Review of Management and Economic Engineering
Vol. 20, No. 4(82), December 2021, p. 320 - 327, ISSN (print): 1583-624X, ISSN (online): 2360-2155

ANALYSIS OF A SMART MAGNESIUM DIE CASTING FACTORY BASED ON TRACEABILITY AND QUALITY 4.0

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Abstract: The technology improvements are setting the base for a new industrial revolution, the Industry 4.0. Following the industrial trend, also the quality management systems are evolving into Quality 4.0. The objective of the new, improved quality system is to assure the generation of better products, better services, faster and cheaper. In order to assure this objectives the Quality 4.0 is evolving from Quality Assurance, Quality Management into a digital quality system embedding new tools as total traceability management, artificial intelligence, big data, remote learning, remote inspection, remote collaboration, remote auditing, predictive failure analysis, quality automation. The benefits are evident as the digitalization of quality is bringing total transparency of the business quality status for shareholders, total process control, increased speed in decision making, higher predictability accuracy, stronger team interaction and involvement. This document presents a brief analysis of several Quality 4.0 and TTM (Total Traceability Management) deployed in a magnesium die casting factory.

Keywords: Industry 4.0, Quality 4.0, TTM, die casting, smart factory

1 INTRODUCTION

The purpose of this document is to highlight the improvements deployed in a die casting process through implementation of TTM (total traceability management) and automation as part of the Industry 4.0 strategy. The need came from the various die casting producers and it was based on the safety and quality aspects of the product and the process. In order to achieve the safety and quality improvements, a data gathering system was developed to extract the key parameters from the various process steps. Based on these parameters an improvement plan was executed consisting in the following key success projects:

- Safety Risk Reduction
- Cycle Time Variation Reduction
- Mold Temperature Monitoring
- Product Quality Controlling
- Remote Service Deployment
- Business Intelligence Deployment

One of the main benefits of the Industry 4.0 is the rapid development of business intelligence solutions (BI). This software solution are transforming the data into performance indicators and based on artificial intelligence it can predict the evolution of a product, process or service (Fig. 1.). The processes are driven by smart machines, capable of communicating through IOT (Internet of Things) devices, sharing parameters and self-adjusting their settings based on process and product inputs. Technology innovations in materials, vision systems, robotics, IT, are reshaping the industrial environment. Suppliers are automatically linked with the customers, both internal and external, product lead times are decreasing and the delivery typology is changing from build on stock to build on order.

Figure 1. Business Intelligence Benefits (www.anigma.de) [4]

2 ANALYSIS

The application of traceability and the Quality 4.0 tools in a die casting environment is a challenging project due to environment factors: extreme heat, dust and water contamination. Moreover this process is designed to cast steering wheels from magnesium alloy, concluding that the process parameters controls are safety relevant. The analysis is done based on the study performed prior to the investment in a smart factory designed for producing magnesium casted steering wheels. [5],[9],[10]

2.1 Industry 4.0 Components

The industry 4.0 is bringing a new set of components:

- Interoperability
- Virtualization
- Decentralization
- Real-Time Capability
- Service Orientation
- Modularity

Interoperability is the connection between employees, CPS (Cyber-Physical Systems), IoT (Internet of Things) and IOS (Internet of Sources). The processes in smart factory are built around the interaction between IoT (Internet of things), CPS, IoS and employees.

	Cyber-Physical Systems	Internet of Things	Internet of Services	Smart Factory
Interoperability	X	X	X	X
Virtualization	X	-	-	X
Decentralization	X	-	-	X
Real-Time Capability	-	-	-	X
Service Orientation	-	-	X	-
Modularity	-	-	X	-

Figure 2. Industry 4.0 Design Components. (Schlick, 2014) [11]

Virtualization develops tools which are creating virtual maps and simulation of the products and services, testing in a virtual mode the potential failures and restriction, therefore reducing the installation and operational costs. Virtualization is also used as a training and learning environment with the help of augmented reality tools.

Decentralization is the autonomy of CPS (Cyber-Physical Systems) to execute certain tasks without command from a central master. The autonomy must be limited for safety application and escalated in cased of critical failures detection. The Total Traceability Management will track all the key parameters of each CPS (Cyber-Physical Systems) for further optimizations.

Real time capability is providing immediate data for immediate decision. Traceability modules are installed for all the critical equipment in order to gather, arrange and share the key process indicators.

Service orientation is the ability of customizing and building specific service by allocating various employees and CPS (Cyber-Physical Systems) in a specific flow to execute the special requested task. Based on an identification system, the necessary CPS (Cyber-Physical Systems) and resource will be appealed to support the process.

