



## COB-2021-2353 DIGITAL TECHNOLOGIES IN A MACHINING AUTOMOTIVE INDUSTRY

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**Abstract.** Tupy S.A is a multinational company present in several countries with over 80 years of history in the automotive industry. With a trajectory defined in 3 moments, the company has built and has been building processes and products with quality and efficiency. In this way, it has been present in people's lives, delivering blocks, heads and automotive parts that provide the best quality of life in different applications in the automotive and industrial machinery sectors. As its main value, Tupy is very concerned with people, not only in providing products to consumers, but also in developing employees, enabling them to face new business challenges. One challenge is related to the rapid technological advancement that the industry is undergoing. With the introduction of Industry 4.0 concepts, the company, together with its highly skilled team, has dedicated efforts to the construction of technologies that enable the integration of current equipment with the digitalization of the factory in a way transforming the current factory in a context of "Smartfactory". This article presents Tupy's model for digital transformation and illustrates some practical examples of digital projects developed on the Machining area of the Company.

**Keywords:** Tupy, people, Industry 4.0, technologies, partnerships.

## 1. INTRODUCTION

The automotive industry is historically characterized by a great differentiation among economic groups, constantly seeking market's expansion, cost reduction and the increase of the profitability. Based on great minds and their legacies, a great industrial development since the beginning of the twentieth century where Frederick Taylor and Henry Ford are certainly the thinkers who determined the foundations on which the world automobile industry develops. In the post Second World War period, Toyota's Taiichi Ohno established very important principles which drove not only the automobile industry, but also many other sectors that managed to learn the waste reduction principles from lean manufacturing (SPEAR and BOWEN, 1999).

Although there are many success stories and several concepts regarding production engineering, the good performance of an organization requires a good alignment between its strategy and the management system which will enable it to achieve the desired results. Allied to this, it is essential to take into account the peculiarities of each organization, such as culture, location, type of business, market in which it operates, among others. A successful production system cannot,

therefore, be applied unrestrictedly without at least being adapted to each organization, that is, each organization needs to develop its own production system, obviously making use of the knowledge generated by other organizations and the success stories in order to make it robust and incorporated into the business.

The production system implementation has a key role in the continuous process improvement, as well as in the application of strategies of automation of production lines, where these aspects are decisive to the machining service competitiveness as part of generating value for customers and the community by improving people's quality of life.

In view of the substantial investments required to the acquisition of new machining equipment in the company, there is a need to ensure the efficient use of these assets, with a view to performing services at a competitive cost, as well as absorbing demand variations and cycles of life of different projects where the Production System plays a major role under this aspect.

Porter (1999) apud Dupont (2010) mentions that the guarantee of good operational efficiency, by itself, does not ensure a proper standard of competitiveness. A company's competitive position is only assured if it has a privileged position, in relation to the competing companies, in the most valued bases in the segment in which the company operates.

The production strategy needs to be deployed from the organization's broader goals and strategies. As these objectives are strongly related to markets that will certainly change over the time, production strategies need to be shaped in order to follow such changes. According to Stock and Seliger (2016), the current globalization comes with the challenge to meet the continuously growing worldwide demand for capital and consumer goods by simultaneously ensuring the sustainable evolution of human existence in its social, environmental, and economic context. In order to handle this current challenge, industrial value creation must be oriented towards sustainability. Currently, the industrial value creation in the early industrialized countries is shaped by the development towards the fourth stage of industrialization, the so-called Industry 4.0.

Duarte (2017) states that innovation can be reached through product design, technology used in the production process and in the market choice niche and Memmi (2014) defends the idea that the traditional industry can only survive with the exchange of knowledge and experience among various actors involved in the production process. Throughout its trajectory, the company has a great concern with people and with people's education, aiming at training and building highly qualified employees for the execution, transformation and construction of processes and products.

