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INTERCONNECTIVITY BETWEEN CNC AND CMM FOR SERIAL PRODUCTION, CURRENT TECHNOLOGY AVAILABLE AND NEW DIRECTIONS FOR DEVELOPMENT

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Abstract: *At this moment we have identified several types of measuring and control systems which are integrated in the production processes. These systems can direct evaluate the Computer Numerical Control machine (CNC) process, tool control by parameter correction and in production cells evaluation of process and parameter monitoring by evaluation of measured results. For current available technology we can identify more types dedicated for specific projects. In this article, based on new development possibilities of Coordinate Measuring Machine (CMM) programing we identified an opportunity of introducing the CMM in the production process not with a passive role of informer of measured result, that can maximum stop the line production, but with an active role witch to provide CNC correction parameters for CNC setup and dimensional measurement results for quality inspectors.*
Key words: *SMED, CMM measurement strategy, Industry 4.0, CMM in line auto setup, interconnectivity.*

1. INTRODUCTION

Metrological and dimensional control laboratory are a very important part of any production process, even if them are located near or in another location they role remain the same, to ensure the good functionality of production processes. It is known that for fast and cost efficiency the control is made with fast measurement equipment like calipers, micrometers, Go/NoGo caliber or comparison samples. These methods cannot be used when we need to validate parts with great complexity, where we need to validate the functionality of part and assembling characteristics. To can do all these requirements we have more options: one is to use specific equipment's dedicated to each project, this is a fast way and involves large investment for every new project, another method is measuring the parts with measurement equipment's, here we have more options that need to be analyzed to be applicable to the project. We can measure the part on the CNC machine, if the volume of produced parts allows it and CNC haze this option, we also have more options available of measuring the parts witch depends to the tolerances and shape complexity of parts. [1][2][3]

CMM producer have identified these needs, that measurement machines must be present as close as possible to the production processes and with integration of new sensors, witch measure different parameters, like temperature and vibrations they succeed to bring CMM's in production area or integrate them to production centralized cells. With all these the CMM haze only an informal role to the process and the biggest decision which can take is to stop the production cell or to give an alarm as the measurement haze dimension out of tolerance.

The modern CNC have integrated measurement systems that help setter to align the clamping devices and set up the reference of the parts, although they can measure some characteristics from produced parts these measurement systems are not used in serial production due to time consuming and difference between clamping or unclamping estate of product.

Having all these dates available we identified the opportunity of creating a new approach in utilization of CMM's in production processes by

changing the passive role as informer to an active role where the CMM to calculate and implement setup parameters to center the production process for the CNC programs.[4]

This concept was started from CNC programs and processes destinated for revolution parts, here we can identify measurements of the tools and diameters of parts that require to increase or decrease the tool diameter, parameter correction, to have the parts always in tolerance.

2. ACTUAL STATUS OF INTEGRATING QUALITY CONTROL DEVICES IN TO PRODUCTION PROCESESS

We have identified 6 major types of measuring systems integrated direct or indirect to the evaluation of production processes. To integrate all these systems, it was developed different constructive options, where the investment was evaluated based on production levels, importance of parts and critical criteria of produced parts. [7]

2.1 In cell production 100% control of critical parameters

This system is used in line production cells and the focus is to verify 100% of parts for critical parameters and characteristics. Part measurement is made completely automatically, and control scrap the parts by defect type and good parts are labeled with a data matrix. The control is calibrated with a master part and all sensors are corrected according to the master.[7]

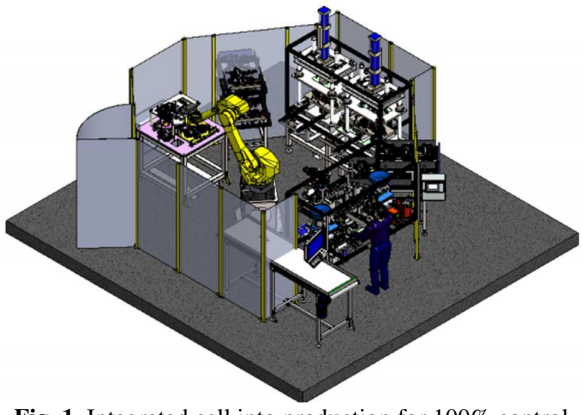

Fig. 1. Integrated cell into production for 100% control of critical dimensions and parameters.

