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CYBER PHYSICAL MANUFACTURING – INTEGRATED QUALITY APPROACH

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Abstract. *Cyber-Physical Manufacturing System (CPMS), relying on the newest and foreseeable further developments of computer science, information and communication technologies, on the one hand, and of manufacturing science and technology, on the other hand, may lead to the 4th Industrial Revolution. In order for that to happen we must face the challenges of operating sensor networks, handling big bulks of data, as well as the questions of information retrieval, representation, and interpretation, with special emphasis on security aspects. Novel modes of man-machine communication are to be realized in the course of establishing CPMS.In our Laboratory, in CPMSs we doingnext researches areas: (i) Digital Manufacturing – Towards Cloud Manufacturing (base for CPMS), (ii) CPMS – Cyber-Physical Quality Model (CPQM) our approach and (iii) Intelligent model for Inspection Planning on CMM as part of Cyber-Physical Manufacturing Metrology Model (CPM3) concept. In this paper we shall show some research results for these areas.*
Key words:*Cyber-Physical Manufacturing, Quality, CMM.*

1.INTRODUCTION REMARKS

Digital quality, as a key technology for CPMs represents virtual simulation of digital inspection in digital company, based on a global model of interoperable products (GMIP). GMIP represents the integration CAD-CAM-CAI models in the digital environment. The essence of this research is solved the concept of metrology integration into GIMP for the coordinate measuring machine (CMM) inspection planning, based on CPM3 [8-11,12a,30].Today's business structure is much more complex and dynamic than ever before, because market demands of the industry's rapid changes in new products, which is directly reflected in the factory. On the other hand, digitalization and information technology (IT) provide new, unimagined possibilities, engineers in the field of design and planning. The two approaches have led to two concepts that have since emerged: digital factory and digital manufacturing [1,23,24,30].

For a manufacturing system with typical machining operations, factory-wide engineering knowledge integration requires an connection CAD-CAPP-CAM-CNC-CAI and integration with other production-related information systems such as enterprise resource planning (ERP), manufacturing execution system (MES), advanced planning and scheduling (APS), etc [25,30]. A standard for the exchange of product data model (STEP), along with a STEP compliant numerical control (STEP-NC), has been developed to enable integration and exchange of design and manufacturing numerical data. STEP is based on feature technology, and it provides a neutral and interoperable format of product data, independent of any system and suitable for transfer, processing and communication among different systems. Feature technology provides us to associate not only geometric and topological information, but also form features and tolerances that could be used in CAD-CAPP-CAM-CNC-CAI chain [4,8-11,26-30].

2.CYBER PHYSICAL MANUFACTURING SYSTEMS (CPMSs) - BASIC CONCEPT

Developed and implement ’’advanced manufacturing concept’’ as a base for Cyber - Physical Manufacturing Systems (CPMSs), will be to evolve along five directions [13,18-22,27,28,30]: (i) on – demand manufacturing: Fast change demand

from internet based customers requires mass-customized products. The increasing trend to last-minute purchases and online deals requires from manufactures to be able to deliver products rapidly and on-demand to customers; (ii) optimal and sustainable manufacturing: Producing products with superior quality, environmental consciousness, high security and durability, competitively priced. Envisaging product lifecycle management for optimal and interoperable product design, including value added after-sales services; (iii) human - centric manufacturing: Moving away from a production-centric towards a human-centric activity with great emphasis on generating core value for humans and better integration with life, e.g. production and cites; (iv) innovative products: From laboratory prototype to full scale production – thereby giving competitors a chance to overtake enterprises through speed, and (v) green products: for example Manufacturing Strategy 2020/30 needs focused initiatives to reduce energy footprints on shop floors and increase awareness of end-of-life (EoL) product use, and there are framework for CPMSs.The merging of the virtual and the physical worlds through CPSs and the resulting fusion of manufacturing processes and business processes are leading the way to a new industrial age best defined by the INDUSTRIE 4.0 project's "smart factory" concept [7,27-30].