The Company Production System started in 2016 and was structured to use concepts, methods and techniques from the Toyota Production System and the Theory of Constraints, among other best practices, to improve company's results. The focus is to better meet market needs, that is, the competitive dimensions which make up the value package that Tupy delivers to its customers. According to Barros Neto, Fensterseifer and Formoso (2003), competitive priorities are objectives that companies must constantly pursue, to increase their competitive market share and profitability. The competitive dimensions cited in the authors' study are: cost, quality, delivery performance, flexibility, innovativeness, and services. Dupont (2010) states that, as the service can be understood as part of the quality dimension, the following criteria are considered as competitive dimensions of the production strategy: cost, on-time service, speed, flexibility, quality and innovativeness.

Additionally it is highlighted in the study of Barros Neto, Fensterseifer and Formoso (2003) that the production function must be prepared for the introduction of new technologies, working with highly creative and motivated people, always seeking to constantly update the innovations that appear in the market.

In terms of mechanical processes, Industry 3.0 techniques were and continue to be applied, starting with automation through the robots application in internal processes such as molding, core molding and machining. Schuh et al (2014) states that the third industrial revolution, or also called as Industry 3.0, is defined by the transition from analogic technology present in processes to digital technology, where the construction of integrated circuits allowed for an increase in computational capacity and a production costs reduction.

According to Freitas (2018) new technologies creation associated with the growing use of digital mechanisms has led organizations to adapt their processes as a way to stand out in the highly competitive market.

Industry 4.0 follows from the digital manufacturing concept and methods which have been present around the industry for several decades, and now with the help of the internet and other newly emerging technologies, it is evolving toward a networked version with a higher level of digitization (LIU; XU, 2016). According Wang and Wang (2016), Industry 4.0 is related to digital technologies as smart factory, big data, internet of things and cyber physical system which have great importance in the manufacturing process.

Nowadays, manufacturing industry is aiming to improve competitiveness through the convergence with cutting-edge information and communication technologies in order to secure a new growth way (KANG et al., 2016). However, according to Carneiro (2021), technology is only one way to achieve digital transformation. High investments in hardware and software are not effective if people are not prepared to absorb new technologies. Thus, the digital transformation starts through changing people's mindset. According to Kane et. al (2019), the great challenge for the development of digital transformation in companies is people, mainly due to the different reactions that people and organizations have in relation to technological advances.

In this sense, people need to be trained, qualified and motivated to act as active agents of digital transformation in companies. Based on this assumption, the company under study structured a Digital Transformation mentoring program

for managers in order to enable them to disseminate and build the digital transformation in the organization, teams and processes.

## 1.1 Objective

Over more than eight decades, the company Tupy has always been positioned at the edge of new technologies, being one of its competitive strengths. Taking into account this historical positioning, and the opportunities that come along with the digital emerging technologies, the present case study aims to illustrate the strategy of the company to take maximum advantage of new digital technology possibilities, and how this strategy, in line with the competitive dimensions highlighted in Tupy Production System, is reflecting the projects on the machining area of the company, through some practical applications developed by its technology team.

## 2. A COMPANY OVERVIEW

The company Tupy, objective of this study, is a Brazilian multinational present in several countries with more than 80 years. Originally metallurgical, operates in complex metallurgy and from their generating complex geometries in its processes and products developed in different cast iron alloys. Its journey is divided into three moments: innovations and achievements, currently sustainable development and enabling future.

The first moment started since the company's foundation in 1935, covering the supply of components with a small establishment already starting a thought as a Startup, getting in 1938, the development of malleable cast iron to build pipe fittings. In 1956 there was a leap of innovation where it was noticed in its processes the vocation of supply to the automotive industry through the manufacture of brake and suspension system for automobiles.

In 1966, with its growth, the company was listed on the stock market and 10 years later was positioned internationally with the presence of sales and engineering offices located in key countries. From that moment on, there was an increased innovation in its process, expanding its products and supply not only for automobiles but also to provide people's quality life with engineering components, blocks and heads for trucks, agricultural, mining and construction machines, among others. In this sense, there is a continuous engagement with research and development and innovative mindset. In 1996, a Machining area was created, implementing production lines to machine engine blocks, heads, and automotive parts. The machining content can vary from a initial targeting operation, through cubing or full machining, including assembly of components assembly and leak tests. Nowadays, the Company has two machining facilities, one in Brazil and one in Mexico, with almost 1.500 direct employees.

