MANUFACTURE SYSTEM OF COMPLEX PRODUCTS

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Abstract. *The complex nature of the aeronautical manufacture system, with your expressive value, and the difficulty of involved prediction, added the requested innovations of the product, they have been configuring the manufacture system as a strategic element in the ability of competing of the companies. This article analyzes several characteristics of the aeronautical manufacture system through the explanation of examples the need to structure conceptually a balanced solution to produce in series complex products. Starting from the exploration of the characteristics and problems of process of development of the manufacture of aircrafts it was emphasized the need to treat manufacturing system design the holistic and systematic activity to approach all life cycle of the manufacture system, balancing team of the activities, technical acting in consistency with the customer's expectations. Like this, an approach of System Engineering is qualified to structure improvements of the process to increase the understanding dynamics manufacture aeronautical system dynamics.*

Keywords: System, manufacture, assembly

1. Introduction

In the current economical scenery, each company should consider the decisions on assemblies as a strategic activity, questioning on which it is the best form of to use and to develop the system of assembly in an efficient way. The acting of the assembly activities not only they determine inside of the assembly system the final quality of the products, but they also affect it team-to-market, Delivery, etc. (Rekiek, 2001) This article seeks the increase of the understanding of the aeronautical manufacture system in the introduction of new way projects to reduce the resources they be invested it and to enlarge your effects.

According to Eppinger and Salminen (2001) the development of complex products and great systems are a highly interactive social process involving hundreds of people and thousands of artifices and relationships of components needing millions of simultaneous decisions. The article analyzes several characteristics of the aeronautical manufacture system in way to structure conceptually balanced solution to produce in series complex products. To set up an aircraft in the smallest interval of time, it can constitute one of the main competitive advantages of the assemblers of aircrafts, because it will be more quickly able to assist your customer and it can reduce the work-in-process. (Gastelum, 2002) The complex nature of the aeronautical manufacture system, with your expressive value, and the difficulty of involved prediction, added the requested innovations of the product, they have been configuring the manufacture system as a strategic element in the ability of competing of the companies. (Ruffa and Perozziello, 2000) In way to allow a larger concurrent process of development of the product the System Engineering it is comes as an unfolding of the approach internal and to multi-discipline collaborative flow, to develop and to verify a balanced solution in the development complex manufacture systems.

2. System Engineering

Systems engineering is fundamentally a problem solving process that translates needs and requirements as inputs into designs and products as outputs. The systems engineering process typically starts with problem definition as requirements are analyzed. Alternative solutions or system architectures are developed, usually initially through techniques such as functional analysis and data flow analysis. Alternative physical designs are then developed to satisfy the functional or data flows. Trade studies and risk analyses are applied to select a preferred design solution, and that solution is verified against the original requirements.

These process, properly applied, results in a flow down of requirements from the system level to the items below system level. As these requirements are flowed down, the design requirements for the items below system level are defined. Once these lower level design requirements are finalized, the design process proceeds to completion. The result is a design that associates physical entities with the functions that the system must perform, and is consistent with the levels of performance required and with the interfaces specified.

This process, applied without constraints, will lead to the design of a system in which every item is optimized to the requirements in terms of function, performance, and interface.

According (Fernandes, 2001), a manufacturing system has the characteristics of a system. A manufacturing system takes inputs (product orders), processes inputs (transformation of raw material into products) and generates outputs (products), there are strong interactions between the various components of manufacturing system, and a system boundary can be identified around a company’s manufacturing system. A manufacturing system typically is made up of multiple subsystems such as single machines, groups of machines, humans, fabrication units, assembly lines, job shops, cells, computer systems, suppliers, of other factories. For the manufacturing system to operate properly, all of these subsystems have to perform their specific functions at the right time and in right quantities. The system performance can be hampered if one of the subsystems fails to perform its task. Likewise, the decisions made within one subsystem without considering the systemic effect, can have long lasting consequences on the entire manufacturing system.

