

APPLICATION OF PPAP TOOLS IN PRODUCTION PREPARATION MANAGEMENT

Józef GAWLIK, Jan REWILAK, Tomasz TOKAJ

Summary: Quality of final product depends on the quality of its individual components. The necessity of reduction production costs results in specialization, and that is why production of components is frequently handed over to external suppliers. The production orders placed outside an organization without complete and unambiguous specifying of the product quality requirements including part acceptance criteria can significantly increase the risk of delivery of non-conforming product. The article deals with the Production Part Approval Process (PPAP) procedure worked out by American automotive industry in order to oblige suppliers to demonstrate proper understanding of all customer requirements and ability to manufacture product meeting all requirements in time and consistently. The article describes the steps of PPAP procedure in convention of a process approach. For each of the steps of PPAP procedure presented are inputs, outputs, proposed effectiveness and efficiency indices, flow diagram of necessary steps and personnel responsible for a given PPAP step. At the end of the paper an attempt was made to assess the actual PPAP procedure state-of-the-art together with probable reasons of most common problems.

Keywords: PPAP, FLOW CHART, FMEA, CONTROL PLAN, MSA, SPC.

1. PPAP as a standard of quality assurance during the introduction of new production project

Each manufacturing company has to generate profit. The contemporary dynamics of market makes the product life cycle becomes continually shorter. This is especially visible in the automotive industry. It is no longer possible that a product is manufactured, without significant changes, for as many years as it was with Polish Fiat 126p, which had been produced – in almost unchanged version – for 27 years, or Volkswagen Beetle, produced in Germany over 40 years. Currently, the life cycle of a car model is several years. This must affect all cooperating companies, whose flexibility and ability to develop new products became crucial. Frequent changes in car designs, including accessories and versions (e.g. face lifting) made Original Equipment Manufacturers (OEMs) face increasing pressure to more frequently launch new products and production processes. Each new product initiates a number of new production launches, both by final producer and in the entire supply chain of component suppliers. Quality management system (ISO 9001) and even its extension for the automotive industry (ISO/TS 16949) turned out to be insufficient to assure quality in such changing an environment. Development of new management tools and methods of new production preparation and its final approval were needed. World-wide known guidelines referring to new product launching are included in the reference manual APQP (Advanced Product Quality Planning) issued by OEM organizations Chrysler LLC, Ford Motor Comp. and General Motors Corp [1] with a supplementary manual containing requirements for product approval before starting production, called the Production Part Approval Process (PPAP) [2]. This manual contains a number of documentary evidence to

be submitted to customer by supplier to prove their competence and capability of launching serial production of components in accordance with specified quality requirements. The documents and samples required for submission are listed in Table 1.

Tab. 1. PPAP requirements for supplier [2]

REQUIREMENTS – PPAP ELEMENTS	LEVEL 1	LEVEL 2	LEVEL 3	LEVEL 4	LEVEL 5
1. Design Record	R	S	S	*	R
- for proprietary components/details	R	R	R	*	R
- for all other components/details	R	S	S	*	R
2. Engineering Change Documents, if any	R	S	S	*	R
3. Customer Engineering Approval **	R	S	S	*	R
4. Design FMEA	R	R	S	*	R
5. Process Flow Diagrams	R	R	S	*	R
6. Process FMEA	R	R	S	*	R
7. Control Plan	R	R	S	*	R
8. Measurement System Analysis	R	R	S	*	R
9. Dimensional Results	R	S	S	*	R
10. Material, Performance Test Results	R	S	S	*	R
11. Initial Process Studies	R	R	S	*	R
12. Qualified Laboratory Documentation	R	S	S	*	R
13. Appearance Approval Report (AAR) **	S	S	S	*	R
14. Sample Product	R	S	S	*	R
15. Master Sample	R	R	R	*	R
16. Checking Aids	R	R	R	*	R
17. Records of Compliance with Customer-Specific Requirements	R	R	S	*	R
18. Part Submission Warrant (PSW)	S	S	S	*	R
Bulk Material Checklist	S	S	S	*	R
Required way of presenting the evidence to customer:					
S	The organization shall submit to the customer and retain a copy of records or documentation items at appropriate locations				
R	The organization shall retain at appropriate locations and make available to the customer upon request				
*	The organization shall retain at appropriate locations and submit to the customer				
**	If required / applicable				

After compiling required documents (according to the so-called submission level agreed with a customer), the Part Submission Warranty (PSW) form is filled and sent to customer with the part sample for a final approval – fig. 1.

