REVIEW OF ADVANCED PRODUCT QUALITY PLANNING (APQP) IN THE AEROSPACE INDUSTRY

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ABSTRACT
This paper provides an image how and why the methodology "Advanced Product Quality Planning" (APQP) has become more used in the Aerospace industry. It presents the current context regarding markets and industries, as well as the history of APQP, starting with discrete usage of some APQP elements, as well as the beginning of APQP in general and in aerospace. A general presentation of APQP is given, that includes definition, main benefits and output (Production Part Approval Process), including a view in the current Aerospace Industry, to give an idea of the current context. General considerations are generated based on the exposed information, to establish if APQP and the Aerospace Industry are a suitable match. It serves as an information pool for any aerospace producer researching into the implementation of APQP in aerospace.

Keywords: Advanced Product Quality Planning, Aerospace industry, Quality Assurance, Quality Management, Knowledge Based Organization

1. INTRODUCTION

In an ever-evolving world, faced with several challenges such as:

- financial crisis, which threaten all aspects of life, but one of the most impacted areas are the producers and in general industries, that experience a decrease in sales, if not adapted to the new situation.
- new technologies in materials and processes or cheaper materials or processes, that are discovered at a fast pace. Any producer who does not incorporate the new materials and processes will most probably face a decrease in customer satisfaction.
- the growing markets, which push producers to ramp-up production processes to levels unseen until now. As the world population and globalization grow, so does the demand. A reality to which the producers need to adapt, by expanding current facilities.

All of the above are important inputs to any market, industry or producer, as they dictate the rules for surviving in a competitive market.
As a summary, producers faced with the following Voice of the Market:

- produce cheaper, at lower costs,
- produce better, than any other competitor,
- produce more, in order to satisfy the demand [1].

In order to comply with the Voice of the Market, producers need to identify robust methodologies that guide them to achieve customer satisfaction. One methodology that stands out is "Advance Product Quality Planning" (APQP), which incorporates a structured way to achieving ultimately customer satisfaction by ensuring On-Time, On-Quality deliveries and to shorter lead times.

2. APQP

2.1. Definition and mission

Although there is no single definition for APQP, but one of the most suitable recognizes that "APQP is a structured methodology, which ensures that customer requirements are met".
The APQP methodology puts emphasis on the planning aspect of any project, in order to identify, as robust as possible, customer requirements.
As soon as customer requirements are identified and understood, APQP is focused on efficient planning and development in order to meet all customer requirements, in the shortest time possible and to the smallest cost possible.
For any organization, early APQP benefits can be extracted, by reviewing the Lessons Learned from previous APQP projects, in order to plan better the project.
An initial deliverable in any APQP project is the Project Plan, which incorporates all inputs from the first phase and documents them as a project timeline that fixes all APQP project milestones and their estimated time of delivery.
By considering product quality directly from the project planning and development phase, the cost of non-conformance (CONC) is drastically reduced once product has been launched and during product life cycle.
The below chart (Figure 1) exemplifies an hypothetical comparison between an APQP approach, marked by the green line and the current state, a Non APQP approach, marked by the red line.
The chart presents the differences in approach as a function between total cost of quality and time.

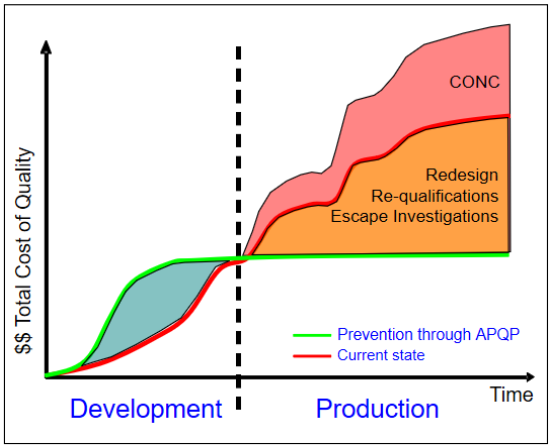

Figure 1. Chart containing the comparison between current state and APQP approach, as a function Total Cost of Quality over Time [2].

During the initial development phase of the project, in the current state costs of quality look to be reduced, as the need of resources is low. By comparison to the APQP approach, where costs look to be slightly higher, puts emphasis on early identification of customer special requirements, as well as, fulfils the requirement of a multifunctional approach, which gets

translated into more costs. In almost all cases, the APQP costs during the development phase are related to:

- human resources costs,
- acquisition of more accurate equipment,
- external consultants or experts.

