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Implementation of Augmented Reality Applications to Reduce Errors in the CNC Machining Process

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Abstract: Nowadays, one of Industry 4.0 technologies, such as Augmented Reality (AR), has been increasingly applied in the manufacturing industries of the metalworking process as a technological application tool whose main objective is to optimize the manufacturing process. This technology can increase the visual experience of the user. At the same time, it results useful due to the great diversity of applications it can be implemented.
This research project aims to implement an AR application tool to reduce errors in the machining processes by Computerized Numerical Control (CNC) to help CNC machine operators work more efficiently through virtual environments. With the application of this project, we pretend to offer an alternative low-cost solution that can be used by companies in the metalworking sector of CNC machining, which will provide the following benefits: optimizing manufacturing processes, improving the efficiency of manual assemblies, accelerating the training of operating personnel, improve efficiency and safety of the operator in maintenance and reduction of manufacturing costs.

Keywords: Augmented Reality, Computerized Numerical Control, Metalworking, Industry 4.0, Manufacturing Processes

1. Introduction

Currently, CNC precision machining has been widely used in the manufacture of products mainly focused on industries such as aerospace, automotive, mold manufacturing and other types of products that demand high production volumes, precision and surface quality. In this sense, Rizvi (2021) conceptualizes CNC manufacturing technologies as the process to transform a digital model into a machined component from a stock model (raw material), using cutters and numerical control programs. On today, the use of industry 4.0 technologies such as Augmented Reality (AR) are increasingly being integrated into Computer Aided Design and Computer Aided Manufacturing (CAD / CAM) applications. Zaki et al. (2019) defines AR as one of the current trendiest technologies where you can create and visualize digital solutions applied to solve problems in the real world. In the same way, Marinakis et al. (2020) mention that AR can offer valuable training for the interpretation of complex models drawn in CAD, which frees up time to explain and describe complex computational geometric processes related to CAD / CAM. On the other hand, Setti A. & Bosetti P. (2018) ensure that the AR application is intended to help machine tool operators in the configuration of the machining process, simplifying and accelerating the identification of configuration errors and misalignments. Finally, Segovia et al. (2015) found that, when applying AR in technician training, errors and the time required to perform machining and sizing of a part can be greatly reduced, as well as eliminating the dependece on expert operators.

2. Method

In this paper, we will analyze the factors that generate errors in the CNC machining process of two leading companies in the area of precision machining. A quantitative analysis of the data is used, based on the Failure Mode and Effect Analysis (FMEA) methodology to identify and classify errors by their critical level.

The objective of this investigation is to prove how the AR can help to the CNC machines operators to guarantee the quality of the products by reducing the errors.

2.1. Data collection and analysis of errors that occur in manufacturing processes by CNC machining

For this study, two machining companies Auma and Honeywell Areospace provided information on their own particular problems that arise in their machining processes. In the case of company Auma located at the west of Chihuahua City, 96 Causes of failures in the D66 rear area machining process was reviewed in an FMEA analysis. From a total of 96 causes of potential failures, the 3 failures with the highest levels of occurrence and detection that obtained the highest cause-effect score were selected. In Table 1 the risk level (NPR) is evaluated by calculating the severity value with the highest levels of occurrence.

Table 1. AMEF applied at rear D66 line (Auma Grupo Bocar, 2021).

