CONNECTIVITY AND AUTOMATIC DATA COMPENSATION ON MACHINE TOOLS

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(VERIFICATION BY MEANS OF OPTICAL SYSTEMS, COMMUNICATION AND AUTOMATIC COMPENSATION ON THE MACHINE TOOL ITSELF).

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Abstract: Tool wear is a common problem in CNC (Computer Numerical Control) lathe machining. This problem can affect the quality of the parts produced, increase machine downtime and generate additional costs due to the need to replace worn tools frequently. This error must be manually compensated for in the CNC's own wear tables.

This project is generated in order to address this problem. We integrate a CNC with a Vici Vision optical measuring machine, communicating both machines and carrying out automatic wear compensation on both machines, using TWC (Tool Wear Compensation) software.

The solution is to integrate advanced monitoring and control technologies, such as process sensors, machine vision systems and real-time data analysis algorithms in the CNC. The idea is to detect and predict tool wear early and accurately, allowing preventive or corrective measures to be taken to minimise its impact on production.

A non-automated smart cell is generated, compensating the values automatically. This autonomous smart cell exemplifies how Industry 4.0 is transforming manufacturing by improving the automation, intelligence and flexibility of industrial processes. This enables companies to increase efficiency, reduce costs and improve the quality of their products, making them more competitive in the global marketplace.

In short, collaboration between Industry 4.0 projects and companies such as Vici Vision seeks to develop advanced solutions to address typical CNC lathe machining problems such as tool wear. By leveraging emerging technologies and data analytics capabilities, these solutions aim to improve the efficiency, quality and reliability of manufacturing processes in increasingly automated and connected industrial environments.

1. Research challenge

The project is based on the communication and automatic compensation between 2 machines. Specifically, between a CNC lathe with Fanuc 32i control and a Vici Vision Machine. The measuring machine measures the part and automatically sends to the production machine the corrections it has to make if the part is out of tolerance. Possibility of generating an intelligent cell, as the compensation between the measuring machine and the production machine is automatic (See Fig1.)

Figure 1 Image of the two machines used in the project

The lathe is a 3-axis CNC turning centre with Fanuc32i control. The Measuring System is an Optical Measuring System designed to measure parts of revolution. This measuring machine has high accuracy and is very useful for measuring bevels, radios, geometrical tolerances (see Fig2.)

Figure 2 Image Checking a part on the Measuring Machine

Both machines are connected via Ethernet, the communication is carried out by means of the Wlynx program. This program has to be parameterised both for control communication and for selecting variables such as: general tolerances, critical tolerances, sample sizes and other variables (see Fig3.)

Figure 3 Image of the TWC compensation and communication software

Once the production process is running, the Wlynx program sends compensation data to the Fanuc32i control's Wear table (see Fig4.) according to the measurements taken on the Vision Machine, with the aim of achieving Zero Defective Parts, "Zero Defects".

Figure 4 Fanuc32i control wear table image

2. Process and methods

First of all, a part had to be **designed** for the test. We selected a part with some specifications to avoid contamination from other Machine Tool error variables. We took into account that the machine tool in general has 21 geometric errors.
For example, for these tests, the Geometric Error of the 2 axes (X,Z) and the interpolation error of the 2 axes were of no interest. To avoid this interpolation error variable between the axes, we avoided designing curvatures or spheres in the prototype . (International Organization for Standardization , 2012) (International Stardazitation Organization, 2014) (International Standartization Organization, 2022)

The first prototypes were machined without any type of compensation .

When machining the parts, the cutting conditions must be suitable so that the parts have an acceptable roughness. The maximum roughness parameter has to be below Ra3.2 microns. Poor part roughness can lead to incorrect Vision Machine Measurement.

We have taken into account these variables for the quality of the Measurement

- Avoiding 21 Machine Tool Geometric Errors in the Prototype of the Part Design (International Organization for Standardization , 2012) (International Stardazitation Organization, 2014) (International Standartization Organization, 2022)
- The machining strategy. Selecting an incorrect machining strategy can lead to incorrect measurements due to possible part burrs, which also affect the Optical Measurement of the Vision Machine.
- The cleanliness of the parts is another factor for proper measurement on the Vision Machine, free of chips or other matter. Important is the machining strategy to achieve a burr free part.
- Finally, another variable to take into account is the temperature of the part. In the case of the study, the prototype was designed with reduced dimensions to minimise the effect together with a correct machining strategy to avoid overheating of the part.