At the beginning of the 2000s, after decades of research, the company has started the Compressed Graphite Iron (CGI) application in the manufacture of its products aiming the following of the growing movement towards the manufacture of parts with low weight, thinner walls, and complex geometries (Figure 1). Additionally, further challenges were raised from the Machining's perspective, under geometries, tools, materials, and other technological aspects. At the same time, research and development partnerships were constantly developed with universities, where this relationship was recently expanded through the inclusion of research institutes and startups, through research initiatives to the company's digital transformation (Figure 2).

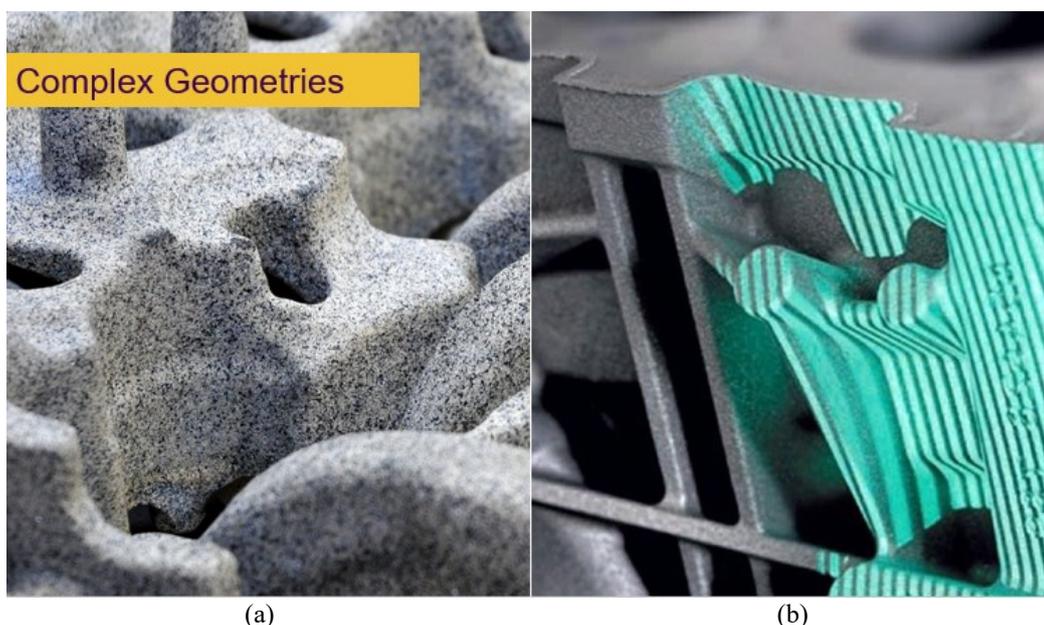


Figure 1. Complex geometries (a) internal sand core (b) engine block casting (Tupy).



Figure 2. World Class Universities Partnership (Tupy).

### 3. METHODOLOGY

Based on the context of technological development of the industry and the growing automation in processes with opportunities for technological improvement and consequent gains foreseen in the competitive dimensions of the company's production system, this article was structured in two steps:

1. Corporate digital transformation model;
2. Cases of new technology implementation.

#### 3.1 Corporate Digital Transformation Method

The Digital Transformation model was developed with the intention to serve as a guide map specially for decision makers in all levels. As new technologies are emerging almost daily, an understanding of the Company drives is required to identify potentials, to mitigate risks and to direct resources for the best result opportunities.

Based on these aspects, the company's digital transformation model was developed according to the following stages:

1. People: forming dedicated experienced teams of digital transformation leaders and promoting intense interaction between different areas;
2. Strategy: development of the organized structuring of the digital pillars and enabling technologies at different application levels;
3. Technology: definition of projects with higher return potential and related enabling technologies;
4. Implementation process: process of validation phases to allow insertion of new solution in manufacturing;
5. Looping: review of method and implementation of improvements on an ongoing basis as needed.

#### 3.2 New technology implementation

Focusing to the specific machining area, some practical examples of projects can illustrate the application of the corporate model of digital transformation.

