Archives of Materials Science and Engineering

Volume 59
Issue 1
January 2013
Pages 5-13

International Scientific Journal published monthly by the World Academy of Materials and Manufacturing Engineering

Damage analysis of composites integrated with RFID chip used in aeronautics

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Received 28.11.2012; published in revised form 01.01.2013

ABSTRACT

Purpose: A new approach to production process by direct integration of the RFID (Radio-frequency identification) chips into the composite parts used during the manufacturing (moulding) process of the composite parts has been presented. This research aims a new application of RFID technology and measurement of the resistance of RFID chips integrated into composite parts under X-ray diffraction beams and also impact choc (crash test). This work gives the actual results of an applied research carried out in laboratory (Supmeca-Paris) scale and also in industrial scales carried out in the manufacturing department of the French aeronautic company (Eurocopter-Paris).

Design/methodology/approach: Application of RFID technology in manufacturing of the composite parts is related to the continuous quality improvement of manufacturing company.

Findings: RFID Chips integrated directly in the composite parts during the manufacturing process can improve the efficiency of the manufacturing process and also decrease the lead time and processing time. This application in manufacturing of the composite parts will enable to achieve success for the aeronautic companies.

Research limitations/implications: In the future, Industrial companies can transform their manufacturing processes by applying RFID technology that increases manufacturing cycle time, maximize efficiency and eliminate unnecessary steps.

Practical implications: Using RFID technology in production will help industrial companies and also customers reduce their time and operating costs significantly and increase employee productivity. This application can also decrease lead time and make faster progress toward their sustainability goals.

Originality/value: A detail comparison was made between two approaches; conventional production system and new approach by integrating RFID in composite part. At the end of analysis, time saving in the production was calculated as 135 minutes (more than 2 hours) by following real data.

Keywords: Composites; RFID-chip; Time processing; X-Ray beam; Crash

Reference to this paper should be given in the following way:

H-A. Alhas, E. Bayraktar, C. Nizam, J. Khalil, Damage analysis of composites integrated with RFID chip used in aeronautics, Archives of Materials Science and Engineering 59/1 (2013) 5-13.

MATERIALS

1. Introduction

Radio-frequency identification (RFID) is the use of a wireless non-contact system that uses radio-frequency electromagnetic fields to transfer data from a tag attached to an object/product, with the aims of automatic identification and tracking. Some tags do not require a battery and are powered by the electromagnetic fields used to read them. Others use a local power source and emit radio waves (electromagnetic radiation at radio frequencies). The tag contains electronically stored information which can be read from up to several meters away. Unlike a bar code, the tag does not need to be within line of sight of the reader and may be embedded in the tracked object [1-7]. Usage of RFID chips in industry has been steadily grooving but its most widespread adaption has been the result of powerful organizations such as Wal-Mart and the U.S. Department of Defence (DoD) that employ the technology in supply management. The DoD uses RFID technology to identify shipping containers and the products within them to ensure appropriate material control within the theatre of war. The DoD learned hard logistic lessons during the 1991 Gulf War and the DoD subsequently mandated its 30,000 suppliers to adapt RFID technology in 2003 [1, 2-9]. RFID provides many new opportunities. Finally, using of RFID Technology effectively throughout production can enhance the competitive abilities of the companies and provide strategic advantages in the global market world. As we have indicated in the previous work [2], we have concentrated on the direct integration of the RFID chips into the composite parts used during the manufacturing (i.e. moulding of the wings in aircraft and/or helicopters) process of the composite parts in order to develop a healthier and safety process and accelerate the operational excellence by decreasing the delivery time substantially. This common research project is going on in the framework of the university and French aeronautic company [7-21].