2. Process approach to PPAP

PPAP can be presented as a process in which certain activities requiring specific resources to transform inputs into outputs are carried out. The input to the process are all

data and records of the product design (including components), according to GD&T rules, usually in electronic (CAD/CAM) form.

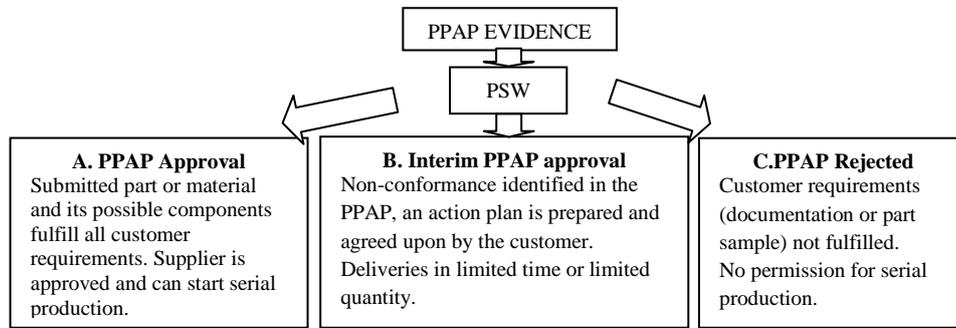


Fig. 1. PPAP decision options (own study based on [2])

Design data and records should also include material specification with accordance to the industry standard (in the case of the automotive industry this is the IMDS system – International Materials Data System [3], which is a global database of materials).

The input to the process are also all authorized documents concerning technical changes, not included in design records. Generally, the input to the PPAP process is the last, current, customer-approved version of the specification, containing all the technical requirements for the product.

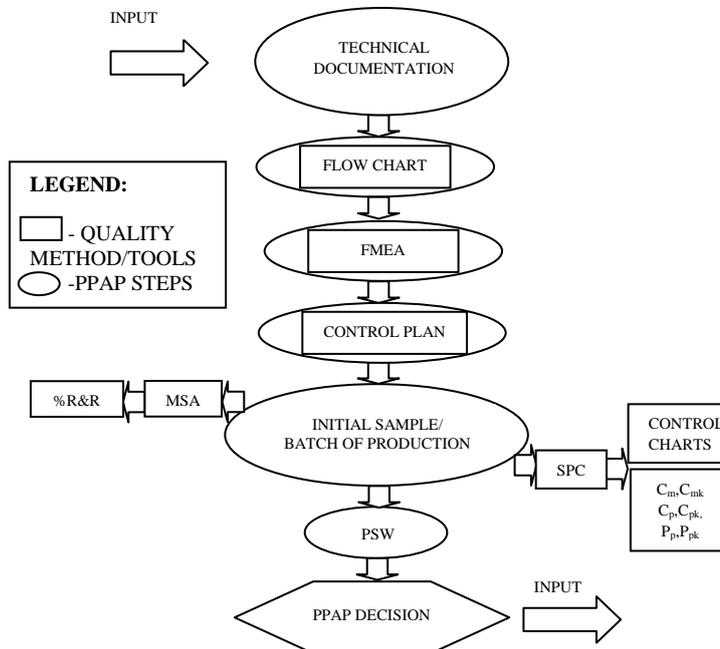


Fig. 2. The general PPAP flow based on quality tools used (own study based on [2])

PPAP can be, in accordance with the process approach to quality management, described algorithmically, in flowchart form, stating the steps/actions that make up the whole process. These actions relate to the use of specific quality tools/methods to achieve the partial goals of the subsequent PPAP steps (to obtain the so called specific PPAP evidence). Achievement of these goals is necessary to achieve the main goal, which is the approval of the whole PPAP, which means the customer's consent to start the serial production. Figure 2 shows the PPAP process as a sequence of steps, requiring application of specific quality tools/methods.