Besides identifying main necessities and opportunities, mainly as a demand of the customers on projects of new components, the team follows some development phases from understanding the required function to delivering an

industrial solution, through proof of concept (POC), prototyping, pilot building and finally implementing. In the Figure 3, the implementation phase can be visualized.

The effort in each one of the phases is driven based on the reached confidence level achieved. Complete new solutions may require a very intense activity on each one of the phases to ensure its success if selected to move further. On the other hand, an incremental improvement on an existing solution may allow minimizing some phase, based on available knowledge on a similar application, and therefore reducing the development time.

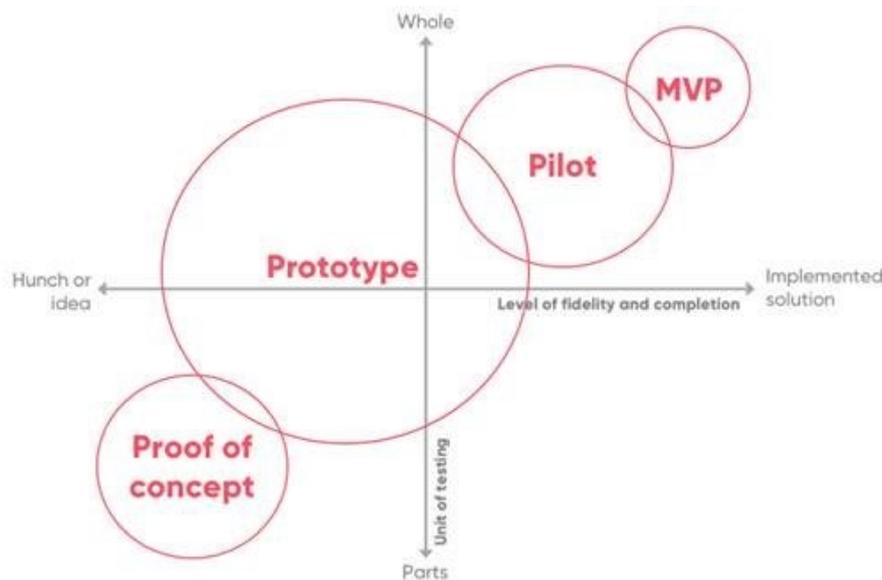


Figure 3. Phases of a new technology implementation (Duggan, K; Leurs, B., 2018).

On the next items, some results of the digital transformation are presented.

## 4. RESULTS

### 4.1 Corporate Digital Transformation Model

The Company's digital transformation model was structured for its technological strategy directed to the innovation process. The digital transformation model was structured around eight digital pillars:

- Business Management
- Customers
- Quality
- Operations
- Equipment Management
- Technological Leadership
- ESG
- People and Knowledge

These pillars have value creation fronts based on solutions connected with the company's business needs. This occurs through the enabling technologies that serve as the basis for building solutions applied throughout the innovation process. In Figure 4 it is presented the digital pillars as well as the application levels of the enabling technologies structured in the company.

The enabling technologies consist of technological solutions that serve as the basis to the construction of solutions applied in the digital pillars distributed in three application levels: edge, fog and cloud, respectively. At the edge level, industrial operations are focused on process control from the application of enabling technologies such as smart sensor, robotization, industrial networks, Internet of Things (IoT), Low Power Wide Area (LPWA) and digital equipment. At the fog level, the approach is defined in industrial data and Support and Operating Systems focused on the data analysis. Technologies related to this level are industrial data networks, data collection, data management, industrial Wi-Fi, connected workers and digital applications and interfaces. At the cloud level, which is the last level of application of enabling technologies, the focus is defined on the intelligence based on the sharing and analysis of massive data. In this

respect, the technologies related to this level are cloud, data mining, Application Programming Interface (API) management and digital models.

One of the key aspects of the presented model is the definition of the level that each type of data must be treated, being edge, cloud or fog. This proper understanding is mandatory to protect the company from potential threats, being intentional or not, considering availability of systems that may affect the daily operation, attacks of external sources, data property protection, among others.