Modularity is developed to assure the flexibility in the processes and the standardization of connections. The modular concepts are able to absorb the demand variation adapting themselves to the new requirements with fast setup methodologies.

Quality 4.0 is a result of Industry 4.0. The digitalization tools are affecting all departments, supplier, process, customer, system and are deployed based on the 3 strategical approaches, quality planning, quality control and quality improvement. [1][2] The Quality 4.0 tools are:

- Interlink quality releases and goods supplier-customer integrate in TTM
- Automatic control of employee's training and certification
- Key process parameters real time monitoring by TTM
- Key product parameters real time monitoring by TTM
- Automatic batch inspections and release
- Finished product traceability-TTM
- Remote auditing system capability
- Failure anticipation algorithms
- Real time customer feedback and process information viewer
- Online document management system with release levels
- Real time and transparent business Intelligence data
- Improvement plans monitoring systems

2.2 *Die Casting and Quality 4.0*

The major challenge is to make die casting process safe both for the employees and product. This task requests a "smart" factory based on total traceability with quality 4.0 tools deployed.

2.2.1 Process Flow

From ingot to finished steering wheel the process is divided in the following steps (detailed in figure 2):

- Receiving
- Spectrometry
- Pre-warming
- Melting

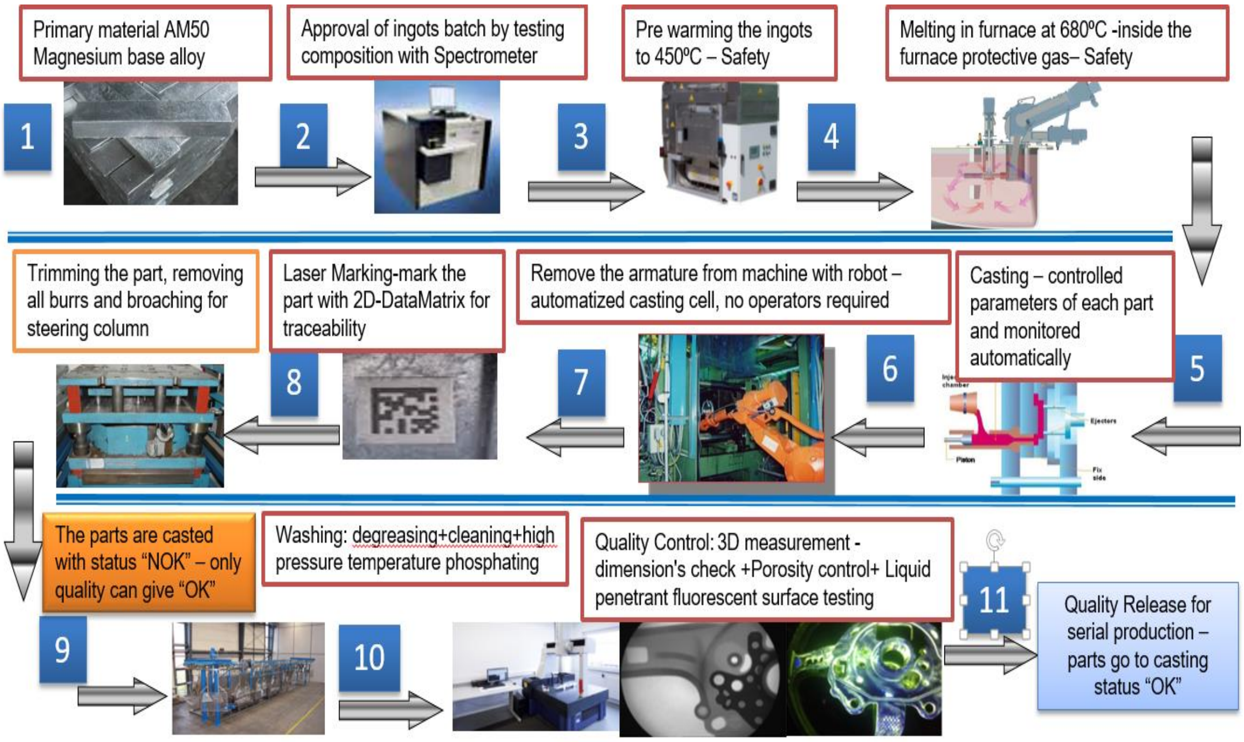

Figure 3. Die Casting Process Flow [5], [8]

