Virtual Simulation of Automatic Quality Measurement System for Tapered Roller Bearing Based on 3D Automate Software

Alhadi Khilil\textsuperscript{1, a}, B Ma\textsuperscript{1, b} and Z Shi \textsuperscript{1, c, *}

\textsuperscript{1} School of Mechanical Engineering, Hebei University of Technology, Tianjin, 300130, China

\textsuperscript{a} 20174000010@stu.hebut.edu.cn; \textsuperscript{b} lymabotong@126.com; \textsuperscript{c, *} z_shi@hebut.edu.cn

Abstract. In present years, the simulation technique has been extensively used in manufacturing processes, solving complex problems with least time, effort and cost. This paper presented a virtual simulation of automatic quality measurement system for tapered roller bearing to aid the decision-making processes, observe system operation processes and provide an initial design for constructing processes using 3D modeling process and Python programming language, the proposed system was intended to check the tapered roller bearing dimensions and to achieve the prescribed goals, the 3D model was built, the virtual environment has been created and the motion control process was applied in 3DAutomate software.

1. Introduction

Nowadays, small and medium industrial companies have the vision to improve their production capability through the automation of various manufacturing facilities and computerization of numerous functions. Since the 1990s, the increasing demand for enhancing the quality of production and efficiency has progressively led industrials to seek solutions of computer software to master the various processes of production \cite{1}. In this context, virtual simulation technology has a huge contribution, it allows simulating the modeling of the production systems, machine installation, and testing the different setup configurations of the virtual system before the actual installation, another major function of the virtual simulation is to provide the real-3D world for decision-maker to observe the running of system \cite{2}.

Virtual simulation is “a technology that combines software tools and other equipment to set up an immersive interactive experience that simulates a real-world scenario in virtual mode”, it used in various fields such as mechanical engineering, mining, civil engineering, etc. this technology can empower the industry decision-making process to be faster and more powerful, and it changed the ways scientists and engineers look at computers for performing data visualization and mathematical simulations \cite{3}. Generally, virtual simulation intended to reduce production cost, time and effort, which can aid small and medium enterprises to adopt global competition, improve their production capability without a huge investment. Therefore, this paper introduces an automatic quality measurement system for bearing. The proposed system was predicted to measure the tapered roller bearing dimensions that shown in figure 1b such as outer diameter, inner diameter, etc. then evaluate and save the process data to build up a production database for the product life cycle. The 3D Automate simulation tool will be used to creating the virtual simulation processes.
2. Related works
Virtual simulation technique involves building a model that represents a real or an existing system [4]. People from various backgrounds and expertise are called upon to use Virtual simulation to solve issues that arise during the design process and it facilitates communication across different disciplines in the project, getting a diverse group to fully understand a particular issue and contribute input from each perspective to achieve good design. A survey conducted in industry sector use of Virtual simulation in product design and manufacturing, the results indicate that Virtual simulation has extremely flourished in the last twenty years [5]. Another study by [6] used modeling simulation technique with ProModel software to measure the capacity of an existing mattress production line and simulate the ability of the improvement for the next five years, the result was clearly shown the suggested requirement of the improvement scenario and its percentage within the exact period. Also [7] are used the virtual simulation for iCIM3000 flexible manufacturing system, to discover the efficiency improvement possibilities of the whole system and the effectivity of its individual devices, CATIA CAD software had been used to create a static CAD model and HTC Vive glasses headset with Simulation software, the result illustrate the optimum simulation scenarios.

3. The structural design of the virtual simulation
This study considered the tapered roller bearing during the manufacturing processes as experimentally sample shown in figure 1a, which consist of a cup, roller, cone, and cage. Through the recommendations made by the manufacturer, the Cone is the main part of the tapered roller bearing. Therefore, this study will adopt the Cone dimensions illustrated in figure 1b as the references for design and create the virtual simulation of the system, figure 2 shows the Structural design of this virtual simulation.

3.1. System planning
According to the experiment sample (Cone) dimensions illustrated in figure 1b, the Initial design of the system mainly consists of three Platforms, the first Platform uses two electro-pneumatic sensors to measure the outer diameter of the cone d1 and d2, then detect another two points to check the tapered slop angle $\gamma$. The second Platform uses other sensors to measure the height of the Cone (B) and the height of the back flange (C1). The third Platform uses an electronic plug gauge to measure the inner diameter of the Cone (d). Then all measurement data were collected will be sent to the control unit to
analyse, evaluate and save. Table 1 shows the simulation components, and figure 3 illustrates the processes sequences between the system components.