It is too difficult to model a manufacturing system due to highly non-deterministic nature of the manufacturing operation. There are too many uncertain variables, the most uncertain of which are the human beings. (Fernandes, 2001)

This discussion of a manufacturing system that is an objective oriented network of processes through which entities flow introduced the concept of a manufacturing system being a system comprised of interacting sub-systems that aim to achieve a particular objective. Given this definition, the analysis and design of a manufacturing system can then be approached with systems engineering principles. (Vaughn, 2002)

Manufacturing system design can be viewed as the process of selecting manufacturing resources and designing an operating policy to produce the strategically chosen products at the right time and in right quantities. These manufacturing resources can be people, manufacturing processes, machines, tools, floor space, software, transport equipment, suppliers, energy source, and information. Therefore, a manufacturing system design activity is not just factory floor improvements, Kaizen events, value stream mapping, changes within the four walls of a factory, and waste elimination. But, it is all of these in addition to, selecting the appropriate layout, developing an operating policy, selecting right processes, technology, location, capacity and suppliers, determining the degree of supplier involvement, selection of organizational structure, and designing the interactions between all of the above. Fernades, (2001) adopting 10 factors to describe a manufacturing system:

Market Uncertainty;
Product Volume;
Product Mix;
Frequency of Changes;
Product Complexity;
Process Capability;
Worker Skill;
Type of Organization;
Time to first part;
Investment.

3. Architecture of product.

An aircraft is composed physically by several systems (electric, hydraulic, environmental, propulsion among other) with different components. These components are installed in the structure of the aircraft and interlinked for electric cables, tubes, mechanical cables and other elements of communication of energy or information. To be organized in a hierarchical way all the parts of an airplane, it was stipulated of the Air Transport Association the denominated norm ATA-100 to represent the components of an aircraft. The ATA-100 norm that describes the aircraft in groups, systems and sub-systems. This norm is followed by the manufacturers of world airplanes, forming like this an universal standardization of the parts of an aircraft for the format of documents and technical manuals.

Product architecture is the outline for which the functions are allocated from a product to physical components (Ulrich, 1995). the conception of the architecture of the product can address the acting not only of the product, but also of the efficiency of production of the product. Physical components implement the functional elements of the product, this drawing among functional and component elements can be one-for-one, many-for-one, or one for many.

According to Ulrich (1995), the distinction in the typology is between a modular architecture and an integrated architecture. A modular architecture includes drawing of functional elements a-for-one in the function structure for the components physicists of the product, and specific interfaces among the components, to the step in integrated architectures, a component carries out more than a function.

For the operational point of view the concept of modules has been plenty used, due to the possibility of interchangeability of components among different products and also and for the possibility of outsourcing groups that they characterize way modules to reduce the production cost and administration of components.

The architecture of the product is important and necessary to organize the project of a system as to understand your behavior. Some architectures are easy to administer during the project, another are easier to administer during your operation. Some are more robust with relationship to the prevention of flaws; others are more robust in the case of fortuitous flaws. The architecture is a road to understand each other complex systems, because the arrangement and the relationship of the entities sketch many of the manners that the system will behave. According to Baldwin and Kin (2000) the modules can be divided as presented below.

Modularity in the project: Each function is projected separately and inserted in a physical component, or they are several combined functions in just a physical element;

Modularity in the production: A group of functions or physical components are built or bought together. (former: production for process);

Modularity for the customer: The customer can combine several functions or physical components when uses, choosing when buying the best group than assist.

The three types of visions on modules can be different, like this, a module that exists in the production it can include parts of many modules or systems in the project. This differentiation in the concept of modules can cause several conceptual doubts when it is the development of complex products. However the use a modular design approach combined with well-defined standards-based interfaces among modules to isolate the effects of change in evolving systems, serving to reduce the need for redesign as the system is upgraded.

In the architecture of an aircraft for instance, the components and the functions are structured hierarchical, like this although it has been projected to execute a lot of functions, a motor in an aircraft a module can be constituted on the point of view of assembly of an aircraft.