MODO POTENCIAL FALLA (POTENTIAL FAILURE MODE)	EFECTO(S) POTENCIAL DE FALLA (POTENTIAL EFECT(S) OF FAILURE)	SEV	CLAS	CAUSAS DE LA FALLA POTENCIAL (POTENTIAL CAUSE(S) OF FAILURE)	CONTROLES ACTUALES DEL PROCESO (CURRENT PROCESS CONTROLS)			DET	NP(P)R
					PR	DETECCIÓN (DETECTION)	DETECCIÓN (DETECTION)		
MACHINING INCOMPLETE	INTERFERENCE FINAL ASSEMBLY AUMA: 100% OF PRODUCTION SCRAP OEM: PORTION OF PRODUCTION SCRAPPED / REJECTED (7) END USER: DEGRADATION OF PRIMARY FUNCTION (7)	8		1) SUJECTION OF PIECE 2) INCORRECT OFFSET 3) FAILURE MACHINE 4)BLUE PRINT INTERPRTATION	2	1) TRAINING OPERATOR, PREVENTIVE MAINTENANCE, AIR SENSORS 2) ADJUSTMENT SHEET, KOR PROGRAM 3) PREVENTIVE MAINTENANCE, TPM	*100% VISUAL INSPECTION ON FINAL STATION (7)	7	112
DIAMETER BIGGER	PIECE WILL NOT ASSEMBLY AUMA: 100% OF PRODUCTION SCRAP OEM: PORTION OF PRODUCTION SCRAPPED / REJECTED (7) END USER: DEGRADATION OF PRIMARY FUNCTION (7)	8	SC-02	1) DIRTY TOOL (BURR) 2) INCORRECT TOOL 3) BROKEN TOOL 4) WRONG MACHINING PARAMETERS 5) TOOL BALANCE 6) RUN OUT 7) MACHINE FAILURE 8) DOUBLE MACHINING	2	1) INTERNAL REFRIGERANT, REFRIGERANT PRESSURE, MACHINING PARAMETERS 2) ADJUSTMENT SHEET, PARAMETERS 3) PREVENTIVE MAINTENANCE, TRAINING OPERATOR 4) PARAMETERS SHEET 5) ADJUSTMENT SHEET, HAIMMER 6) PREVENTIVE MAINTENANCE 7) PREVENTIVE MAINTENANCE, TPM 8) TRAINING OPERATOR, AIR SENSORS	*SAMPLING INSPECTION WITH ELECTRONIC GAGE (6) *SAMPLING INSPECTION ON MMC (6)	6	96
PROFILE OUT OF SPECIFICATION	INTERFERENCE FINAL ASSEMBLY AUMA: 100% OF PRODUCTION SCRAP OEM: PORTION OF PRODUCTION SCRAPPED / REJECTED (7) END USER: DEGRADATION OF PRIMARY FUNCTION (7)	8		1) TOOL VIBRATION 2) TOOL BALANCE 3) WRONG MACHINING PARAMETERS 4) INCORRECT PROGRAMATION 5) FAILURE MACHINE 6) SUJECTION OF PIECE 7) INCORRECT OFFSET 8) SEQUENCE SEARCH (PROGRAM)	2	1) PARAMETERS SHEET, ADJUSTMENT SHEET, PREVENTIVE MAINTENANCE 2) ADJUSTMENT SHEET, HAIMMER 3) PARAMETERS SHEET 4) TRAINING ADJUSTERS & ENGINEERS, CHIP EUCHNER 5) PREVENTIVE MAINTENANCE, TPM 6) TRAINING OPERATOR, PREVENTIVE MAINTENANCE, AIR SENSORS 7) ADJUSTMENT SHEET, KOR PROGRAM 8) INI PROGRAM, KEY MASTER	*SAMPLING INSPECTION ON MMC (6)	6	96

From the previous FMEA analysis, it is determined that the most frequent errors that cause problems in the machining process of the D66 rear area are: failure in clamping the part, interpretation of mechanical drawings, incorrect selection of tools, machining parameters errors and errors in programming.

In the other case, the Honeywell Aerospace company, located south of the city of Chihuahua, provided its own information in an FMEA, of which out of a total of 66 causes of failures in the Case Line area, the 3 failures were selected that obtained the highest levels of occurrence and those that obtained the highest level of severity. The most severe risk level values (RPN) are shown in Table 2.

Table 2. AMEF applied at Case Line (Honeywell Aerospace, 2019).

3° Modo/s potencial/es de fallo	4° potenc /es del	5° Grav ed	6° poten es) del fallo(s)	7° Ocur rencia	ción(es) y/o	Dete cción	10° NPR	) recomend	persona(s) responsable(s) y
PIECE OUT OF SPECIFICATIONS	PIECE NOT ASSEMBLY	9	WRONG MACHINE PARAMETERS RUN OUT MACHINE FAILURE SETUP ERROR	1	Cálculo	1	9		Diseño 30/10/2009
MACHINE FAILURE	PROCESS STOPED		DAMAGE TOOL INCORRECT TOOL BROKEN TOOL INCORRECT MACHINE PARAMETERS	10	Ninguno	10	0	Ensayos	Juan Pérez 02/11/2009
WRONG PIECE	HOLE IN OTHER FACE	9	BAD BLUE PRINT INETRPRETATION	10	Ninguno	10	900	Especificación de resistencia	Diseño 30/10/2009

In the same way, with the previous analysis of the Case Line area in Honeywell, we can determine that the most common causes of failure are: incorrect parameters in the machining, errors in the initial setup, incorrect or damaged tools and problems due to the interpretation of drawings.