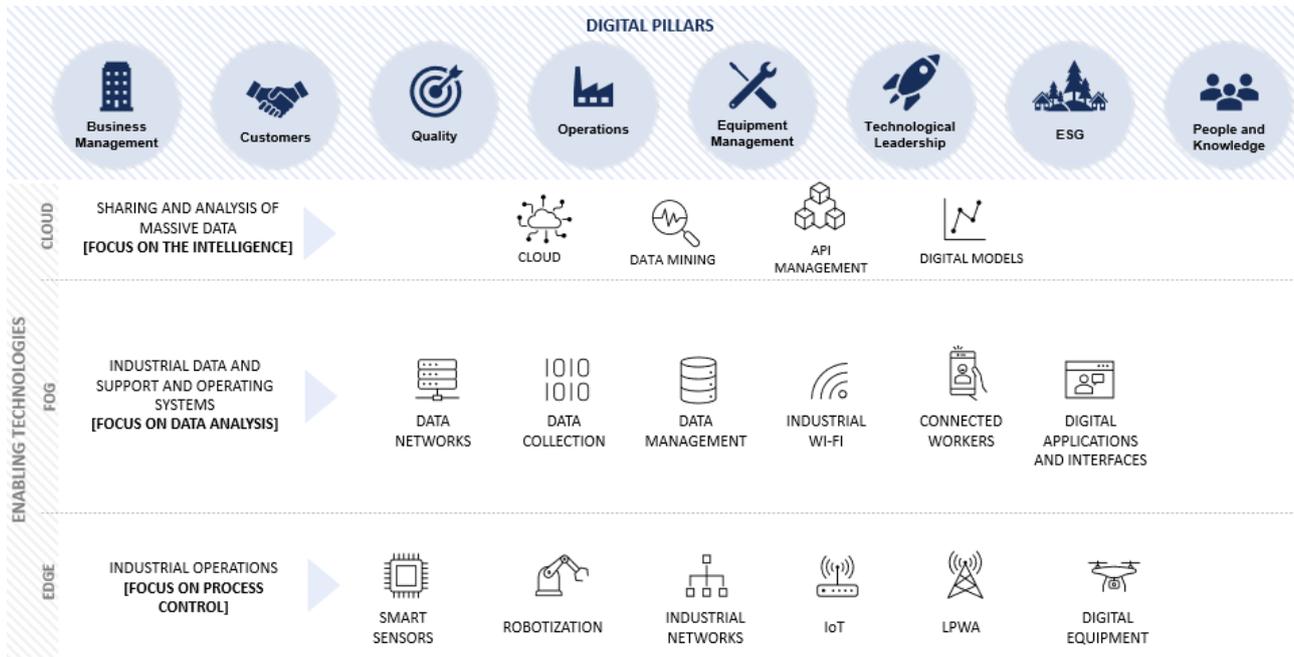


Figure 4. Digital pillars and enabling technologies (Tupy).

## 4.2 Cases of digital solutions

The company has been strongly involved in the preparation and execution of projects with enabling technologies that provide value generation to processes and products and agile decision-making through the use of structured model. The structured model, in turn, is constantly being revised, at the same time that new technological competencies emerge for the teams and also technological trends raised in the market in order to improve technical solutions and create new businesses.

The following items are examples of robotized automation, at the edge level on the digital model, focused on providing value for the customer, through competitive solutions.

### 4.1.1 Automated flexible deburring system

A demand of high-quality deburring of casting pieces has two main challenges: the competitive cost comparing an automated solution with a manual activity and the quality of the deburring on machined to casting interfaces, that can vary the position from part to part.

This development took into account previous knowledge on the deburring of sand cores and considered a proof of concept to define alternatives for the position compensation of casting to machining interfaces. Additionally, the restriction of cost, when compared to human activity was overcoming maximizing the occupation of the machine, through the flexibility to deburr different component geometries, and the optimization of deburring speed, allowed by a combination of different factors, such as type of robot, stiffness of the clamping device, type of deburring spindle and programming strategy.

The automatic deburring machine design (Figure 5) was developed to attend quality, ergonomics and safety criteria and promote machining product's competitiveness. From a flexible modular concept for different parts, it will be possible to reduce the acquisition costs for new equipment.