The architectures of aircrafts are also described by families of products as Boeing 737-XXX (series). The different versions possess the same fuselage diameter, and other characteristics as the system of control of the pilots' cabin, but they can differ in the size of the fuselage and wings. (Crawley at. al.) Like this, the new versions of this aircraft should insert if the project rules and production, in way are mounted in a same one it manufactures, and again by the same pilots without the need training. These rules also include a type of own architecture of the family of products as well as physical interface characteristics. The fig. 1, display two methods of joining to the fuselages and of the distribution systems installed inside an aircraft. Each method offers advantages and disadvantages. The geometry of "half barrel" or "Trough and drape" it is more appropriate for the assembly of small aircrafts while in the assembly of a larger aircraft it would be more appropriate the junction of followings in the form of "barrel" or "build and join barrel sections" making possible the inclusion of new members besides the family of aircrafts.

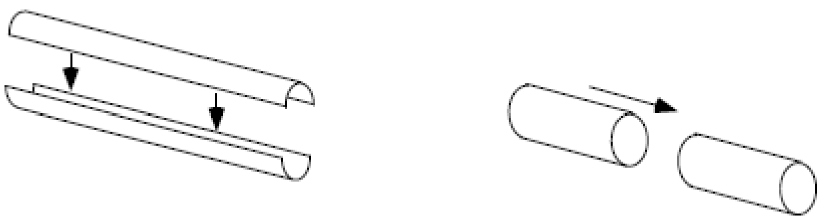

Figure. 1 – Alternatives to Building Aircraft Cylindrical Fuselage Sections

The conception of an aircraft with segments of half barrel can be more economical, but if the market chooses for an aircraft a little larger, this solution can be a due economical disaster the high cost of the implementation of the tolling involved, while the solution barrel implementation cost is smaller. In the same way if the assembly system in half barrel can be the most economical in case the market demands a larger cadence of aircrafts, the solution barrel it can be more economical case the demand of the market it is for a larger mix of products. The conception of the aircraft also defines the possibility or not of automation of the process of assembly of aircrafts, like this, a technology that is unviable in the phase of conception of the system of assembly of the aircraft, it will also be unviable in the phase of operation of the assembly process, due to the need of changes in the conception of the project of the aircraft. The change in the conception of the project is very costly due to the high cost of the process of certification of the product and for treating of a product highly integrated.

During the process of conception of the sequence of assembly of a product it just is not enough to know the functions of each component, but it is also necessary to know the road of the value in full detail, knowing as of value each component joins to the product, because it can like this if equation a better distribution of the work-in-process.

For manual assembly systems (as the systems of assembly of aircrafts), the index of more interesting acting is as the work load this balanced.

An assembly sequence can be subdivided in several logics and physical components. For the analytic point of view, it is convenient to subdivide a line in several components, and to work separately with each of them. At the same time, theses components should be projected in the way more integrated possible.

The limit is to have all the components interacted simultaneously, however, as it is usually difficult to work at the same time with many difficult tasks, the works are contained and divided in several levels.

Some products are very big for they are removed, so that the choices for a product to be set up in fixed layout is based on the product size and your form. Examples of products that request fixed layout are airplanes, ships and rockets. For such a project, once the basic structure is built, the several tools of demanded assemblies will be inside about located a same physical space of the product.

4. Aeronautical assembly process

The assembly of an airplane requests a synchronized series of industrial processes that are organized as a simultaneous chain and melted flows. (Gastelum, 2002)

The net of precedence of commercial aircrafts of great load involves hundreds of activities that have your certain structure in the conception of the project, although it is focus of the improvement activities it continues and possess adaptations and current necessary fittings of the manufacturer's internal and external sceneries. These changes are also current of technological improvements in the productive process and evolution of the learning curve that given to the complexity of the assemblies and the level of details is quite accentuated in the aeronautical assembly

With the demand every time larger on the part of the customers for private configurations they demand that the assemblers of aircrafts your equation strategy of configuration of the product considering your assembly efficiency with the operational efficiency of the product.

The increment of activities alters the cycle of assembly of the aircraft, resulting in the increase of the work-in-process of the assembler. An alternative for a better swinging of the activities would be, for instance, that all the aircrafts are manufactured her they possess provisions for optional assembles.

The decline of the curve of learning activities that optional items involve is also affected, committing the robustness in the cycle of this activity, increasing the difficulty of the planning of the activities rises in function of the great number of activities and great number of optional equipments.