![Diagram](image_url)

**Figure 3.** The measurement process system sequences

| Component Name                  | Numbers | source              |
|--------------------------------|---------|---------------------|
| Lathe machine                  | 2       | 3D Automate         |
| Quality Measurement Platform   | 3       | (UG) NX software    |
| Converyer Belt                 | 4       | 3D Automate         |
| Robot Arm                      | 3       | 3D Automate         |
| Work piece                     | 1       | (UG) NX software    |

### 3.2. 3D Modeling

The 3D Modeling is “the process of manually creating geometric object models which meet desired design criteria” [8] and Computer Aided Design (CAD) software are used. The increasing power of CAD software has a significant impact on the product development process, allowing improved quality, reduced cost, and aids products to get to market faster [9]. Nowadays, there are many different CAD software packages for different purposes are available such as CATIA, SolidWorks, and AutoCAD. In this study UNIGRAPHICS (UG) NX software package from Siemens has been chosen. It is one of the world’s most advanced and tightly integrated CAD/CAM/CAE product development solution [10]. The software has been used for building and visualizing the experimental prototype components, figure 4 shows the assembled model of Platform 1 in order to export it to 3D Automate software.
Figure 4. The assembled model of Platform 1

3.3. Virtual Simulation Environment

There are several issues associated with the proper development of virtual simulation environments including the translation of data generated by (CAD) systems, implementing the physical behaviour and constraints of objects, collision detection [11]. The 3D Automate software will be used, it is the powerful, flexible, and scalable platform for 3D manufacturing simulation solutions to support critical planning and decision-making processes. To create the intended Virtual Simulation the steps shown in figure 5 will be followed:

- Import the CAD model into 3D Automate software. Rendering and organizing the models set in one parent geometry set.
- Create moving joints, which means split the joint geometry set form the parent geometry and transfer it to a new link to become an independent interactive joint.
- Add components from works library, 3D Automate software provides hundreds of industrial components and facilities which can be used to create a virtual simulation where we used several components such as lathe machines and conveyors.
- Organized the 3D world, rearrange the imported and added components into the simulation interface.
- Tasks and machining processes, these processes will be done for the components which added from works library, by creating a virtual network to implement the intended tasks and exchanging signals.
- Programming processes, it will apply on the imported models to implement the desired functions using an object-oriented programming language is called Python.
- Virtual Simulation Environment, testing and modifying the system to confirm the required motion control and proper operation sequences

Figure 5. The steps of creating the Virtual Simulation

- Import the CAD model
- Create moving joints
- Organize the 3D world
- Programs processes
- Virtual Simulation Environment

- Add component from Works library
4. Simulation Result
Based on the stated objective, the final virtual simulation environment was built as shown in figure 6, including the tow CNC lathe machines feed it by Conveyor 1 and Robot1, conveyor 2 received the product from the production line and send a Boolean Signal to Robot 2 to pick the product to feed the Platform 1 and send a signal to execute the measuring processes, Robot 3 received a signal from Platform 1 to remove the product and feed Platform 2 and Platform 3 respectively, it also controlled the signals to execute the measuring processes, and received the signals to remove the product. The system ended with tow conveyors, used for separating the accepted or rejected products as a result of measuring and evaluation process. ATA _Report Output storage are attached to the conveyers to calculate the production rate.

![Figure 6. The virtual simulation environment](image)

Finally, it can be said that the simulation provides the product flow process for the entire system in the real world which allow the intended user can observe and check the operation process sequences and design of the system structural elements to support decision-making processes. In addition, many different scenarios have been implemented to get the optimum design and simulation result which will strongly aid the construction process of the experimental prototype.

5. Conclusions
Virtual simulation one of the most recent useful tool in the industry sector, it used to develop a simulation of an Automatic Quality Measurement System for tapered roller Bearing attached with an existed production line, the construction of 3D modeling has been done in (UG) NX, 3D Automate is considered for the virtual environment. The current simulation providing the real world to aid the decision-making process and optimum scenario for the experimental prototype construction process. In general, the developed system was intended to reduce the production cost, time and effort, improve the production capacity without a huge investment.
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