This type of control is used for big projects and give feedback in real time about the current production status. Due very expensive investment required the number of characteristics controlled is an important aspect of this control cell, another point is that it can be used for unique projects and cannot be used for multiple purposes.[5][6]

2.2 CNC live measurement data

Measurement of parts directly on the CNC was a developed and automated process which involves measurement of complex parts during production of parts. For expensive projects were one machining operation error can destroy the part it is very important that this control can intervene and confirm that operations are running in good condition. We can conclude that measurement aspect became more and more important during production processes and converting the measured result in active corrections for machines will not be just an option but a must have for important projects. [20][21]

For this process the machine measuring probe the part in clamped estate and give corrections to the process so that production of the part can continue. Even if this method helps us to understand process variations and at the same time require production to be stopped to can perform direct measurements, the measurement report will evaluate the part according to a 3D model in CNC axis. The CNC measurement strategy being unable to respect if drawing haze other measurement requirements to measure the parts. Another aspect is that part can suffer un tensioning after its release from the CNC clamping device and give other results.

2.3 Diameter measurement direct by CNC

Another example is represented by the option of inserting measurement equipment direct in the CNC tool changer. With these option after machining the parts one by one or from time to time depend on how it's defined in the process, machine can measure the part and give correction to the affected tool. The not conform parti is scraped and if consecutive parts are out of tolerance machine is stopped until the setter identify the issue. [22]

This system is developed more for diameter measurement and measurement is made regular in two points.

Fig. 2. Installation of measurement system on the CNC toolholder.[22]

The system didn't measure location or shape deviation and measure only diameters of the part, each diameter must have a different tool as the interval of measurement is lower than 1mm per each measuring equipment. The system can be used as well near CNC machine and can be operated by a robot or an operator to measure the part.

2.4 In line CMM measurement system with auto measurement of different parts

Developed to be used within the production, this system connected to a CMM provide the possibility to measure production different parts continuously. The operator must fill the drawers with parts and confirm to the system.[11]

Fig. 3. Tempo system to measure parts from production.

Machine measure the parts and send the result to Tempo system, as when operator comes will find a map of good and bad parts for all parts that were measured. The system hazes the possibilities, if it's configured in this matter to send e-mails of measured results or to activate warning lights or alarms if a part is not conformed or at the limit. Tempo system take for each reference the measuring device, install it to the CMM table adaptor, clam the part and give to CMM to start the specific program developed for that reference.

2.5 Online controlling of all measurement equipment with real status of running production.

Another system developed to assist measurement of production processes is found in "Smart Manufacturing" system where we can find the module HxGN SFx. This system controls all measurement equipment for errors, running programs, temperature variation, vibrations, and stationary times.[11]

Data reports can be accessed live or from back-up by any user at any time and any hour. The system can indicate anomaly of measured data as well, anomaly, which are influenced by temperature variation, vibrations, or different pressures of the ear.

All data can be accessed from any laptop, phone or computers, operator only need to login in the system and ask the report he need to analyze.

2.6 In line 100% control with laser sensors

Created for 100% control we identify another system developed to ensure a big volume of parts from different references. These parts can be simple or very complex and can be measured very fast. The system is automatic and uses a set of linear laser sensors called "LMI", witch scan, by passing over the part all characteristics. With this scan create a virtual map of the measured part and compare it to a 3D model by giving a fast result over the part. [20]

Fig. 4. Measurement system for 100% control with laser linear sensors [19]

The focus of this measurement equipment is not literally design to measure tight tolerances of measured parts but to identify if the part is complete machined and no missing operations are detected. The other scope is to be able to measure a big volume of parts in a short time and to be able to change from a reference to another one simple and without to many modifications.

3. NEW APROCHE TO CHANGE THE CMM ROLE AS AN ACTIVE MEMBER OF PROCESS

The actual article presents the concept of introducing the CMM into production process and attribute the role of automatically correct the process by sending correction to the CNC programs. Development concepts of this project are started from the idea that report to be separated in two, one for the dimensional quality control report (as the CMM was initially created) and the second to elaborate a G-Code for CNC where parameters to be adjusted based on CMM measurement results.[16]

The phases to have this concept running must respect the following steps:

- Part is machined on the CNC.
- Part is measured with the CMM.
- CMM program elaborate a measurement result for quality inspector.
- CMM program is developed based on logical schematic and analyze the measurement based on this to elaborate the G-Code for CNC.
- Results are delivered to CNC and production process continue.