Due to high level of demands for the certification of an aircraft, the production activities and assembly of an aircraft request of the involved people a high qualification degree and understanding, with this, activities that would be treated with a smaller degree of attention in other industrial activity are considered critical in the aeronautical industry. Like this, the inserts of fixation components with structural function (screws) they need the values of applied torque during the assembly are registered by qualified mechanics in documents auditory for aeronautical authorities to certificate the aircraft production system.

The same demands are also necessary for activities that if neglectful they can offer risk the flight safety as: electric boarding (process that guarantees the electric road between two or more conductive parts, in way to assure the same electric potential), protection against erosion, and protection against electric discharges among others.

Several components also need that your series number and or validity are controlled road registration in specific books. Those demands do that the installation of a screw in an aircraft is an activity that burdens the time much more than in other sections of the industry. The time is also high due to the understanding of the assemblers with relationship flight safety that takes, for instance, that the assembly of an aircraft is interrupted when a simple one (however in some situations can be fatal) tool is lost in the productive process.

The balance of the activities of assembly of an aircraft is planned starting from the net of the technical precedence of assembly. An aircraft being a product with high physical dimensions can be considered that several activities can be accomplished in parallel with other, in way to reduce the total cycle of assembly. Like this in the elaboration of the conception of the precedence net it is necessary to know the critical roads of assembly (assemblies that affect directly to the assembly cycle)

The techniques for elaboration of a precedence net usually divide the product in physical areas, which limit the number of people in a determined area. Like this if the areas of the aircraft possess different assemblies, these can be accomplished simultaneously.

When integrating several components, it can be obtained a module, like this of the point of view of time of assembly execution (independently needs special tools) as larger the size of the modules, smaller it will be the total cycle of assembly due to the reduction of the number of items they be her mounted in the critical road and more activities will be accomplished in parallel. However this decision can implicate in the creation of special tools and dedicated to each assembly. The project of modules that integrate several functions can elevate the time of development considerably due to the increase of the complexity of these modules.

The process of development of aircrafts current introduces one it accentuates interaction among the planners integrate due to the use of models of simultaneous engineering with the teams' multi-functional of integrated product development. The exploration of the Design concepts of Assembly they are more accentuated in function of the increase flow of information and synchronization between different work groups. The fig. 2, presents a model of the aircraft process development.

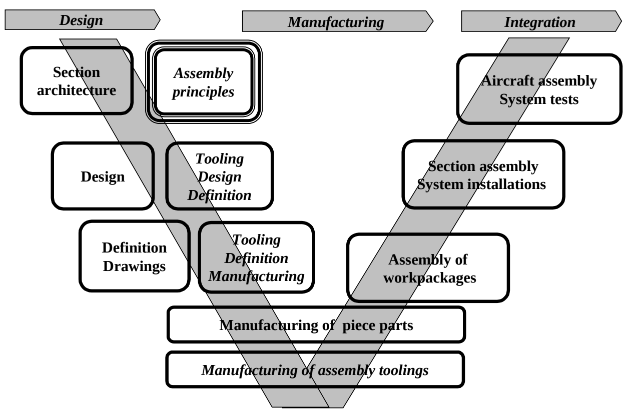

Figure. 2 - Process Development of aircraft (Marget, 2001)

The administration of the needs of assembly conceptions is only possible during the process development of the product, although the manufacture system is an element of competitive advantage in the other phases of the product life cycle. Due to the great number of uncertainties (external to the domain of the organization) in the phase of definition of the architecture of the aircraft, is necessary continues adaptation of the manufacture system along the product life cycle for the company it can absorb all the uncertainties of the market as: cadence production variation and mix products variation, hindering the constitution of a manufacture system optimized.

Companies assemblers with processes development systems manufacture superiors are capable to introduce new products more quickly in the market and with better quality, and at a lower cost, taking advantage opportunities of market in a more efficient way along the whole life product cycle.

The difficulty to optimize the manufacture process due to the technological evolution in the methods and manufacture processes is more accentuated in the assembly process because the assembly process is defined in project conception function of the product (due to the integration of functions in the product hierarchy), the processes production of primary components can be like this technologically updated with a larger frequency for they possess a smaller conception dependence of your product project. This characteristic is presented in fig. 3.

