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Composite manufacturing data management in aerospace industry

Erdal Tekin[a], Özge Kapan[b]

[a,b] *TAI, Turkish Aerospace Industries, Kazan, Ankara, Turkey*

* Corresponding author Tel.: +90 811 18 00 2933. *E-mail address:* etekin@tai.com.tr

Abstract

Increasing global demand for composites continues to be driven by the aerospace industry. However, expensive raw material and the complexity of manufacturing process increases the risk level in composite technology. Considering the complexities of composite manufacturing, our paper describes a data management application in composite manufacturing at an aerospace manufacturer. The scope of this manufacturing data management application is from the raw material issuance from warehouse to the painted final composite product. After a description of the application, we will discuss potential problems and possible solutions and improvements of the data management in composite manufacturing in the aerospace industry.

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Keywords: Composite Manufacturing; Computer automated process planning (CAPP); Manufacturing Data Management

1. Introduction

Composite parts are manufactured to achieve high levels of performance under high demanding conditions. The increasing global demand for composites continues to be driven by the aerospace industry. However, expensive raw material and the complexity of manufacturing process increases the risk level in composite technology. Issues like sensitive raw material with short shelf life and wide range of manufacturing variables must be closely controlled during composite manufacturing. Appropriate tooling, manufacturing techniques, automated manufacturing and inspection techniques for composite materials will result in competitive products.

Considering these issues of composite manufacturing, our paper describes a data management application in composite manufacturing at an aerospace manufacturer. The scope of this manufacturing data management application is from the raw material issuance from warehouse to the painted final composite product. After a description of the application, we will discuss potential problems and possible solutions and improvements of the data management in composite manufacturing in the aerospace industry.

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2. Data management in composite manufacturing

2.1. Data Requirements before Manufacturing Process

Composite parts manufacturing process requires a considerable amount of information such as

- Process specifications specific to composite manufacturing like cutting process of raw materials, lay up process and curing process
- tool requirements to shape the materials,
- material specifications,
- the NC programs for cutting the material
- and manufacturing work instructions

Manufacturing work instructions should have necessary details such as the location and orientation of the cut-pieces of material on the tools, the curing method and conditions in the autoclaves, the specifications of material.

2.2. Data management during manufacturing process

Manufacturing process of a part starts with a shop order issued for that part as an output from the ordering function of ERP. The issued orders are queued for processing in the shop floor. They are grouped according to their raw material in order to reach economies of scale in the cutting process. Since the prepreg material is stored in deep freeze (-18 ^{o}C), the rolls should wait 10-12 hours until they are ready for cutting. Also, the cumulative duration of the unfrozen prepregs are limited. For these reasons, once a roll of prepreg is ready for cutting, as many pieces for different parts should be cut even they don't have an actual order yet. The pieces cut for the parts which don't have actual orders are stored as kits. The material data (producer and production date/time and remaining frozen and unfrozen lives in hours and minutes) for these kits should be managed individually after they are cut from the roll.

On the other hand, the prepregs should be tested to verify declared remaining life when they are received to the warehouse of the company. The remaining life of material should be updated according to the result of this test. Also, when the shelf life of the material is expired, they can be re-tested to check whether their life can be extended. The actual life of the prepreg rolls and the life of the pieces of material cut from them is another data to be managed.

Starting to layup process for a part depends on three conditions. The prepreg material should be cut and ready, the tool for the part should be available and prepared for lay-up. Finally, honeycomb material which will be added to prepregs is cut and ready. Since, the remaining time for the unfrozen prepreg is limited, synchronization of these conditions is very important. Thus, the priority data of the orders and status of the tools and honeycomb material is another set of data to be managed.

The time dependent segment of the composite manufacturing process finalizes with curing process in autoclave. Curing process takes a considerable time of hours and is an expensive process. For this reason, once a cure is started, the parts having the same cure-cycle should be cured in the same load. Cure cycles of the parts, the schedules of autoclave runs and the status of the orders with the same cure cycles is another critical data to be managed.

2.3. Data management in the engineering change process

Changes in the design of the final products are a reality of today's aerospace industry. When an engineering change for a part is issued to manufacturing, the status of the orders for the changed part should be reported and they should be stopped for necessary changes. The necessary updates on the work instructions and reworks to the finished or in process parts should be executed. The incorporation of engineering changes to the parts or orders requires manufacturing data to be managed.