2.2. Errors classification by critical level.

According to the previous analysis, most of the critical errors are classified by: 1. Drawings interpretation errors of mechanical parts, 2. Interpretation errors of assembly operations, 3. Setup and initial configuration errors and 4. Errors in the operation process of CNC machines. Table 3 shows the most common causes of these errors.

Table 3. Critical errors classification

Type of errors	Causes
1. 1. Errors in the interpretation of the manufacturing drawings.	Errors when interpreting views (projection type) and cut sections. Lack of knowledge in the interpretation of manufacturing symbols. No idea what the part looks like in 3D
2. Errors in the interpretation of assembly drawings	Interpretation errors in reading drawings of sets of mechanical parts. Failed to interpret assembly views No idea of the assembly sequence
3. Errors in the initial setup of the workpiece and cutting tools	Tools Setup errors Part zero setting error Improper clamping of parts and tools
4. Errors in the operation of the CNC machining process	Improper operation of machines Inadequate machining paremeters (feeds, speeds and cuts) Position errors for tool changes Poor cleaning of tools and work surfaces Errors when not correctly applying preventive maintenance Programing errors

2.3. Proposed solution with application of AR to machining processes.

This project consists of the development and implementation of Augmented Reality Apps (AR-Apps) created and designed by engineers and programmers from the machining area in collaborative work through a Team Center using CAD, AR and programming software. These Apps will be created and installed on mobile devices and tablets ready to be used by operators and technicians in the work area to scan markers or QR codes in worksheets (Datasheets), which will show 3D objects, animations and data in AR following the default forms. and standards so that the user can identify the information and the type of machining process to be carried out. The operation of this application is detailed below: first, a mobile device or AR glasses with a built-in camera will be used to scan reference markers, which through an algorithm developed in the Unity and Vuforia software will display 3D images that will offer detailed information over manufacturing drawings, assemblies, operations and maintenance, offering a guided virtual assistance. The Figure 1 shows the diagram that describes the process of applying AR to the recognition of QR codes.

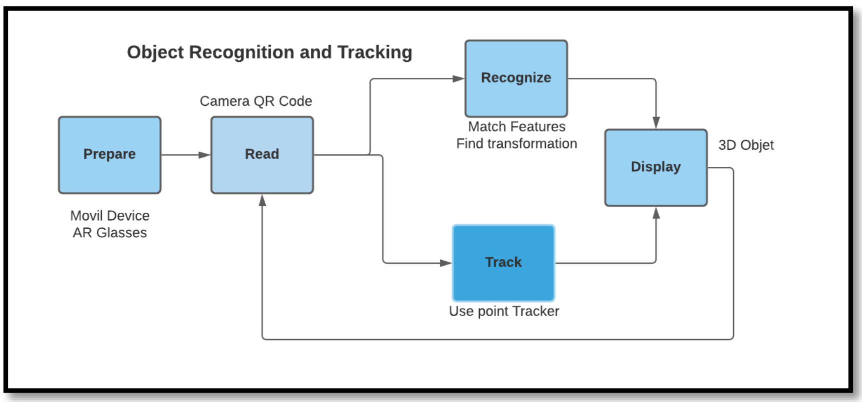

Figure 1. AR sequence operation diagram

3. Results

With the implementation of an AR-App for drawings, interpretation errors were reduced, achieving 0%, The App consists of scanning a QR code which will project a 3D image as shown in Figure 2. This image can be rotated, zoomed in, show cut sections, animate and show information manufacturing that helps process operators avoid misunderstandings in drawings.

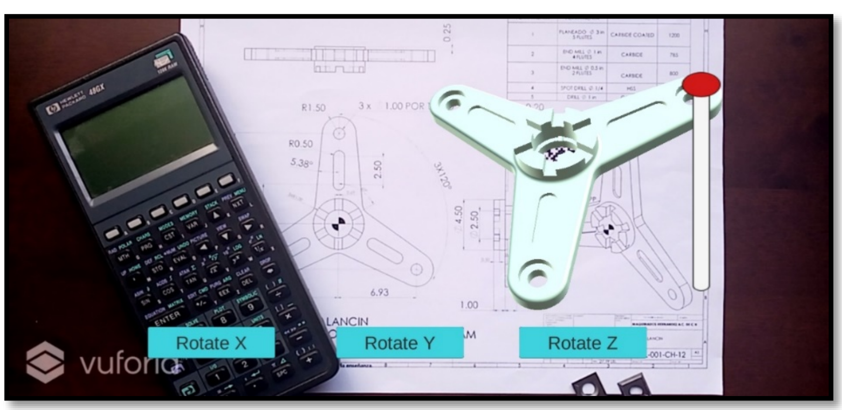

Figure 2. AR-App for manufacturing drawings

With the development and implementation of an AR-App for assemblies, errors in interpretation were reduced achieving 0%. When the operators scan the QR code located in the drawing of the assembly sheet, a 3D of the assembly is shown in an exploded view as shown in Figure 3. With this application it was possible for the operator to zoom, view parts or details internals, rotate, move, sequence assembly, animations, and view project information.