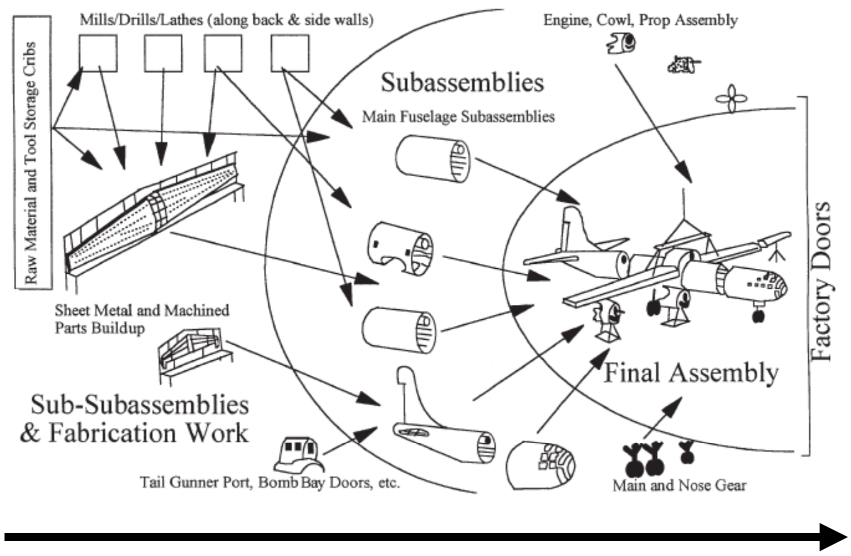

Figure. 3 - Difficulty of improvement of the productive process (adapted of Ruffa and Perozziello, 2000)

The needs of better acting with low operational cost on the part of the customers and the requirements of certification of the aircrafts turn the cost of modifications of the conception of the extremely high project. In that way difficultly are viable the technical order to implementation in the system of assembly of an aircraft in seriate production. In compensation during the conception of the aircraft the companies don't still possess a wallet of request of the aircraft that you/they are projecting enough for us to liquidate the development costs. This paradox interferes deeply in the decision of investment of new manufacture technologies during the phase of development of the aircraft owed the involved risk. Another risk increment if it owes to the fact of the assembly tolling and test of aircrafts they be not commodity, (as they are the machines used in the production of components, although they possess higher value) and they demand qualification it specifies of people for your use.

Due to the presented complexity is fundamental an approach of Systems Engineering to derive, to develop and to verify a solution balanced in the complex manufacture systems development. Through the introduction product views, processes and organization is possible to learn on the phenomena of the manufacture process development, studying the interaction patterns among the product, the processes and the organization domains along the whole manufacture system life cycle.

It is possible to influence the risk on domain of the own manufacture process, knowing the internal dependences of the system of way manufacture to simplify the product and processes architecture, to adjust the processes in agreement with the head offices of the project structure, and with the alignment members of the organization. It is fundamental to promote the communication with a better administration of the created data, defining with clarity the responsibilities and synchronization activities. The approach of System Engineering also supports a more select investigation of the involved risks and the results evolution verification.

5. Conclusion

In the future, it is unlikely that products of complex systems will only compete in base of technical acting. What will differentiate such systems, and your promoting ones, it is the ability to balance all the dimensions of product acting, besides functions of development cost and production cost and your respective time of cycle. Besides, this balance has to be corresponding with the perception of the customers' value. Once this value is discovered or approximate, the promoting of systems will demand the capacity to adjust from all the processes to the expectations of value.

It can be concluded that the complexity of the product itself increases the complexity of the manufacturing system design effort if appropriate process capability (or process technology) is not available, which in turn increases the complexity of the system itself.

The more flexible the manufacture system, adult will be the time of life of the product in the market and larger they will be the chances of an plan to be lucrative and to guarantee the survival of the company.

Starting from the exploration of the characteristics and problems of process of development of the manufacture of aircrafts it was emphasized the need to treat manufacturing system design the holistic and systematic activity to approach all life cycle of the manufacture system, balancing team of the activities, technical acting in consistency with the customer's expectations. Like this, an approach of System Engineering is qualified to structure improvements of the process to increase the understanding dynamics manufacture aeronautical system dynamics.

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