After obtaining the product specification, the supplier's first task is to perform a feasibility study. Then, the production /assembly process is being planned, i.e. a process map is to be presented in a form of a Flow Chart.

2.1. Flow Chart

PPAP handbook [2] specifies that the organization must have a Flow Chart in a format specified by the customer. Flow Chart must clearly describe all the stages of the production process, together with the assignments of the customer's requirements (for the product and the process, both their parameters and methods of control). To describe the subsequent operations in the process graphic symbols are used, agreed with the client. There are many conventions of the graphic description of the flow (steps) of the process.

Objective: To define a diagram of the production process flow for a new product.

Input: information obtained from the analysis of the technical documentation (specifications).

Output: Flow Chart, i.e. the map of the flow of production processes.

Procedure: according to company process design procedure (from goods inwards, through storage, flow to production/assembly, followed by all subsequent processing and logistic operations, to the final product quality control, storage or shipment of finished goods to the customer).

Algorithm: the steps performed during the creation of the Flow Chart can be represented as a process using the algorithm presented in figure 3.

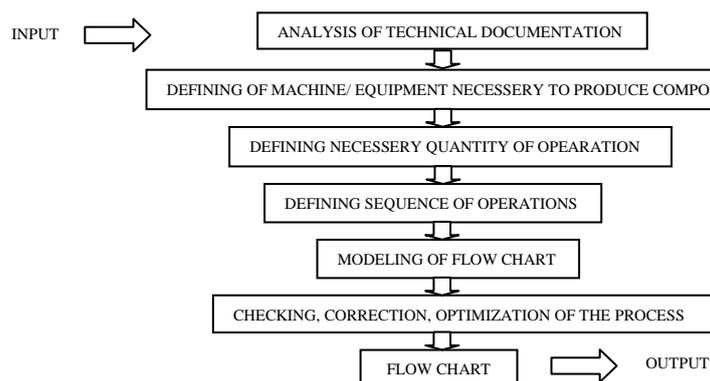


Fig. 3. Flow Chart elaboration process (own study)

Responsibility: the technical department and process engineers appointed for the purpose are generally responsible for the mapping of the process flow.

The assessment, indices - proposed indices:

- Efficiency (timeliness): the number of days of delay in developing the final version of the Process Flow Chart in relation to the deadline imposed by the project schedule;
- Efficiency (timeliness): the number of days of delay in developing the final version of the Process Flow Chart in relation to the planned, total number of days of the PPAP process according to the schedule of the project (%);
- Effectiveness: the number of significant changes made to the Process Flow Chart from the development of the first version until the first submission of the PPAP;
- Effectiveness: the number of working hours of people (engineers) involved in the development and updating the Process Flow Chart, in relation to the total number of hours devoted to preparing the PPAP, until approval (or final rejection) of the PPAP (%).

2.2. FMEA

The FMEA Method (Potential Failure Mode and Effects Analysis) [4] is used to identify and reduce potential product and process risk (failures, their causes, effects and controls). Using risk indices (Severity of failure effects, Occurrence - probability of failure causes and Detection of failures or causes) decisions are made about necessity of preventive actions.

Objective: The execution of the risk analysis and implementation of the preventive action to ensure an acceptable level of risk for the product/process.

Input: diagram of process flow (for FMEA process), quality requirements - approved by the customer's product specifications (for FMEA design and FMEA process), including special characteristics, quality requirements for the process, historical data (quality records) for a similar product/process.

Output: risk analysis – identified risks, risk ranking, identified critical risks, plan of preventive action, preventive measures taken, planned control measures for the production process (input for the Control Plan).