The basic idea of this research project is that RFID chips are integrated directly in the composite parts used in aeronautical engineering during manufacturing. In fact, we put brain inside the composite parts to make them intelligent. After manufacturing process, there are some obligation tests for inspection of composite parts to detect the cracks, deformation, delamination, lack of composite material, density etc. One of the important inspections is usage of X-Ray diffraction as an efficient non-destructive testing of advanced engineering composites. X-ray diffraction methods are based on the attenuation of X-rays and used to help the damage visibility in certain composites. So that, the present work concentrates on X-Ray diffraction test applied on composite parts in which RFID chips are integrated. X-ray tests must be performed on composite parts (RFID chips integrated) after demoulding in order to check and evaluate the resistance of the RFID chip after the X-Ray diffraction test. It means that RFID chips can be used and keep data stored on it during the manufacturing process [21-32].

We will provide with this test a very considerable operations and time saving during manufacturing processes.

At the former paper [2], we have given detail information on the application of RFID technology, integration of an RFID chip into the composite parts, expected progress. We have also shown the preliminary simulated test results at the laboratory scale (Supmeca-Paris) and we have informed the real test results in industrial scale carried out in the manufacturing department of the French aeronautic company (Eurocopter-Paris) by integrating RFID chips in an aeronautical composite part.

At the second stage of the present project, we will review the following aspects: Application of RFID technology, integration of RFID chips into the Composite Parts, control and measurement of the resistance of RFID chips integrated into composite parts under X-ray diffraction beams, impact choc test. After that, we will give the actual results of an applied research carried out in industrial scale in the manufacturing department of the French aeronautic company (Eurocopter-Paris) by integrating RFID chips in a real size aeronautical composite part.

An important damage control will also be made on the composite parts in which RFID chips are integrated to check if the data control can be keep or not after a random accident with the composite parts. For this reason, a special damage test (drop weight-crash test) was applied on the composite parts containing RFID chips to check the reliability of the information that we stored on it.

In our knowledge, in literature, there is no real application in this area. In the frame of this industrial research project, we try to improve the manufacturing operations and make a considerable saving of production time by changing conventional manufacturing method by using integration of RFID chips in composites parts during manufacturing. In fact, we will decrease the delivery time very significantly. We will also show development of the production quality and traceability. These points give important advantages to the manufacturing of composite parts and also give many facilities to the customers during the use of these parts.

2. Components of an RFID System

A short information will be given here: an RFID System is composed of only a few separate components: a tag; an RFID tag reader; an antenna; and a host computer that equipped with necessary software. Reader has radio frequency module to receive and transmit the data, and is able to forward the data to another system like a PC. Transponder is called data-carrying device, and has an electronic microchip [2]. General idea is to reduce the manufacturing time significantly by entering these RFID chips in the composites parts that these RFID chips contain all of the information related to the manufacturing processes and keep this information after the manufacturing. Thanks to special characteristics of these chips, we have carried out to keep all of the real information related to the manufacturing of the composites parts. We believe that a successful operation has been carried out direct Integration of the RFID chips during the manufacturing of the composites used in French Aeronautical Engineering. It is a device/chip without wire which is attached to a satellite/an antenna for communication, navigation and identification In this way, it is possible to transmit and receive radio signals and has ability to transmit identification information, data from Reader, or transmitting data to Reader [1-7, 9-21]. Passive tags can operate in temperatures of -155°C to +150°C under 194 hPa maximum. RFID chip protects the data on itself during 30 years. For this reason, we will use passive tags in our experimental work. As an example, the main principle of data flow in a typical RFID System is presented in the Figure 1. In reality, this is a reader that it is a device which is able to read data from a tag or transmitting data to a RFID tag.

3. Experimental conditions

At the first stage, we had prepared five different compositions in the laboratory scale in order to simulate industrial manufacturing conditions as given in Table 1.

After that, we have introduced each of these compositions in the five prepared RFID chips by means of the portable readers and we had manufactured five pieces by direct integration of these RFID chips in the pieces by following the same procedure used aeronautical industry. For example, production of a composite part starts with the moulding and then sent it to the high pressured vessel between 120°C and 180°C for cooking operation and then waited minimum 24 hours in an isothermal oven for finishing of the final thermosetting reaction during this stage. Composite parts are laid up on special tools in a manually intensive moulding process. These parts are then cured in very long pressured vessels before being removed from the tools, sent for mill work and off to final assembly. There are many vacuum vessel cycles; each one is typically requirement many hours to complete it.