Once production has started, both approaches start usually, from the same level of costs regarding quality, but the similarities end here. In the current state approach, in most of the cases, gaps will emerge between the actual results versus the customer special requirements.
The gaps identified are usually related to:

- needs to redesign the product or process,
- re-qualification of the product,
- re-qualification of the process,
- quality escape investigations.

All of the above are translated in higher costs of quality for the producer, as the product or process need to be adapted during the serial production process, which unavoidably will lead to customer dissatisfaction and loss of reputation by the producer.
In the preventive approach through APQP, all of the above are avoided, by the robust design of the product and of the process, as well as, the verification of the match between product and process, to deliver all customer requirements to the expected levels.

2.2. History

Throughout the history, some elements of APQP evolved as a standalone principles or procedures such as:

- Statistical Process Control developed by Walter A. Shewhart during his stay at Bell Laboratories in the early 1920s. As foundation for Statistical Process Control, Shewhart used the tool named Control Chart and the concept of statistical control state.

The concept of statistical control was based on an similar concept developed by logician William Ernest Johnson, the concept of exchangeability in his book Logic, Part III: The Logical Foundations of Science.

- Failure Mode and Effects Analysis (FMEA) has its beginnings right after the Second World War in the late 1940s as procedures developed by the US Armed Forces.

NASA took over this tool in the early 1960s, as more and more of its contractors used the FMEA tool. Some of the programs on which NASA used variants of FMEA are: Apollo, Apollo Lunar Module, Viking, Voyager, Galileo, Magellan, and Skylab.

- The principles of quality planning as pioneered by W. Edwards Deming from the 1950s, such as Plan-Do-Study-Act.

PDSA expresses ideally, the method to perform any activity, whether is the introduction of new products, changes to existing products or processes or continuous improvement.
It sets the four main rules: “Plan” the activity, “Do” or perform the planned activity, “Study” or check the output of the activity compared to the planned, “Act” in case output is not fulfilling the planned requirements.
All of the above principles and procedures, plus other which are not mentioned in this paper, have been used by the three main US automobiles producers “Big Three” (Ford, General Motors and Chrysler) to create APQP. They were undergoing an obvious degradation in customer satisfaction, due to poor quality, as well as, a reduction in market share, as Japanese producers were on the rise.
The “Big Three”, three automotive original equipment manufacturers (OEMs) and the Automotive Division of American Society for Quality Control (today ASQ - American Society for Quality) created the Supplier Quality Requirement Task Force for developing a common understanding on topics of mutual interest within the automotive industry.

APQP is still utilized today by these three companies and in general by the automotive industry. Tier 1 suppliers are typically required to follow APQP procedures and techniques.
APQP in the automotive industry is now guided by the Automotive Industry Action Group (AIAG), which has released a series of interrelated manuals for APQP and the core elements such as: PPAP, FMEA, MSA and Control Plan [3].

3. APQP IN AEROSPACE

3.1. History

In aerospace, APQP is a fairly new methodology, although some producers used in the past some APQP elements sporadically due to the lack of APQP guidance and standards, directed to the aerospace industry[4].
Only in 2013, the International Aerospace Quality Group (IAQG) published the APQP/PPAP manual, which describes the guidelines for using APQP [5]. In 2017, IAQG released revision B of the APQP/PPAP manual, which contained a major overhaul of the manual, including changes in order to align the manual to the standard. Changes included element renaming, elements being merged, in general a restructuring at the element level and below.
IAQG is an organization within the aerospace and defense with the purpose to establish and maintain a cooperation based on trust between aerospace and defense companies, in order to facilitate the continuous improvements efforts throughout the value stream.
Initial focus, to continually improve the processes used by the supply chain, to consistently deliver high quality products, thereby reducing non-value added activities and costs.
SAE International released the first APQP standard in aerospace, in November of 2016, with the name AS9145 – "Requirements for Advanced Product Quality Planning and Production Part Approval Process" [6]. It defines rules for APQP in aerospace by adjusting the methodology to the aerospace type of production. Compared to automotive APQP, the methodology for aerospace contains more elements and to a higher complexity. The addition of other elements allowed the expansion of the following sub flows inside the APQP methodology: requirements identification, product design, product and production planning, product and production verification, capacity planning and verification, product and process quality, packaging specification.