Procedure: according to [4].

Algorithm: the process of performing the FMEA analysis can be represented by the algorithm depicted in figure 4.

Responsibility: leader/project manager, the interdisciplinary team.

Assessment, indices - proposed indices:

- Efficiency (punctuality): number of days delay in the development version of FMEA showing an acceptable level of risk for the (product/process) in relation to the deadline imposed by the project schedule;
- Efficiency (punctuality): number of days delay in the development version of FMEA showing an acceptable level of risk for the (product/process) in relation to the planned, total number of days of the PPAP process according to the schedule of the project (%);
- Efficiency improvement (through standardization of solutions between projects): the number of preventive actions introduced by the FMEA team in relation to the number of defined risks (rows in FMEA) documented in the FMEA until an acceptable level of risk for the product / process is achieved;

- Efficiency improvement (through standardization of solutions between projects): the ratio of the total risk measure for the product/process (total RPN) obtained before the preventive action for the given project, to the total measure of risk for a similar previous product/process (total RPN) obtained before the preventive actions;
- analysis effectiveness: the number of unforeseen hazards within the FMEA, which led to customer complaints in the course of the production, in relation to all the risks foreseen for the product/process;
- Improving efficiency: the elimination of risk factors - ROI (Overload Risk Index), DOI (Overload Detection Index) according to [8];
- Effectiveness analysis: the number of working hours of people involved in the development of FMEA to the time of approval (or final rejection) of the PPAP, in relation to the total number of working hours devoted to preparation of PPAP.

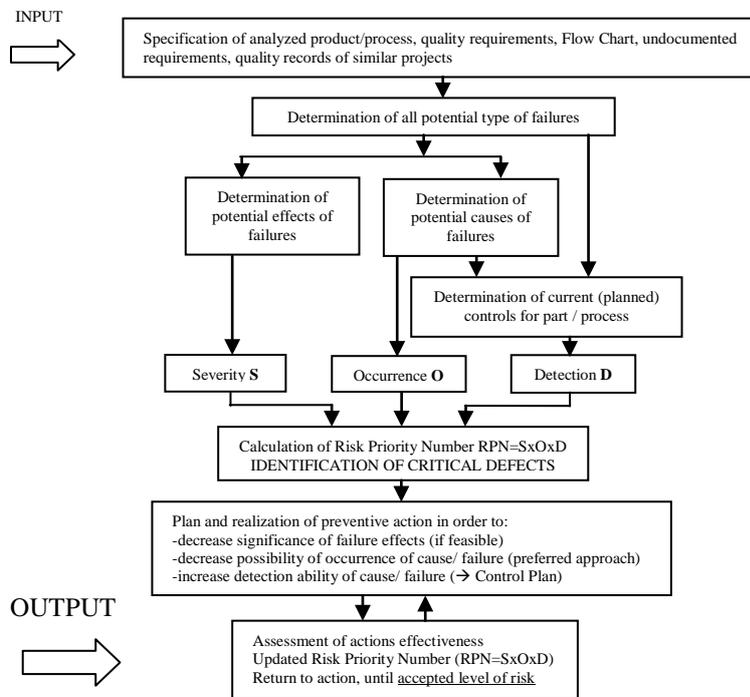


Fig. 4. The process of creating the FMEA (own study based on [4] and [5])

2.3. Control Plan

Process parameters and product characteristics determined by the FMEA as important risk sources or critical risk sources (the latter often referred to as special characteristics) must be subject to supervision and control. To define all planned product / process controls, a Control Plan is defined on the basis of performed FMEA.

Objective: identification of all controls planned for the production process in detail to allow the implementation of these controls and their development (to keep up with changes in specification, FMEA, customer requirements, etc.).

Input: Flow Chart, specification of technology, process FMEA analysis, list of the special characteristics specified by the customer, the customer's requirements concerning the control of the product/process,

Output: the Control Plan covering the entire production process,

Procedure: according to [1].