At the final manufacturing stage, we have controlled all of the pieces by using again the same portable reader to receive initial information on the pieces (composition, manufacturing stages etc.). The same operation has been carried out at the industrial scale as a real application of RFID chips by direct integration in the industrial parts during their manufacturing stage. This industrial application has been carried out in the manufacturing department of the French aeronautic company (Eurocopter-Paris) by direct integrating RFID chips in an aeronautical composite part. We have respected all of the manufacturing rules and followed the entire manufacturing stages after the integration of the RFID chips in the composite part [2].

After demoulding process, there are certain inspections obligations during the production of the composite parts in order to detect certain defects coming from materials and manufacturing processes such as cracks, deformation, demoulding, lack of composite material, density etc. One of the important inspections is X-ray diffraction beams used for non-destructive testing of advanced engineered composites in aeronautical engineering. X-ray methods are based on the attenuation of X-rays and used to help damage visibility in certain composites. X-ray tests must be performed on composite parts integrated with RFID Chips after demoulding stage in order to check and evaluate the resistance of the RFID Chip after the X-Ray diffraction test whether RFID chip can be used and can keep data stored on it during the manufacturing process: X-ray parameters: 100 kV * 10 mA=1000 Watt, 15 min, distance between X-ray spot and composite samples is 1.30 m.

A special damage test (drop weight-crash test) was applied on the composite samples containing RFID chips to check the reliability of the information that we stored on it (To measure damage on RFID chip memory after crash test). The details for this test were given in another publication [8].

4. General results and discussion

In the previous work, we had implemented a new and low cost methodology in an industrial composite production that is used as usually in the aeronautical applications and we had obtained a considerable decrease in the production time [2].

By means of enhanced processes, we need to simplify, improve and accelerate our whole production processes to take under control all supply chains from supplier up to the end customer. This is a reality for the French aeronautic manufacturing company that produce the composite parts as daily production process (Eurocopter-Paris, Fig. 2). All of the manufacturing stages of the composite parts produced in this company were shown in this figure in detail [2].

Table 1.
Compositions of the pieces introduced in the RFID chips as data storage, Airbus-Toulouse [2]

Specimen N°	Composition								
	Al_2O_3	Epoxy	Fe_2O_3	B	SiC	TiO_2	Fe	Glass-Fibre	Rubber
Chip I	20%	67%			1%		1%		
Chip II	20%	53%	10%	5%					
Chip III	20%	45%	10%	1%		20%			
Chip IV	20%	45%	10%	1%		20%		5%	5%
Chip V	20%	49%	10%	3%		10%		10%	5%

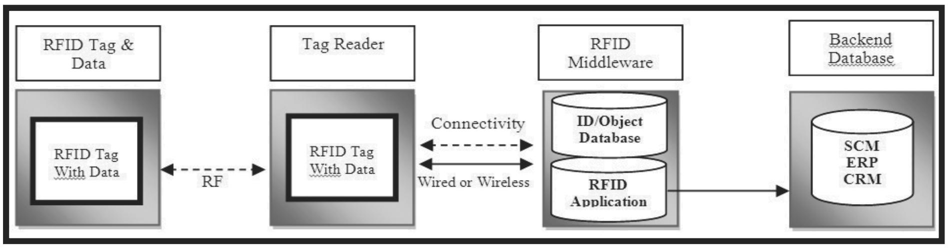

Fig. 1. Data Flow in a Typical RFID System [2]