Spectrometry is done by sampling from each batch. With several suppliers the product inspection is done automatically by having an automated inter-link supplier-customer to have automated release. The pre-warming temperature is a critical parameter, if the temperature is tool low the water content can create an explosion. The melting temperature must be strictly controlled. Due to high heat and contaminated environment the utilization of automatic concepts is mandatory. The extraction is performed by robots and the transfer of products is made by conveyors or automated vehicles. The full system is controlled by the TTM which is coordinating the allocation of parameters from die casting to each steering wheel unique identification. Based on the parameters resulted the robot (element number 8 from figure 4) will allocate the nonconforming product to a separate blocked storage location.[5]

2.2.2 Quality 4.0 and traceability in die casting

The following parameters are critical:

- Chemical composition alloy
- Casting in mold
- Automatic removal with robot from mold
- Laser marking
- Trimming
- Automatic segregation of nonconformities after die-cast
- Washing
- Automatic optical inspection
- Automatic porosity inspection
- Release in traceability
- Pre-warming temperature
- Melting furnace temperature
- Melting furnace injection pressure
- Protective gas layer density
- Mold surface temperature
- Laser mark readability

- Trimming force resistance
- Trimmed product burrs
- Sensors auto-check
- Spraying unit debit
- After washing aspect
- Cooling tank temperature
- Washing liquid chemical composition
- Product geometry
- Product porosity
- Operator authorization level and skill

All the above parameter are part of the TTM algorithm and are synchronized to provide the best output in terms of quality and cost. The software includes different layers of authorization based on skills and activities, eliminating the possibility of human error due to inadequate access to parameters. [3], [5], [8]

1 -Protective gas mixing station
2 - Pre warming ingots unit
3 - Automatic furnace feeding
4 - Furnace for melting
5 - Die casting high pressure cold chamber machine
6 - Ventilation and cleaning of air with gas protection
7 - Automatic spraying robot
8 - Robot for handling parts and inserts
9 - Sensors for armature quality control
10 - Laser marking traceability system
11 - Cooling tank
12 - Trimming press

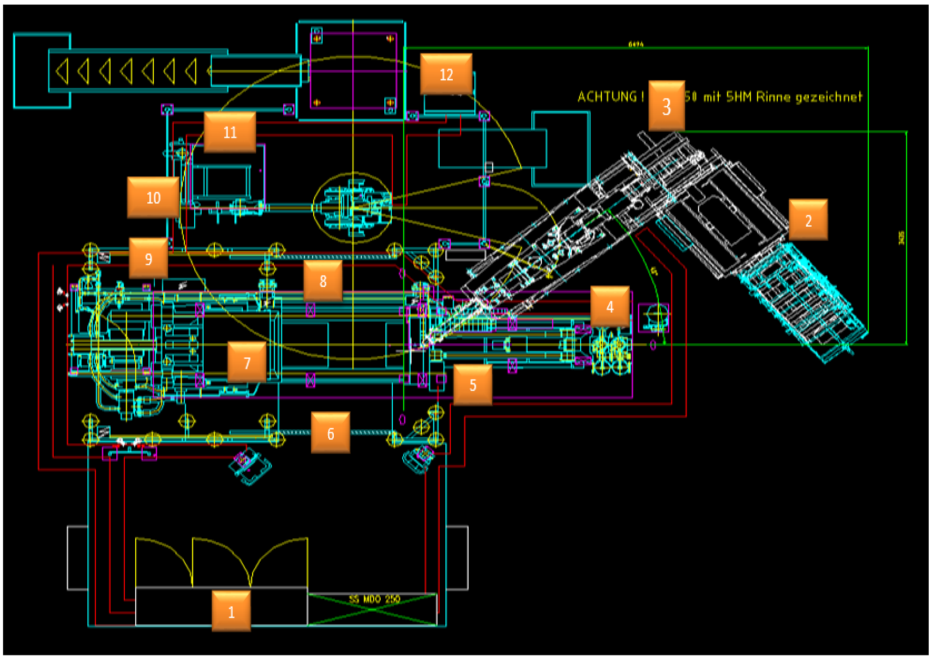

Figure 4. Automatic die casting cell layout [5]

The Quality 4.0 methodologies are supported by various tools such as Total Traceability Management which is providing the interoperability, real-time capability, and decentralization, providing the environment for data analysis, data prediction, local decision and Business Intelligence reports generation. Augmented Reality is used for maintenance intervention, Artificial Intelligence is used for communication between smart vision systems, robots and autonomous industrial vehicles to synchronize events and parameters. Modularity is assured by standardizing the product and tooling design rules in order to assure the self-changeover without human intervention. Integration of 3d automatic measurements, automatic optical inspection with porosity verification inline, 100% X-ray with image analysis are the must have features for a safe die-casting factory (figure 5.)