An important step is to parameterise the 3 programs used in the project FANUC, TWC, Wlyncs. This section of parameterisation requires adequate training for the correct communication and transfer of values.

The programme of the Optical Measuring Machine generates a ".csv" that the Wlynx programme uses for the transfer, generating a control graph with the deviations and compensations (See Fig2.).
Another important point **is the transfer** of data. The transfer of the values has been a key point, since at the beginning the transfer was not correct, an error of a decimal in the transfer was made. It was necessary to enter in files of the own folder of installation of TWC (Tool Wear Compensation)

The next step would be **the verification** of the first parts using the Vici Vision machine (see Fig.3).
Automatic transfer of the values and automatic compensation of the part errors to the wear table of the Fanuc32i Control (See Fig.4).
Once the transfer of the part errors had been carried out, the second series of parts was machined.

The last step is **to check** that the second series of parts with the active compensation in the wear table, sent previously by the TWC program, has been effective.

It is checked on the Vici Vision machine whether the parts are machined within the set parameters and tolerances.

3.Results

The first result to highlight is the **communication o**btained by means of a Production machine and an Optical Measuring System, by means of ETHERNET cable and TWC software. Communication was one of the most important milestones of the project. At first there was no communication between the two machines.

To achieve this milestone, it was essential to select a specific cable and parameterisation of the 3 controls. The Fanuc32i Production machine control, the MTL Vision Machine Software, and the TWC communication software.

For the correct communication among the three software, FANUC, TWC and Wlynx, the connecting file format needs to be a ".csv" file, otherwise there is no communication

The **correct parameterisation** of the TWC (Tool Wear Compensation) software is important, in which the number of samples to apply the tolerance threshold can be selected and the uncertainty of the measuring equipment itself can be taken into account, together with other fields to be parameterised depending on what is to be achieved.

The TWC program developed by Vici Vision, possibly for use in the field of industrial automation or machinery. "Tool wear compensation" typically refers to a feature or capability within software used in manufacturing or machining processes.

Tool wear compensation is a technique used to adjust machining parameters based on the wear and tear experienced by cutting tools during the manufacturing process. As cutting tools are used, they gradually wear down, which can lead to deviations from the desired dimensions and surface finish of the machined parts.
The software TWC (Tool wear compensation) allows to automatically adjust machining parameters, such as feed rate or cutting speed, to compensate for this wear and maintain the desired level of precision in the finished parts.

In the context of Vici Vision El software, Tool Wear Compensation might be a feature that helps users optimize machining processes by automatically adjusting parameters based on real-time feedback about tool wear, ensuring consistent quality and accuracy in manufacturing operations.
Once we achieved the desired communication and wear compensation level, the produced part characteristics are correct. And the next series of parts produced were actively compensated, machining all the parts with the required specifications.

The overall **results** have been very satisfactory. The company itself had the need to carry out tests and parameterise both controls, that of the Vision Machine and that of the Production Machine itself.

Both entities, the company and the schools, have benefited from the interaction that has arisen from the project, and we had both gained knowledge at the same time. It has been a trial and error process.

We have **learned** the reality and complication of establishing communication between different machines, one a Production Machine and the other an Optical Measuring Machine, two different "worlds" such as metrology and production, which in this project have been combined to give a satisfactory result.

College teachers were unaware of the problems of optical measurement in the process. They had to acquire knowledge in this field. How to modify programmes and suitable cutting conditions to avoid errors in the measurement process, such as roughness, burrs and temperature.

On the part of the company, they did not know the world of Production and its complexity, as it was a Metrology company, and they did not have the knowledge of a Production Machine. Concepts such as Geometric Machine Tool Errors. Influence of these errors in the project and in the in-process measurement by the company was very satisfactory.