Algorithm: the Control Plan development can be represented by a sequence of consecutive actions, shown in figure 5.

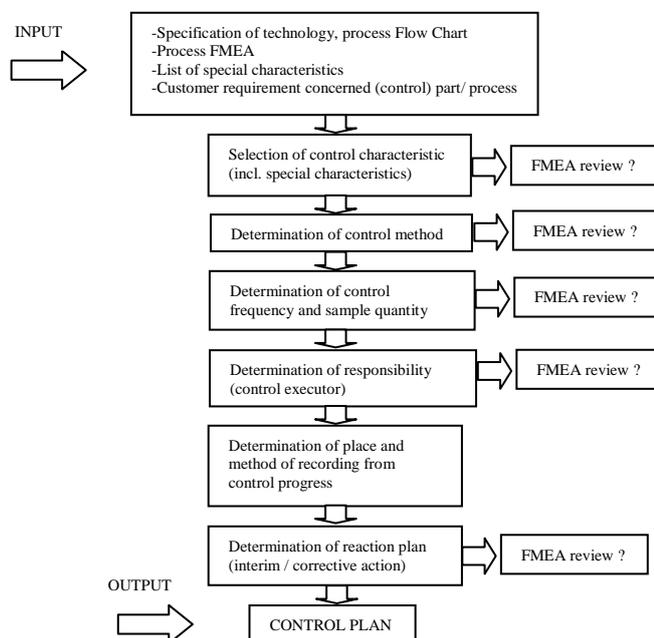


Fig. 5. The process of creating the Control Plan (own study)

Responsibility: the leader/project manager or a person designated by him – often a quality engineer in the quality department, participates - the interdisciplinary team (like FMEA).

Assessment, indices - proposed indices:

- Timeliness: the number of days of delay in developing the final version of the Control Plan for the prototype stage (if any) in relation to the deadline imposed by the project schedule;
- Timeliness: the number of days of delay in developing the final version of the Control Plan for the trial production stage compared to the deadline imposed by the project schedule;
- Timeliness: the number of days of delay in developing the final version of the Control Plan for stage production in relation to the deadline imposed by the project schedule;

- Efficiency (timeliness): number of days of delay in developing the final version of Control Plan in relation to the planned, total number of days of the PPAP process according to the schedule of the project (%);
- Effectiveness: the number of major changes made to the Audit Plan from the development of the first version to the first submission of the PPAP;
- Effectiveness (link FMEA - Control Plan): The number of controls defined in the Control Plan for the product and the process in relation to all the controls listed in the FMEA process for the product (target: 100%);
- Efficiency (control): the number of control for the process parameters in relation to the total number of checks (for product characteristics and process parameters);
- Efficiency (control): the number of checks carried out at source (where non-conformance happens) in relation to the total number of checks (for the product characteristics and process parameters, performed at all points: at the source, between operations and at final inspection);
- Effectiveness (development): the number of working hours of people (engineers) involved in the development and updating of the Control Plan in relation to the total number of working hours devoted to preparing PPAP, pending approval of PPAP.

2.4. MSA

The PPAP manual [2] defines that the organization must have evidence of qualification for the measurement systems listed in the Control Plan. These proofs are to be obtained by appropriate MSA (Measurement System Analysis) methods, e.g. analysis of repeatability and reproducibility (R&R), bias, linearity and stability.

Objective: The classification of measurement systems provided to perform measurements and tests specified in the Control Plan.

Input: the Control Plan, equipment and personnel foreseen in the Control Plan, relevant samples of products.

Output: a measurement system capability assessment (indices %R&R, %EV, %AV, ndc, Kappa etc.), decisions on the qualifications of measurement systems, MSA testing plan for the normal production phase.

Procedure: according to [6].

Algorithm: the process of MSA analysis can be represented by the algorithm depicted in the figure 6.

Responsibility: typically the quality department or laboratory test/measurement chamber, supervision: leader/project manager.