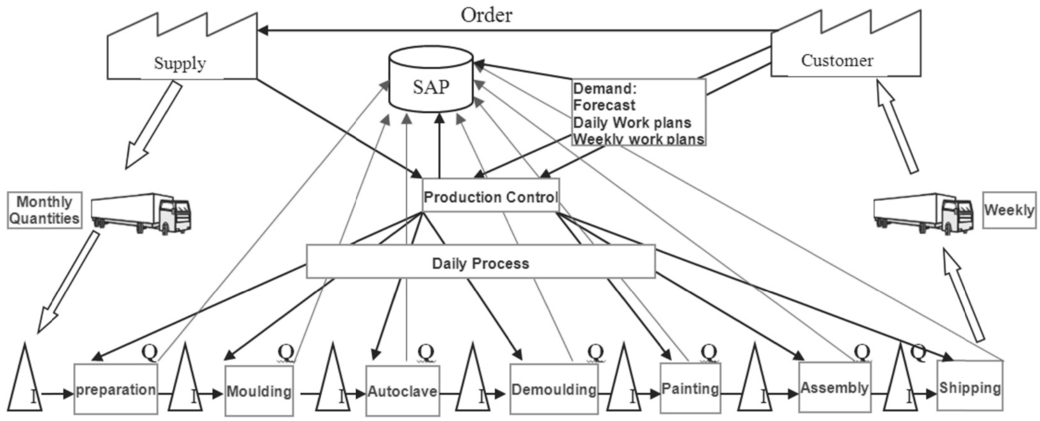

Fig. 2. Conventional daily production process in French aeronautic company (I: Inventory Q: Quality Gates) [After Eurocopter-Paris, 2]

For this reason, X-ray diffraction methods are based on the attenuation of X-rays and used to aid damage visibility in certain composites.

4.1. Application of X-ray diffraction test

After demoulding process (see Fig. 2), there are certain inspections obligations during the production of the composite parts in order to detect certain defects coming from materials and manufacturing processes such as cracks, deformation, demoulding, lack of composite material, density etc.

A special industrial application has been carried out in the manufacturing department of the French aeronautic company (Eurocopter-Paris) by direct integrating RFID chips in an aeronautical composite part. We have followed all of the manufacturing rules and all of the manufacturing stages after the integration of the RFID chips in the composite part. After demoulding stage, we have waited during 15-30 minutes in the X-ray diffraction zone and radiographies of all of the specimens containing RFID chips were taken for inspection in this stage (Fig. 3). X-ray beam is passed through the composite parts in order to check and evaluate the resistance of the RFID Chip integrated in the composite parts after the X-ray test whether RFID chip can be used and can keep data stored on it during the manufacturing process (damage control of CHIP memory). By this way, we have tested the resistance of the RFID chips integrated composite parts against X- ray test.

By using this new idea, we would like to change and replace the conventional manufacturing method by modern manufacturing method by the integration of RFID chips in composites parts during manufacturing of the composite parts. For this reason, we should make extensively some X-ray tests and damage (drop weight-crash test that will be discussed in chapter 4.2). By this way, we can optimize three important the Key Performance Indicators (KPIs); decreasing delivery time and cost, increasing the quality of the process and product. These results drive us to the better customer satisfaction.

In conventional manufacturing processes, the results are written in paper form and then directly into the System during the X-ray diffraction test. As we know, these results are very important at the next stage in order to analyze and evaluate the results for shifting the product to the next step (painting or assembly). If we store these results directly on the RFID Chip during X-ray test instead of typing into Systems, applications, and products for data processing (SAP) System per hand, we will be able to reach to the results in a short time at the next step and also eliminate unvalued added steps (Ex. paper work, documentation). As a result, the software time will be decreased significantly and we will also decrease the decision time, shipment time, and eliminate the using and printing of paper. The time that we need to take decisions in quality and production department that will be decreased with a better quality. Instead of analyzing of the documents, we will be able to see all important data on the screen live which are transferable directly from production lines to the decision makers from RFID chips on to a screen. The distance is not a problem; data can also be transferred from RFID reader to SAP System then to another country. Then, we can transfer the results from RFID Chips on to screen board just in a few second to take important decisions in a very short time. We will get data in time to guarantee our on “Target Delivery” and “Targeted Quality”. The process will be “LEAN” and “Robust”. We can get data on line just with a click directly from production area to meeting room. We need always the actual data not frozen data for a strategic solution. This experiment is very important to get the information stored related to the previous production steps. In other case, we should print many pieces of paper to gather information. The RFID chips that we use are high memory passive RFID chips can be used and can keep all of information 12 years. It is also a big advantage for the traceability.