Smart factory manufacture brings with it numerous advantages over conventional manufacture, as example [3,6,27-30]: (i) CPS - optimized manufacturing processes: smart factory "units" are able to determine and identify their field(s) of activity, configuration options and manufacture conditions as well as communicate independently and wirelessly with other units; (ii) Optimized individual customer product manufacturing via intelligent compilation of ideal production system which factors account product properties, costs, logistics, security, reliability, time, and sustainability considerations; (iii) Resource efficient production; and (iv) Tailored adjustments to the human workforce so that the machine adapts to the human work cycle.

3.RESEARCH IN THE FIELD OF CYBER-PHYSICAL MANUFACTURING QUALITY MODEL IN OUR LAB

Feature-based technology and STEP standard could be considered as a main integrator in terms of linking the engineering and manufacturing domain within various CAx systems. To specify the part data representation for a specific application, STEP (ISO 10303) uses Application Protocols (AP). Beside STEP APs, the following standards and interfaces are important for CAI. A vendor-independent Dimensional Measuring Interface Standard (DMIS) provides the bidirectional communication of inspection data between systems and inspection equipment, and is frequently used with CMMs. It is intermediate format between a CAD system and a CMM's native proprietary language[11,26],

Dimensional Markup Language (DML) translates the measurement data from CMMs into a standardized file that could be used for data analysis and reporting. I++ DME-Interface provides communications protocol, syntax and semantics for command and response across the interface, providing a low level inspection instructions for driving CMMs [15,16], On Fig. 1. show the working process with the integration of design, production and coordinate inspections. Master Assembly represents the mechanical assembly with all associated parts. This assembly consists upper and lower tools and wind turbine. The experiment was done on the bottom of the tool CAM or CAI is executed in a separate part-file that consists the original geometry of the part. Only this way it is possible to make changes on the original geometry that can reflect on some of the engineering activities. Part file CAD/CAM is usually obtained as STEP AP203 or AP214. It represents the basis for the preparation of manufacturing technology. At the same time a geometry inspection is being prepared so that when a part is manufactured, its inspection can be implemented on the CMM. As an output from CAD/CAM, STEP AP203/214 is obtained which is the input for PC-DMIS Wilcox. S/W Wilcox PC-DMIS uses its integrated translator to convert it into DMIS format. At this stage GD&T and the motion of measurement probe are defined. Based on the acquired measurements, „DMIS output" was generated which can be a printed report or STEP too, but now with measured geometry. This STEP can be loaded again into a CAD/CAM system or some other coordinate system for inspection, and contents for the same part of DMIS file (Figure 14), give procedure CMM inspection.

The measurement was performed in Decartes coordinate system XYZ and measurement analysis is presented in the on Fig. 2. Measured values should be within a tolerance field +0.15mm -0.35mm as shown in the flowchart with a blue dashed line.Blue solid line represents the theoretically ideal surface while the red line represents the measured value. By analyzing the flowchart, we can conclude that the measured values are within the limits of the tolerance field.

The analysis of the measured values indicate that the measured surfaces are within the limits of specified tolerance field.