2.4. Data management after manufacturing process

When the part is ready to be used in its next assemblies, data accumulated during manufacturing process should also be ready and available. In any case of problems, the root cause of the problem can be investigated through utilizing the manufacturing process data. The accumulated data consists of raw material, the location and orientation of pieces of material, clean room environmental parameters, autoclave cure cycle parameters, etc.

In addition to the routine manufacturing process data, quality assurance records for problems faced during manufacturing process and the results of tests of the specimen manufactured with the original parts should be kept for future reference.

3. Problems related with composite manufacturing Process

The remaining useful time of the prepreg material can be expanded through re-testing the material in the laboratory. The new remaining time should be updated on the rolls and the cut pieces on the orders which are spread over the shop floor. Keeping the shop orders up-to-date with this remaining life expansion requires too much effort.

Keeping useful life of material used for the orders in the shop floor up-to-dated, necessitates a digital data management system.

Shop floor scheduling is another problematic area in composite manufacturing. Zhongyi, Peiyong has a research on production planning schedule to deal with this complexity [1]. Specifically, working with chemical material with limited useful life, autoclaves with limited capacity and long curing durations and personnel with specific skills leads to a highly complex process.

Composite manufacturing process involves specific part routings through various tool preparation, honeycomb core cutting, layup, trim, paint as well as batch processing like prepreg cutting (many pieces for different parts) and autoclave curing (many parts with same cure cycle) which confounds traditional workflow scheduling practices.

Solution for composite manufacturing scheduling problem requires detailed cure cycle models for parts, real time data for prepreg material (in the freezer and in the shop floor) and status of layup process for each part. In order to keep so much real time data in the shop floor requires an integrated manufacturing data management system which is described in the next section.

4. Manufacturing data management system (e-SOIR)

4.1. e-SOIR in manufacturing process

As a solution for information management problems in Composite Manufacturing process, e-SOIR system which is a module of e-Factory System is developed.

e-SOIR is used for shop floor data management system. The content of the process plannings is managed on the shop floor through this digital system. A process planning includes, descriptive data of the part, routing data, work instructions, visual aids, manufacturing part list, material description, input fields and/or tables for shop floor data capture.

e-Planning module of e-Factory System is used to manage master versions of process plannings which are validated according to product design information and stored in the corporate manufacturing database. As a parallel process to process planning preparation, Manufacturing Bill of Material (MBOM) is managed. The MBOM is released to Corporate ERP System.

As the shop orders are released from ERP system, the SOIR (Shop Order and Inspection Records package) is prepared through e-Order functionality of e-Factory System. The process planning of the part ordered is prepared through copying the master process planning data under SOIR number. A set of manufacturing data package including routing data, work instructions, visual aids, manufacturing part list, material description, input fields and/or tables for shop floor data capture is generated as an instance with SOIR number.

The data generated for a specific SOIR is accumulated in the e-SOIR database. Also a traveller document for material handling in the shop floor is printed on paper and issued to the prepreg cutting center. The SOIRs are grouped according to their prepreg types and a daily cutting plan is generated for the next day, since the prepregs require several hours after taken out from freezer to be ready for cutting. When a prepreg roll is ready for cutting, material for ordered parts are cut. However, in order to optimize the prepreg rolls out of freezer time, material for unordered parts using the same prepreg type are also cut. These cut pieces of unordered parts are stored as prepreg kits in the freezer for later usage.

The traceability data of the material (manufacturer, batch no, roll no, remaining life of the material and date/time out of freezer) are recorded on e-SOIR database and the pieces of material cut are labeled with a barcode of the digital record reference. During layup of the material on the tool, the traceability data is transferred to the SOIR of the part through reading the barcode on the pieces of material.

There are many additional parameters to be recorded on SOIR such as the direction of the pieces of prepreg material, the sequence of layup actions, material data of chemicals applied, temperature and humidity of the clean room during layup process, etc. All these parameters are recorded related with SOIR in e-SOIR database.