The particularity of this concept is that all coordinate and requirements from the drawing must be translated and converted to the CNC parameters which are different from machine to machine and from each clamping device in particularity.

We are working to implement this new approach by choosing a serial production product. By measuring multiple parts from the process, we identify the tools deviations, the CNC references offsets and, with CMM program, we generate two reports, one according to drawing requirements and second as an output report that is structured to contain the correction for axis deviations within a CNC variables macro format (*.nc). This file is copied to CNC via network or by an USB drive and before reference program is loaded to primary program it is updated by running the file copied from CMM. The primary program will have the new references that are formed by updated values received from CMM. The CNC parameter programs are developed to have the coordinate for each axis plus the variable that will be delivered by CMM program. When CNC program is used on more machines the variables will affect only the correction values variables and not the real references that are given by each machine coordinate, clamping device, CNC rotation table deviations.

We can identify in Figure 5 and Figure 6 that coordinate translation between drawing and CNC are different due to positioning of the part on the machine.

The CMM measure all dimensions in XYZ system axis coordinate and move the coordinate system to the references from where the evaluation is done.

The CNC coordinates are depending on machine type horizontal or vertical and on rotation of CNC table. If we consider that we use a Horizontal CNC, then Z axis will be the tool axis and X and Y the movement of tool on CNC machine. The positioning of part to be machine create after each rotation a new alignment that in CNC coordinate remain on the same axis the single thig what will be changed will be the rotation of device.[12][13][14][15]

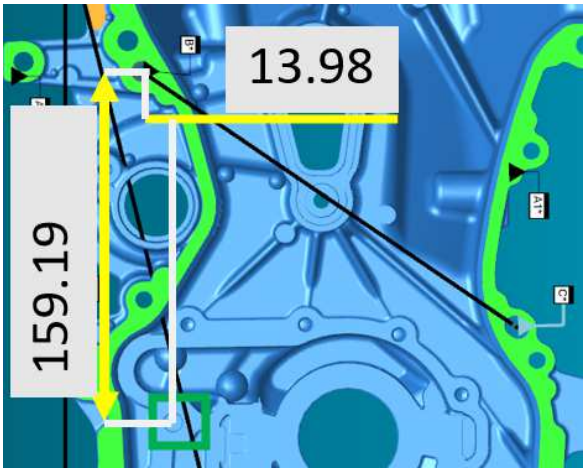

Fig. 5. Drawing measurement coordinate system ABC and reference P coordinates.

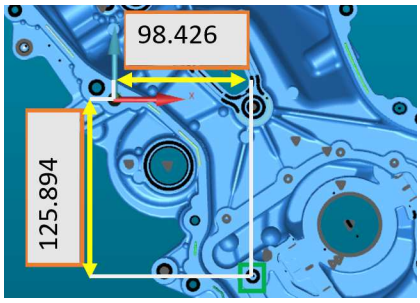

Fig. 6. Machine CNC coordinate system ABC and reference P coordinates.

This situation creates the biggest risk when setups of process are made. The new evaluation will focus exactly to avoid this problem and evaluate first time the measurement according to the drawing and second time based on the results to correct the CNC null program. This is made by evaluating all 0 point of CNC program and based on the analyzed data give correction where the risk of getting out of tolerances exist.

4. CONCLUSION

The need of automatization and new technical solution, witch to assist to take a faster decision it's increasing a lot. Measurement and process validation goal is to decrease setup time and increase product quality and process performance.

To achieve all these the actual article, present the approach of increasing the level of automatization and decision to be made automatically by the CMM program witch to provide to CNC setter or true network connection direct to CNC, the new CNC correction values.[8][9][10

If we evaluate the applications described at chapter 2, we can observe that all developer focus is to decrease the number of non-conform part to reach final customer and to make the process run softly. By introducing the optimization described at chapter 3 we can increase all these demands and the OEE (Overall Equipment Effectiveness) and SMED (Single Minute Exchange of Die) processes will perform much more efficiently by automatically parameter optimization process sent from CMM to CNC.

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6. REFERENCES

[1] Childs, P., *Mechanical Design,* www.elsevier.com, ISBN:9780080473420, Butterworth-Heinemann, 2003.