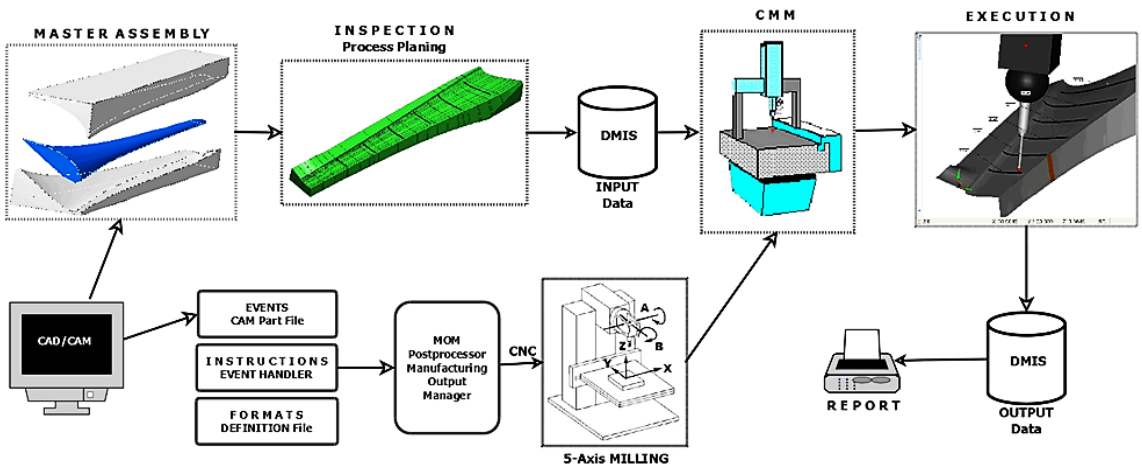

Figure1. Process with the integration of design, production and CMM inspections

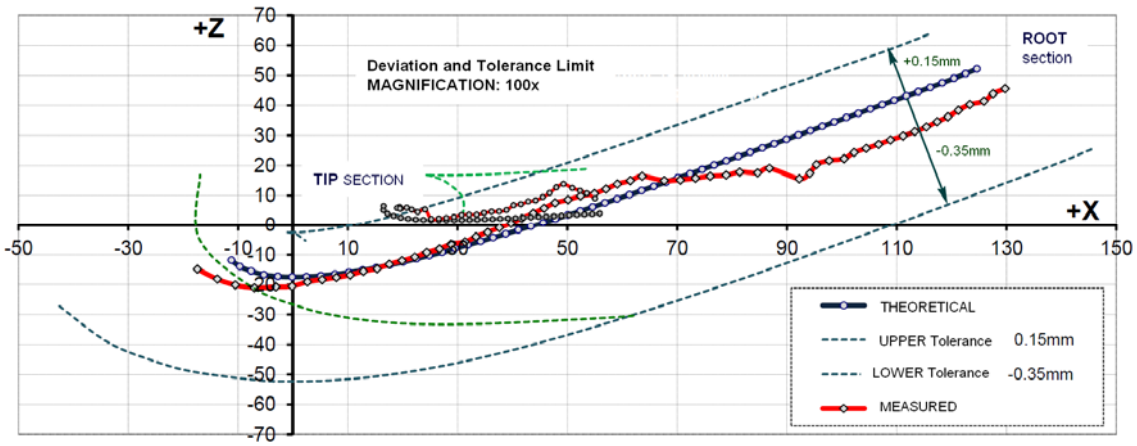

Figure 2. Graphical presentation of measurement results

The development Intelligent model for Inspection Planning (IMIP) for prismatic parts involve following activities: (i) development ontological knowledge base presented in [12,16]; (ii) local and global inspection plan, and (iii) optimize path of measuring sensor. Output from the local and global inspection plan (LGIP) is initial measuring path. The first element LGIP's is sampling strategy or model for the distribution of measuring points for features presented in [14-16], and second element define the principle for collision avoidance between workpiece and measured probe. By modifying the Hemmersly sequences [17], we define the distribution of measuring points for basic geometric features such as plane, circle, cylinder, cone, hemisphere, truncated hemisphere and truncated cone.

4.CONCLUSION

In the first part of the research it was shown SPMSs for quality as a CAI model, it is important to consider the newly developed AP242 that is designed to improve the interoperability in STEP, support model-based GD&T and allows for CMM programming based on the inspection features. AP242 enables 3D product manufacturing information (PMI) with semantic representation and 3D model-based design and data sharing on service-oriented architecture (SOA).

The complex geometry of the PP by IMIP changes to the set of points whose sequence defines the measuring path of sensors without collision with workpiece. Presenting measuring path by set of points with a defined order is optimizing by solving TSP with ants colony. Finding the shortest measuring path, the main criteria for optimization, influence to the reduction of the total measurement time, which is one of the goals of this research. The ISIP is especially suitable for use in case of measuring path planning for geometrically complex PPs with large numbers of tolerances. The simulation provides a visual check of the measuring path.

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