These methodologies are based on the following tools and equipment [7]:

- Inductive Sensors
- Capacitive Sensors
- Vibration Sensors
- High Temperature Sensors

- Smart Thermal Imaging
- Smart Vision System
- 3D Scanning Systems
- AMR - Autonomous Mobile Vehicle
- Augmented Reality Glasses
- Equipment IOT (Internet of things) modules
- Robots
- Cobots
- TTM
- ERP (Enterprise Resources Planning)
- Predictive Maintenance CMMS
- Business Intelligence
- Laser Marking
- Building Management Systems
- Self-Setup Tool Designs

Figure 5. Quality 4.0 features in die casting [5]

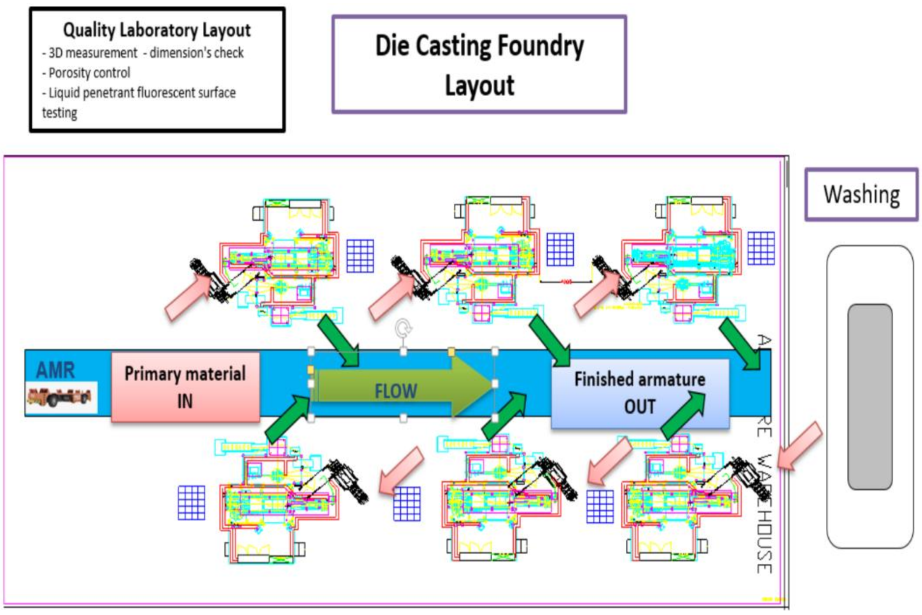

Figure 6. Smart Factory Layout [5]

3 CONCLUSIONS

The implementation of the traceability and Quality 4.0 tools had delivered the following results in the project presented above:

- Safety risk highly reduced due to robot driven process
- Cycle time stabilized, therefore better output and lower scrap rate
- Lower number customer complaints due to implementation of porosity inline inspection, thermal imaging and automated process control
- Big data availability, all process parameters are monitored for every shot making process improvement possibilities

The concept must be designed and conceived from the beginning as a smart factory (as shown in figure 5). The material flows are smooth, one piece flow, assuring the FIFO and no risk of collision for the AMRs (autonomous mobile vehicles) which are transporting the goods.

Any robot can produce the same product or others product in the same time, as the die casting molds are having a modular-universal design.

By laser marking-mark the part with 2D-data matrix for traceability, we monitor in every step what part, where, with what parameters, what operator was produce, resulting a better tracking and a higher operator responsibility.

The health and safety hazard for the employees is reduced to zero due collision detection systems, and error proof systems for employee access. Also the controlled authorization level based on qualification with continuous updated is proven to have a perfect output as health and safety incidents.

The quality of the product is assured through quality 4.0 tools and methods, the digitalization bringing a 30% output improvement and a 90% reduction of customer complaints. The warranty cost is down with 90% also after full implementation.

The training system is based on augmented reality, bringing a better effectiveness and speed in qualifying the personnel. Due to the fact that is done in a virtual environment the assessment process is objective and the scrap resulted is zero.

The financial result in terms of scrap is better with 50%, due to better process control and order scheduling and levelling, avoiding therefore the unnecessary setups.

The flexibility is assured by service process design, by modularity and the setup for a new product is done much faster than in the past. The concepts of quality planning, quality control and quality improvement are improved and supported with real-time factual data from the process, based also on the evolution of data gathering products, sensors and cameras. The skills of the employees will be upgraded to face the new job requirements in terms of data analysis, process automation, software utilization and development. Augmentation of the skills will be executed in an accelerated method due to augmented reality trainings and simulation.

The focus will be on predictive analysis and process simulation before the physical execution providing a valuable aid to the industrial performance.

The decision making process is now based on factual data, available instantly, making the organization more lean an adaptable to market variations.

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