Assessment, indices - proposed indices:

- Timeliness: the average delay (number of days) of MSA qualification for all measurement systems listed in the Control Plan, for which the MSA is has not been made in time imposed by the project (or MSA) schedule;
- Timeliness: the number of measurement systems in Control Plan, for which the MSA is not performed within the period imposed by the project (MSA) schedule;
- Timeliness: the number of measurement systems listed in the Control Plan, for which the MSA qualifications (%R&R > 30%) had not been obtained within the time limit imposed by the project (MSA) schedule;
- Timeliness: the number of measurement systems under Control Plan, for which qualification was decided with a rate of 10% $< \%R\&R \leq 30\%$ and the customer's

consent to use the measurement system, within the period imposed by the project (MSA) schedule;

- Timeliness: the number of measurement systems under Control Plan, for which the qualification MSA was obtained ($\%R\&R \leq 10\%$) within the time limit imposed by the project schedule;
- Timeliness: the number of measurement systems under Control Plan for controlling special characteristics, for which the MSA qualification was obtained ($\%R\&R \leq 10\%$) within the time limit imposed by the project (MSA) schedule;
- Effectiveness: the number of measurement systems under Control Plan, for which the MSA classification is made prior to the PPAP submission, in relation to the total number of measurement systems under Control Plan;
- Effectiveness: the number of measurement systems in Control Plan (count as specimens), present in number greater than one (specimen) on the shop floor, which were qualified with MSA methods prior to PPAP submission, in relation to the total number of all specimens (representing the measuring systems listed in the Control Plan), occurring in number greater than one on the shop floor;
- Efficiency: the average time (working hours) devoted to the classification of the measurement system;
- Efficiency: the number of measurement systems under Control Plan, for which the qualification was obtained ($\%R\&R \leq 10\%$) for the first time (no corrective action), in relation to the total number of measurement systems under Control Plan (%).

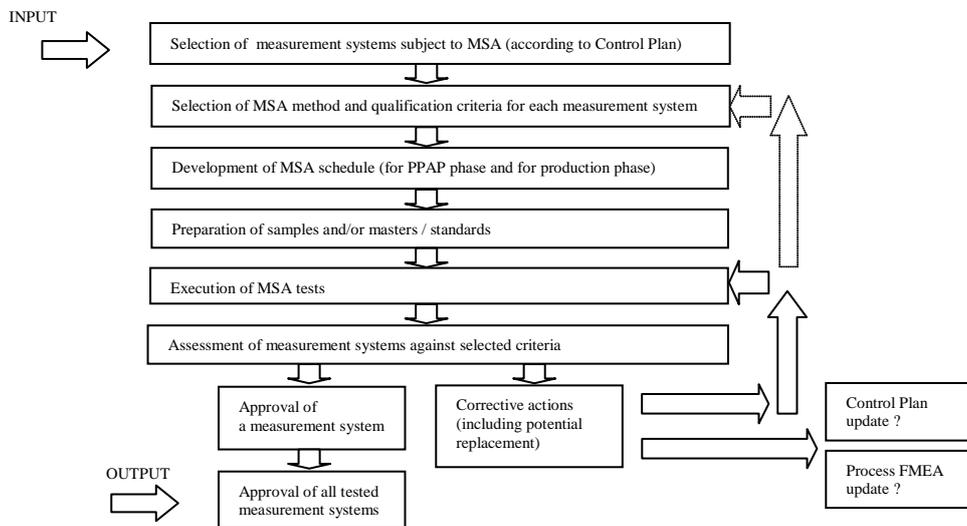


Fig. 6. The assessment of measurement systems (own study)

2.5. SPC

After the FMEA analysis, the working out the Control Plan and qualification of measurement systems using the MSA methods, the manufacturing process can be

considered as ready for initial evaluation of its capability and stability. The FMEA analysis with preventive actions have provided the risk reduction to an acceptable level, the Control Plan has defined all the required checks and measurements, and the MSA showed the capability of measurement systems specified in the Control Plan. The examination of the production process capability should now demonstrate supplier's readiness to start and control (by SPC control charts) normal production.