The company was also unaware of various concepts such as the concept of the "Wear table" of the Fanuc32i control, a very important concept as this table is the basis for the communication and compensation of the deviations measured in the process. Concepts such as "Geometry Table", whose communication is possible but not recommended. Or the concept of part origin on the machine tool, a vital concept in CNC lathe machining.

4.Potential applications

In-process verification and above all communication between machines, with **intelligent communication** being an added value, is an increasingly demanded requirement in the context of Industry 4.0.

Machine-to-machine communication, and especially intelligent communication, is a requirement and a reality in today's industry. The automatic compensation of errors in the process, and the fact that the machines themselves are automatically compensated in a loop without human intervention, is a necessity in industry.

In-process verification using a Vici Vision machine offers a number of significant advantages over other verification methods. Some of these advantages include:

High accuracy: The Vici Vision machine uses advanced coordinate measuring technology that offers exceptional accuracy in verifying dimensions and tolerances. This ensures that manufactured parts meet design specifications with high accuracy.

Measurement speed: The Vici Vision machine can measure quickly and efficiently, allowing for agile in-process verification without production delays. This is especially beneficial in high-speed manufacturing environments where fast feedback on part quality is required.

Automation: Automation of the verification process using the Vici Vision machine enables continuous operation without human intervention. This reduces the possibility of human error and increases measurement consistency, resulting in greater reliability of results.

Full inspection capability: The Vici Vision machine is capable of inspecting a wide range of features and geometries, including complex shapes, irregular surfaces and fine details. This provides a comprehensive assessment of the quality of the part in process, identifying any deviations or defects accurately.

Detailed report generation: The Vici Vision machine can generate detailed reports on measurements taken, including numerical data, graphical representations and comparisons with design specifications. These reports are useful for quality control, trend analysis and documentation of compliance with manufacturing standards.

In summary, in-process verification using a Vici Vision machine offers key benefits in terms of accuracy, speed, automation, inspection and reporting capabilities, contributing to improved quality and efficiency in part manufacturing.

The potential application of this project opens a very interesting field in several fields such as:

1-**Creation of an Intelligent Cell**. Once both machines are robotised, by having intelligent communication between the 2 machines as the compensation is done automatically, an autonomous intelligent cell could be generated. Control process automatically with the aim of making "ZERO DEFECTS" key points in the context of industry 4.0.

2-The effectiveness of the compensation has been demonstrated with the Fanuc32i control. Tests with **other controls** such as: FAGOR, Heidenhain, Siemens, etc. are still to be carried out.

3- This project opens another door which would be **the digitization of the production process** and the analysis of data in the cloud.

INFORMATION ABOUT THE PARTICIPATING AGENTS

This project was generated by a phone call from a Metrology company in the area called SARIKI, to “**Armeria Eskola.** The company wanted to test their new In-Process Verification product with the aim of generating non Defective parts. The resources required by the Metrology company were: A Fanuc 32i CNC lathe and the workshop itself in order to carry out communication and compensation tests between a Vici Vision Measuring Machine and a Production Machine.

The project was developed between a private metrology company and two VET Centres, The “Armeria Eskola” and “Fadura Eskola”.

The “Armeria Eskola” is a public vocational training centre in the town of Eibar in Gipuzkoa, the Basque Country, Spain. It was the first Spanish vocational school in which the learning of a profession was accompanied by theoretical and technical teachings. It was based on the "École d'Armerie" in Liège (Belgium).

The Armeria Eskola is an integrated public vocational training centre. This centre offers 8 study programs in three study fields, electricity and electronics, manufacturing and mechanical maintenance.

Involved in several national and international projects as well as collaborations with companies through Tkgune (network formed by VET centres).

The CIFP Fadura LHII is an Integrated Vocational Training Centre with a wide offer both in Regulated Training and in Continuous and Occupational Training, as well as other services for a wider public (Lanbide, Learning Mediation, Services to companies...).

Sariki is a company that was founded in 1985, [2] Sariki Metrology was born to cover the entire Mitutoyo product in Spain, but direct contact with customers and direct involvement in solving their dimensional measurement needs has led to research projects in the area of Metrology in the industrial sector of various types.

5.REFERENCES

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IMAGES TABLE