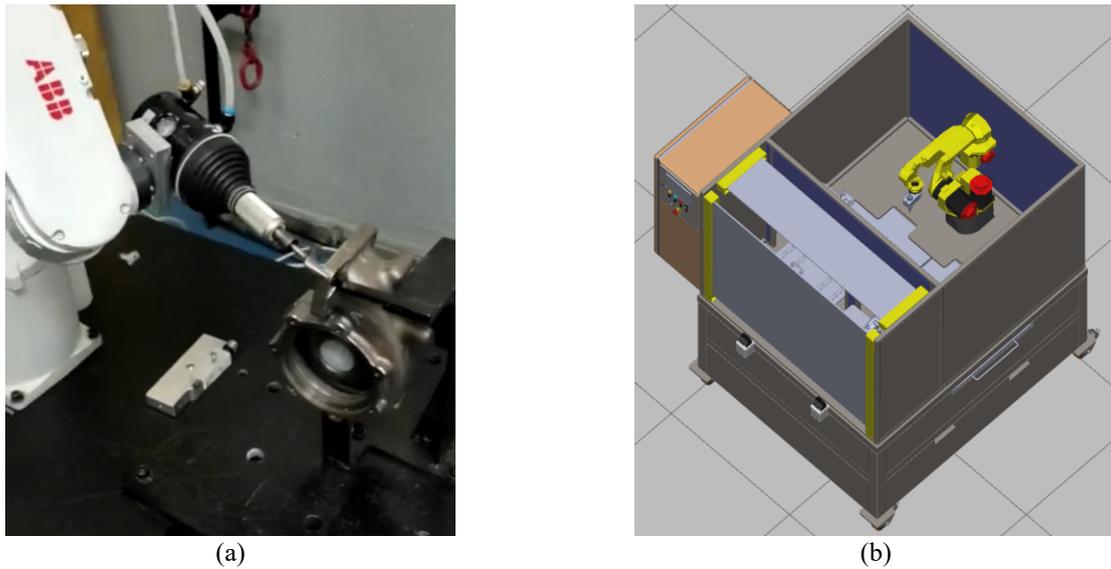


Figure 5. Deburring machine development (a) POC (b) final design (Tupy).

#### 4.1.2 Computer vision system with integrated artificial intelligence

Inspections carried out visually by a person may have quality deviations related to human factor such as physical fatigue, visual fatigue, accumulation of activities in the work and external factors in the inspection process. In this sense, an automatic solution is required to be applied at this stage of the process in order to avoid mistakes at the quality approval which can imply in significant costs due to non-conformity. Based on this aspect the following objectives were defined:

- Establish an inspection process fully automatized to avoid human errors in the decision-making at the quality inspection process;
- Standardize the cycle inspection time;
- Increase the quality level at the piece inspection.

As a first step for the project, it was necessary mapping all process defects which can cause human error and need to investigate at the inspection activity. The following defects are: missing operation, incomplete threads, inclusions, missing material, obstructions, rust regions, scratches, kneaded regions and break edge.

According to the current process the operator needs to perform a quality inspection at flat machined surfaces, cylinders, holes, threads and galleries. Considering the kind of application, three solutions were selected in the market: computer vision system, scanner and laser cameras to 3D inspection, and level probes. Assuming that the inspection process will be free from human errors, so the best solution will be that on which promote an autonomous inspection. Therefore, it was defined that the computer vision system with integrated artificial intelligence is the technical solution which will be applied in the project.

The computer vision system with integrated artificial intelligence is the advancement of comparative image analysis with the aid of technological tools such as Deep Learning and Machine Learning, allowing inspection and quality control in a fully automatic way. In Figure 6 it is exemplified the Computer Vision System with artificial intelligence application in the product. The highlighted regions (red and yellow colors) represent defects found in the inspection process.