Objective: preliminary assessment of the capability and stability of the production process, obtaining the required capability of the process, obtaining an evidence of the stability of the process, preparation (design and validation) of the control charts for the production stage.

Input: Control Plan, qualified measuring systems (MSA).

Output: a positive evaluation of the capability and stability of the process, the design of control charts for the normal production stage.

Procedure: according to [7].

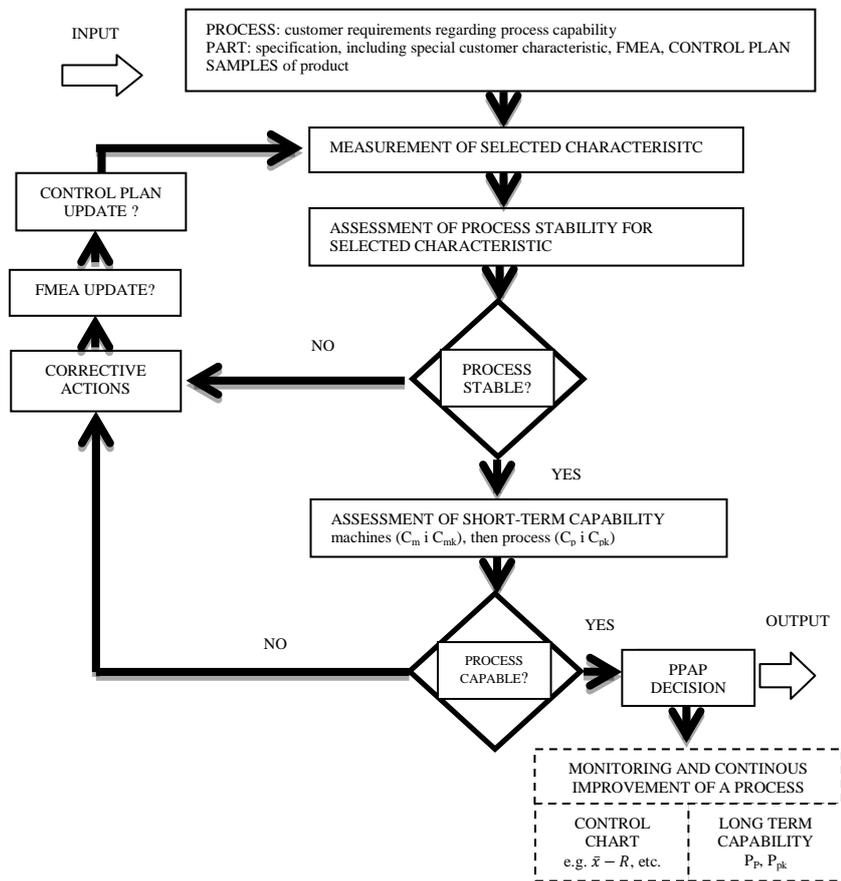


Fig. 7. Process examination and obtaining process stability and capability (own study)

Algorithm: the evaluation of the capability and stability of the production process can be represented as a process of shown in figure 7.

Responsibility: typically the quality engineer or process engineer, supervision: leader / project manager.

Assessment, indices - proposed indices:

- Effectiveness: the number of characteristics for which the study was performed to yield positive results before the PPAP submission in relation to the total number of characteristics that are scheduled in the SPC;
- Efficiency: the average values obtained in indices C_p , C_{pk} for all the special characteristics as reported in the PPAP;
- Efficiency: the number of characteristics for which the SPC is conducted, for which stable courses were obtained in a control card without corrective action, in relation to the total number of characteristics for which the SPC is implemented;
- Efficiency: the number of characteristics for which the SPC is conducted, for which the satisfactory capability ratios were obtained without corrective action in relation to the total number of characteristics for which the SPC is implemented;
- Efficiency: the number of characteristics, for which no satisfactory ratings were obtained (poor capability or instability) for the first time in relation to the total number of characteristics, for which the process test was done;
- Efficiency: the average number of process capability tests performed for the characteristics, which did not give satisfactory ratings (low capability or instability) for the first time.