3.2. Pillars

In any aerospace organisation, which wants to implement APQP, there must exist three principles, in order to succeed (Figure 2):

- Organizational Commitment and Management Support – first pillar, without which APQP has no chance to be implemented, in an organization, as resources will not be allocated to this scope.
- Cross Functional Team – second pillar, which enforces the multifunctional approach, as not all information is held by one person, thus requiring multiple individuals working together in order to achieve the best result.
- Effective Project Planning – third pillar and core activity inside APQP. Any project, which is not planned correctly, might deliver products on quality, but probably not on time, thus contributing to customer dissatisfaction.

Figure 2. Three main pillars of APQP [5].

All of the above are key for implementing and using APQP, as well as reaching the end goal of Customer Satisfaction.

3.3. Principles

As declared in its definition, APQP is a structured methodology, which is constructed on three levels: Phases, Elements and Deliverables.

Phases, the top level, breaks APQP in five distinct phases: planning, product design and development, process design and development, product and process validation, ongoing production.

This split in phases identifies the different areas of responsibility between Project Management, Design Organisation and Production Organisation, in some cases, phases can happen concurrently.

Elements, the middle level and most complex, split each Phase in logical sub steps, which generally are set in a linear flow, but in some cases allow also complex interactions between elements, such as feedback loops. Usually one or more elements are incorporated in the same procedure, inside the Quality Management System, in order to fix the way of work and responsibilities [7].

Deliverables, the bottom level, have the role of capturing output information from Elements and are very valuable due to their documented nature, which can be used as evidence when audited. Customer deliverables are only a portion of the APQP deliverables, but are considered interface documents.

The general input into APQP in aerospace are the Program requirements. By Program is to be understood a certain type of aircraft and all the components that come together to form the final product.

At the same time one main element and output is identified, which is PPAP the “Production Part Approval Process” [8].

4. CONCLUSION

One of the first factors that needs to be taken in account, is the number of in-service aircraft, thus the aerospace industry needs to satisfy the high number of spare parts needed by the MRO (Maintenance, Repair and Overhaul) centres.

Predictions regarding the future of the aerospace market, as the one generated by Airbus and Ascend, show an expected needed number of 36500 new passenger aircraft in the interval 2018-2037. This would mean an average of 2000 new passenger aircraft per year.
Taking in consideration that the total number of deliveries from 2017 for both major OEMs, Airbus and Boeing, of 1500 aircraft, it is fair to say that the aerospace industry needs to use any tool available to reach the high number of deliveries per year, expected in the future.
To support the growing demand, better planning tools need to be used by the aerospace industry and its members, in order to facilitate the development of more standardized and robust products. This would enable an easier industrialization by producers, as well as, cheaper maintenance costs of the product through the product lifecycle.
Current aircraft design contain up to 7 million individual components, which are individually industrialized, creating a huge stress on producers due to time constraints, engineering resource costs, equipment and tooling costs.
Correct understanding of the demand is critical, when planning the development of new processes, especially regarding production capacity, but also regarding quality. As a newly developed process could deliver on quality, but not on time, leading to major customer dissatisfaction, during the product lifecycle. In case of delivery problems, a producer might block the OEMs final assembly line, leading to a nonfulfillment of the planned deliveries to the airlines.
APQP comes to the support of all mentioned above, by providing the structured methodology for any project, including the requirements for the organizational mind-set “the three pillars” as formalized in AS 9145.
With the release of the AS 9145 standard at the end of 2016, a portion of the aerospace industry supply chain has identified the opportunity to implement and use APQP in the aerospace industry.
By the end of 2017, small number of producers from the aerospace industry have implemented APQP into their Quality Management System (QMS).
The producers which implemented APQP, took it as an investment for the future and allocated enough resources to fully implement APQP per AS 9145 and the IAQG APQP manual.
As this pioneers of APQP in the aerospace industry, started to improve rapidly, all the benefits of the methodology became known also to the OEMs.
The OEMs, such as Airbus, acknowledged the successes of the APQP methodology, as implemented by the pioneer producers, and have asked that, for the future, all suppliers from its supply chain to implement the APQP methodology.
By doing so, Airbus and the APQP pioneers have achieved the necessary awareness regarding the APQP methodology, including demonstrating successes, and have ensured that the APQP methodology will continue to grow and develop in the aerospace industry.

5. REFERENCES

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