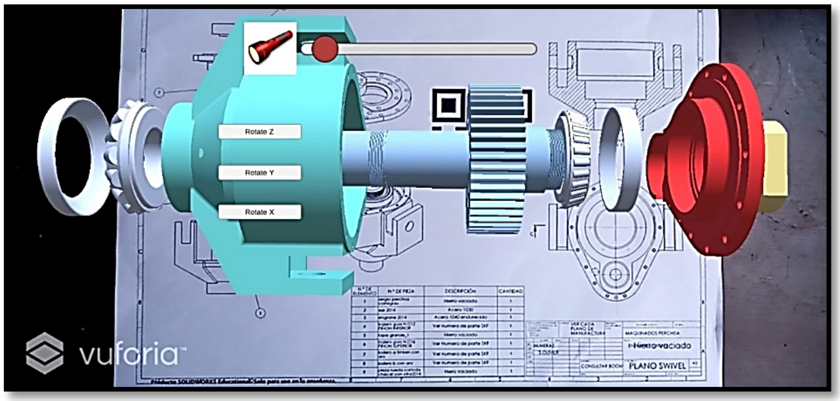

Figure 3. AR-App for drawings of mechanical assemblies.

With the development and implementation of the AR-App for Operations, errors were significantly reduced. When the operators scan the QR code, information such as: types of tools, clamping methods, geolocation of the Work Coordinate System (WCS), configurations and cutting parameters will be displayed as shown in Figure 4.

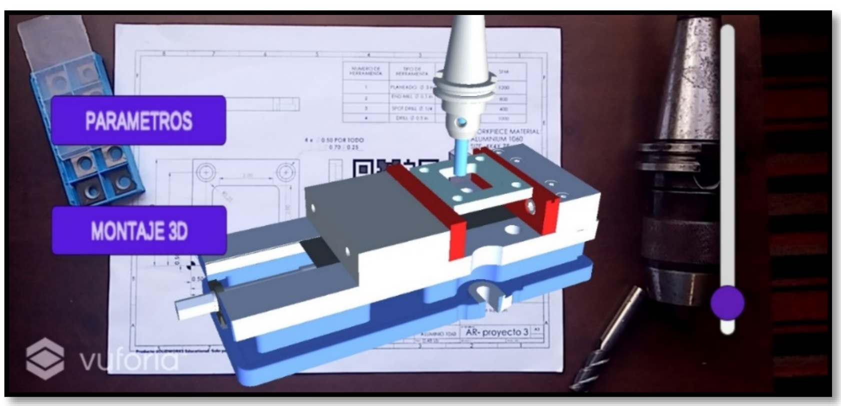

Figure 4. AR-App for Operation and Setup

Finally, the results that were obtained in this project is the reduction of the average times of the Setup in a maximum of 1 minute, reducing *Scrap* and rework by eliminating the errors in 0% that occur in the machining. By reducing these errors, a great number of benefits will be achieved for owners of CNC machining shops, since reducing them will increase productivity, improve product quality, avoid tool collisions, decrease Scrap and rework, in addition it will be verified that the instructions with AR are easy to use and implement. In addition, the AR application provides a better visualization of the values so that operators who lack spatial visualization skills do not comment on errors in the process.

4. Conclusions and Discussion

In CNC machining processes, several key factors must be considered to ensure the optimization of the manufacturing process, if these factors are not well reviewed, errors in the process will originate that can result in additional costs not contemplated that impact losses for the company. The implementation of I4.0 technologies such as AR is a powerful tool to help CNC machine operators to work more efficiently through virtual environments reducing errors and optimizing the machining process, these technologies are useful for modeling and manufacture virtually as they reduce costs, increase yields, improve product quality and shorten the production development cycle. This project offers an alternative low-cost solution that can be used very easily by operators and technicians of CNC machines through the development of specific AR-Apps that solve the problem of errors trough the implementation of applications that result easy to use and economical for companies.

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