3. PPAP – a Good Practice of assuring quality of suppliers vs experiences

The approval of the products before normal production has become common practice (often mandatory) not only in the automotive sector, but also in other industries.

The quality proofs submitted to the customer to obtain "PPAP approved", if prepared correctly and with full involvement of engineers who thoroughly analyze the implemented process, are able to effectively prevent against majority of non-conformances prior to serial production. Such preventive approach is indispensable for suppliers whose customers has begun to require failure rate 0 ppm.

Why then, despite successful PPAP approvals, non-conformances occur during the production, resulting in customer complaints, more frequently than expected ?

The problem is complex, but certainly one of the explanation is definitely an inadequately developed PPAP and its undue acceptance granted by a customer representative. The causes are to be found at each party: supplier and customer. The root cause seems to be a lack of adequate human resources assigned to PPAP, which in turn results from poor project planning and deficiencies in necessary qualifications for both performing PPAP (supplier) and verify/approve it, i.e. professionally assess quality and credibility of submitted documents (customer). Actually and quite often, submitted PPAP documents are reviewed briefly, the most important document being considered a report of product measurements results and the submitted product itself. Surely this is the most obvious and simple document to verify. It is on these PPAP elements (albeit very important) that the most of customers seem to focus. Thus, quite often, a conforming product and conforming measurement results means a success for a supplier (PPAP approval) and gives the green light for the serial production and supplies. Other PPAP documents becomes only a formal addiction (verified by crossing out subsequent evidences

on a checklist). Consequently, manufacturing process becomes the least important issue in the whole PPAP, which is a contradiction of the PPAP concept. Thus, a supplier mainly focuses on costly corrective actions after start of production, instead of preventive actions when preparing PPAP. Authors of the paper see the need of improvement of PPAP management by supporting the PPAP process by relevant indices measuring its effectiveness and efficiency. This should allow to set up criteria allowing to more thoroughly monitor and assess the PPAP course and outcome.

References

1. Advanced Product Quality Planning and Control Plan APQP. Reference Manual. 2nd Edition. AIAG, 2008.
2. Production Part Approval Process (PPAP). Reference Manual. 4th Edition. AIAG, 2006.
3. The International Material Data System – www.mdsystem.com
4. Potential Failure Mode and Effects Analysis (FMEA). Reference Manual 4th Edition. AIAG, 2008.
5. Hamrol A.: Zarządzanie jakością z przykładami. Wydanie drugie zmienione. Wydawnictwo Naukowe PWN, Warszawa, 2007.
6. Measurement System Analysis MSA. Reference Manual 4th Edition. AIAG, 2010.
7. Statistical Process Control SPC. Reference Manual 2nd Edition. AIAG, 2005.
8. Rewilak J.: Characteristic of quality improvement the proposal of measurement the process improvement managed by FMEA. Advances in Manufacturing Science and Technology. Polish Academy of Sciences Committee of Mechanical Engineering. Vol. 35, No. 4, 2011.

Prof. dr hab. inż. Józef GAWLIK
Dr inż. Jan REWILAK
Instytut Technologii Maszyn i Automatykacji Produkcji
Katedra Inżynierii Procesów Produkcyjnych
Politechnika Krakowska
Al. Jana Pawła II 37
31-864 Kraków
tel./fax.: 12 374 32 46
e-mail: jgawlik.pk@gmail.com
tel./fax.: 12 374 32 83
e-mail: jr@tqm.pl

Mgr inż. Tomasz TOKAJ
Dyrektor Zarządzający
PPUH Malbox ZPChr
32-300 Olkusz
Osiek 212a
tel./fax.: +48664124952
e-mail: t.tokaj@malbox.com.pl/
tokaj79@poczta.onet.pl
Doktorant WM PK