After layup operation is completed, the part is ready for curing. Autoclaves are loaded with the parts with the same cure cycles. The actual run parameters of autoclave are also recorded in relation with SOIRs.

After curing of the part, demoulding, rout/trim and paint follows. Manufacturing steps which are listed on e-SOIR system are also stamped by technicians and quality inspectors. When the final inspection of SOIR is stamped by quality inspection, the SOIR is completed and an electronic archive record is created.

4.2. Change management in manufacturing process

Engineering changes or manufacturing process changes are incorporated to process plannings through e-Planning module. New revisions of the process plannings are stored in the corporate manufacturing database. The SOIRs will be issued to shop floor with the new revision.

The SOIRs which are issued with the previous revision are in work on the shop floor. For these SOIRs, changes are incorporated through two different methods; Rework Planning or Order Planning.

If the progress of a SOIR is beyond the point of incorporation of the change, the work on the SOIR is stopped. Since the progress created a physical reality in the shop floor, some additional steps should be planned. For this reason a rework planning should be prepared and issued to shop floor as a new SOIR.

If the progress of a SOIR is not beyond the point of incorporation, change on the remaining part of the process planning for the specific shop order (SOIR) can be changed through order planning feature of e-Planning and issued directly to shop floor through e-SOIR system.

4.3. *Quality assurance in manufacturing process*

Quality inspection requires measurements on the parts during manufacturing process. The results of these measurements are also recorded on e-SOIR. If the result of inspection is a discrepancy, the disposition is transferred to a rework planning through e-Planning and a new SOIR is issued.

All discrepency, disposition records and reworks are all recorded on e-SOIR database. Records on e-SOIR database are related with SOIRs for future traceability needs.

5. The benefits delivered by e-SOIR application

With manufacturing data management in composite manufacturing shop, in general, we increased production, reduced errors and scrap, and delivered better quality. However, we can say specifically e-SOIR application delivered following benefits to composite manufacturing:

5.1. Configuration Control and Change Management

Manufacturing instructions and visual aids required for manufacturing are all subject to configuration control. As a digital tool, e-SOIR manages these revisions. Also, tables, forms to be filled with actual values are all in digital environment under control of the e-SOIR System. Changes on any part of manufacturing data, directly transferred to shop floor through e-SOIR System as a single source, users have access to only the most recent, and accurate information.

5.2. Management of quality information

The results of the measurements performed during inspection steps of manufacturing processes are recorded through e-SOIR System. All variations are controlled, and any reworks or repairs are documented.

All data accumulated during manufacturing, are recorded in the as-built database. As-built database keeps all traceability data of raw material, chemicals, standard parts with their manufacturers, lot/batch numbers etc. Additionally, all parameters of manufacturing process such as autoclave reports, paint compositions and test results of specimen manufactured with the same conditions of the SOIR(s).

e-SOIR manages data during the manufacturing process. The system records and archives each step as a permanent record. Automated data management is especially important for companies regulated by the 14 CFR Part 21 Quality Requirements.

5.3. Common source of actual manufacturing information.

e-SOIR System gives us the tools for a consistent source of information for actual manufacturing process. System provides a single source of real time manufacturing data. All documentation, work instructions, and data collected during manufacturing process are kept in the system. This data is used by all the manufacturing team as a single source.

5.4. Maintenance of as-built database

Using a digital manufacturing tool like e-SOIR helps us to record the progress in manufacturing process step by step. Additionally all material data is recorded in real time and remaining life is tracked by the system automatically.

The data accumulated in the As-Built database is critical for composite manufacturing, and vitally important to the trend analysis necessary for process improvement. Determining the variance to specifications is one part of eliminating errors and improving processes.

Maintaining an accurate as-built database will be valuable when the parts are assembled as components or installed to aircraft.

6. Future plans for composite manufacturing

Deployment of e-SOIR System in the composite shop created a database as a real time data source. We are planning to develop new tools for manufacturing planning and control through using the real time manufacturing data,

Development of process improvement tools through utilizing e-SOIR data is also in our future plans.

It is found that the emerging Internet of things (IoT) infrastructure can support information systems of next-generation manufacturing enterprises effectively [2]. Thus, utilizing IoT, we are planning for fully integration of the physical things on the shop with the e-SOIR.

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