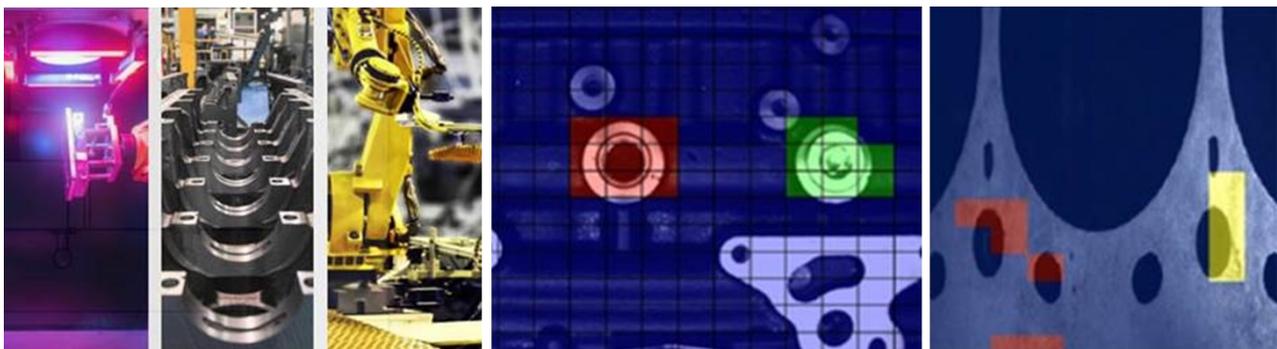


Figure 6. Application of the Computer Vision System (Tupy).

A Proof of Concept (POC) was performed at the company to ensure that the solution will be capable to capture all machining defects described in the project scope. Through POC was possible to conclude that with computer vision system with integrated artificial intelligence will be possible to remove human factors in the inspection, making the process more agile and reliable, as well as having a record of the situation in which the product was at the end of the production line through traceability and communication current supporting systems at the company, making the entire quality process agile and efficient. Based on positive conclusion to the application of the technology, the project was developed (Figure 7).

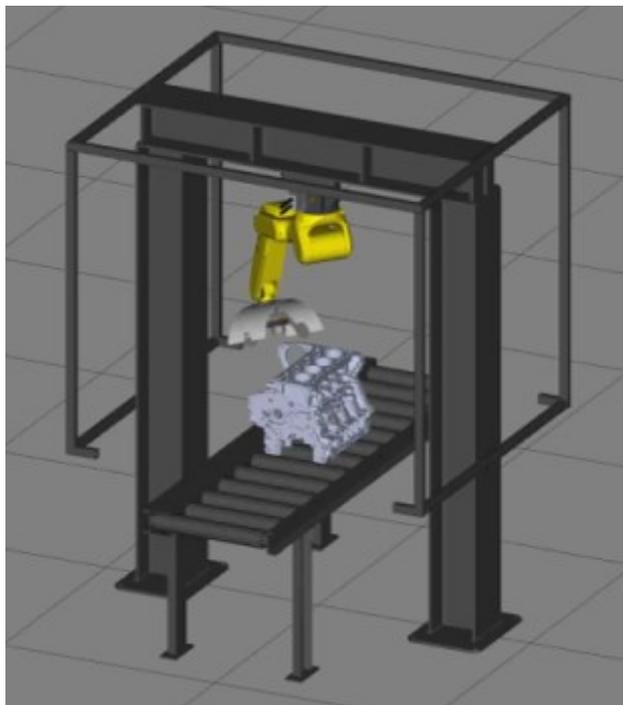


Figure 7 – Automatized inspection cell (Tupy).

Through the computer vision system with integrated artificial intelligence applied in the automatized inspection cell, it will be possible to promote a technological development in quality and operation digital pillars with enabling technologies in the EDGE and FOG levels in the digital transformation model.

## 5. CONCLUSION

Throughout its trajectory, Tupy has been concerned with adding sustainable technologies and initiatives to the company's processes, meeting customer requirements with greater efficiency and quality and providing products that contribute to a better quality of life for people.

Together with its greatest value, which are people, the company has implemented new technologies over the years and has been heavily researching and developing partnerships for future technologies that support its industrial evolution and competitive position in the market. Highlighting Machining and its processes, this article presented some company's history highlights with a specific focus on technologies implemented over the years and also some strategy and example of initiatives towards Industry 4.0.

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