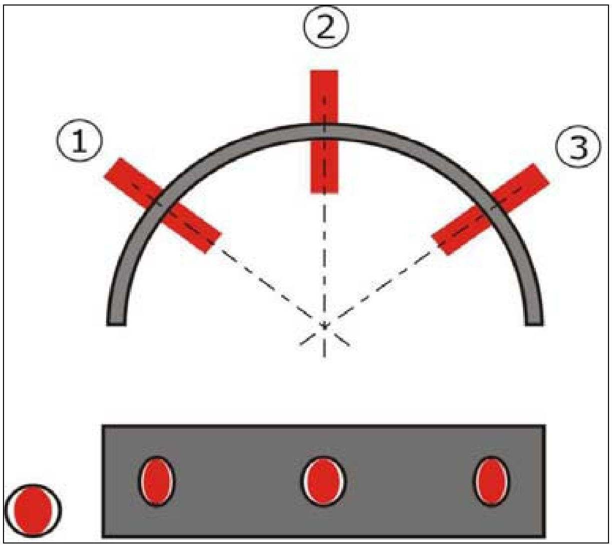

Fig. 7a.

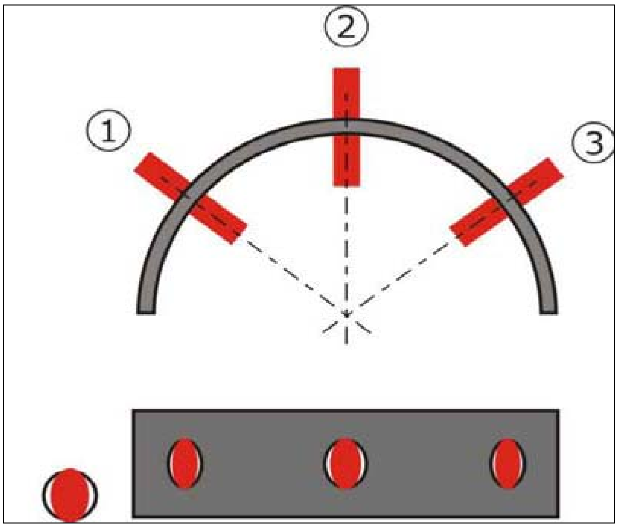

Fig. 7b.

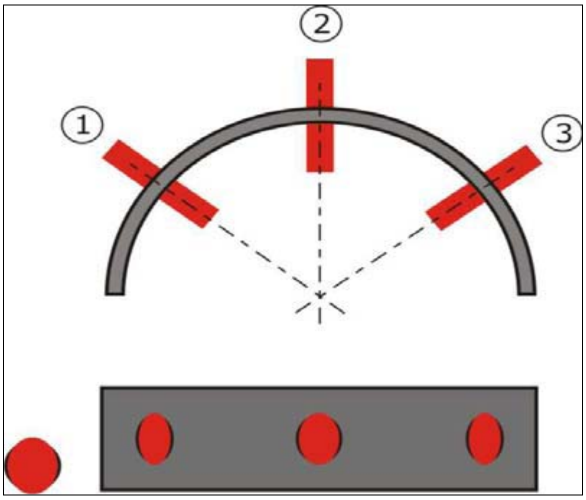

Fig. 7.c.

Fig. 7a-c: Settings of the laser beam for the testing of position of the lubrication hole in relation to the angle and width of the bearing.

5. Conclusion

The main aim of designing and production of the liner bearings control device is to eliminate rejected material on the basis of the control of three bearing aspects which were not controlled during the production process until now. The control is performed in-line, during the production process. With this measurement procedure, we can determine whether the measured values are within the prescribed limits or not, without stopping the work procedure. Occurrence of up to three rejects is tolerated. After that, PLC signal stops the production line and notifies an operator to take corrective and appropriate techniques in order to locate the cause of reject occurrence.

Reduction of the rejected materials, by using the abovementioned device, from the economic point of view directly reduces material and production costs, reduces production time and increases profit and workers´ payments. Customers will be better satisfied with a final product, because that product was controlled and of more quality.

Tests of the device prior to its installation in the production line showed good results, which were later on verified since the production process was better with the new device installed.

Due to its complexity and unfavourable economic aspect of the in-line metrology adaptation procedure for the in-process measurements, for the existing line, project is not planned.

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