[2] Tambare, P., Meshram, C., Lee, C.C., Ramteke, R.J., Imoize, A.L., *Performance Measurement System and Quality Management în Data-Driven Industry 4.0: A Review,* https://www.mdpi.com/1424-8220/22/1/224, MDPI vol 22 issue 1, 2019

[3] *Numerical control,* https://en.wikipedia.org/wiki/Numerical_control, 2023

[4] Dragici, G., *Concepția proceselor de prelucrare mecanică.,* Editura Polotehnica , Timisoara, 2005.

[5] *Coordinate-measuring_machine,* https://en.wikipedia.org/wiki/Coordinate-measuring_machine, 2023

[6] Danford, M., *Probing Feedback Keeps CNC Machining on Track,* https://www.mmsonline.com/articles/probing-feedback-keeps-cnc-machining-on-track, 2023

[7] Mutilba, M., Gomez-Acedo, E., Kortaberria, G., Olarra, A., Yagüe-Fabra, J.A., *Traceability of On-Machine Tool Measurement: A Review.,* MDPI, https://www.mdpi.com/1424-8220/17/7/

[8] *ISO 230.2 standard*, 2023

[9] *ASME B5.54 standard,* 2023

[10] *VDI 3441 standard*, 2023

[11] https://hexagon.com/products/product-groups/measurement-inspection-hardware/coordinate-measuring-machines/cmm-probes-sensors, 2023

[12] Ganea, M., *Module si echipamente specifice celulelor si sistemelor flexibile. Calitatea si receptia masinilor unelte,* Ed. Univ. din Oradea, ISBN 978-606-10-0339-6, Oradea, 2010

[13] Manlay, J.F., *Fast checking of CMM geometry with a patented tool.,* Academia, https://www.academia.edu/71351369/Fast_checking_of_CMM_geometry_with_a_patented_tool, 2016
[14] Ferreiraa, F.A.M., Olivab, J.V., Perezc, A.M.S., *Evaluation of the performance of coordinate measuring machines în the industry, using calibrated artefacts.,* Procedia Engineering, https://www.sciencedirect.com/science/article/pii/S1877705813014458, 2013
[15] Hammad Mian S., Al-Ahmari A., *New developments în coordinate measuring machines for manufacturing industries.,* https://www.cambridge.org/core/journals/international-journal-of-metrology-and-quality-engineering/article/abs/new-developments-in-coordinate-measuring-machines-for-manufacturing-industries/6CAAC535F90BC212F3838FA012185D17, 2014
[16] Vidosav D. M., Numan D., Yasuhiro T., Slavenko S., *Advanced Manufacturing Metrology in Context of Industry 4.0 Model,* SpringerLink, https://link.springer.com/chapter/10.1007/978-3-030-18177-2_1, 2019
[17] Mahmood, K., A Performance Evaluation Concept for Production Systems in an SME Network., Procedia CIRP, https://www.sciencedirect.com/science/article/pii/S221282711830341X, 2018
[18] Majstorovic, V.D., Stojadinovic, S., *Cyber Physical Manufacturing Metrology,* Iopscience, https://iopscience.iop.org/article/10.1088/1757-899X/968/1/012001, 2020
[19] https://vantage-corp.com, 2022
[20] https://aat3d.com/cappsnc-on-machine-measurement-software/, 2023
[21] https://aat3d.com/cappsnc-on-machine-measurement-software/, 2023
[22]https://www.diatest.com/en/products/automated-measurement-and-complex-measurment-solutions/automatic-measurement-in-cnc-machines/, 2023

INTERCONECTIVITATEA DINTRE CNC ȘI CMM PENTRU PRODUCȚIA DE SERIE, STATUSUL ACTUAL AL TEHNOLOGIEI ȘI NOI DIRECȚII DE DEZVOLTARE

Rezumat: La momentul actual am identificat mai multe sisteme de măsurare și control dimensional, care sunt integrate în procesele de producție. Aceste sisteme pot evalua în mod direct procesele de prelucrare CNC, sculele și parametrii pentru corecțiile acestora și în celule integrate pot evalua procesul prin analizarea rezultatelor măsurate. Pentru nivelul tehnologic actual putem identifica mai multe soluții tehnice specifice pentru fiecare proiect. În acest articol, pe baza noilor opțiuni de programare valabile la software-ul CMM-urilor am identificat oportunitatea de a introduce CMM-ul în procesul de fabricație, nu ca un element pasiv de informator cu privire la rezultatele măsurate, care poate maximum să oprească CNC-ul, ci ca un element activ, care să transmită corecțiile necesare reglării CNC-ului și raportul dimensional către inspectorul de calitate.

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