Fig. 3 shows the RFID integrated composite parts in X-ray diffraction test under X-ray beam with certain parameters that we have explained in the former section. We did this test on the composite parts to see the resistance of the RFID Chips under X-ray beam in aeronautical engineering. After X-ray test, we have checked the integrity of the information that we have saved before on the RFID Chips. Composite parts (RFID chips integrated) are controlled again by using portable reader after X-ray diffraction test.

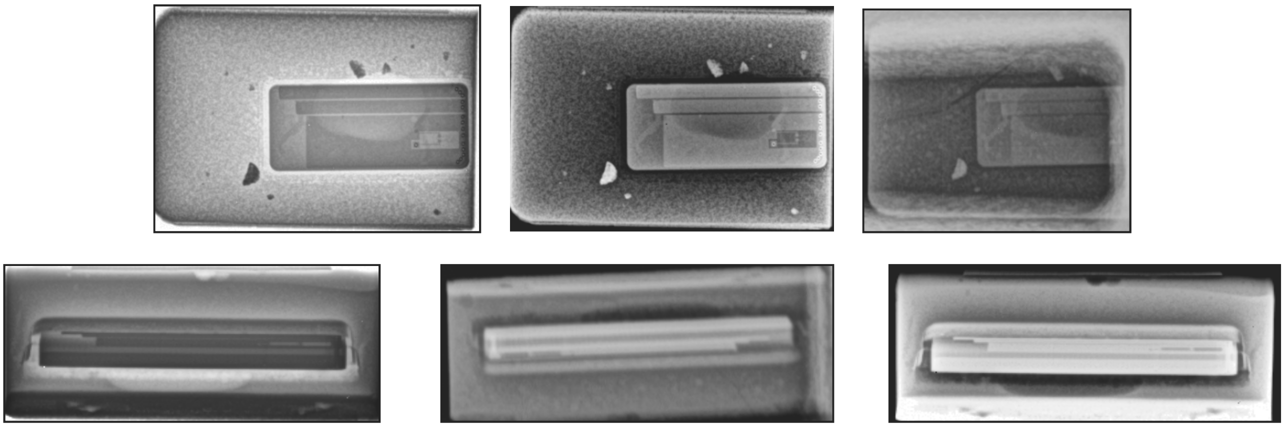

Fig. 3. Samples containing RFID Chips in X-ray environment (Test parameters: 100 kV*10 mA=1000 Watt, 15 min, distance between X-ray spot and composite samples: 1.30 m, Test Area: Eurocopter Main Manufacturing Hall-Paris)

4.2. Application of drop weight-crash test

Under the service condition or during transportation of composite parts can subject a random accident across production buildings or country to the customers and some information and production history can disappear in case of damage on these composite parts. In this experiment we would like to show crash resistance of the RFID-chips whether they can keep manufacturing information related to the production history including composition and treatments saved on the Chip or not. Figs. 4 and 5 show composite parts prepared before the damage test and drop weight testing device for the RFID integrated composite parts.

Force-Times graphics given in Fig. 6 indicates maximum damage force as a function of time. In that maximum force (~400N), damage is occurred on the RFID integrated composites samples. The tested composite parts (RFID integrated) after drop weight crash damage is shown in Fig. 7. Results of composite samples after checking by portable RFID chip reader and passive RFID tags reader entire data collector are given in Figs. 8a and 8b. Here, only sample #4 was shown as an example. All the other tested specimens have given the same agreement results. As seen from these figures, the integrity of the data saved on RFID chips before manufacturing of composite parts has been checked after both of the tests (X-ray diffraction and drop weight crash test) by Portable RFID chip reader. The entire results are very satisfaction - very fulfilment.

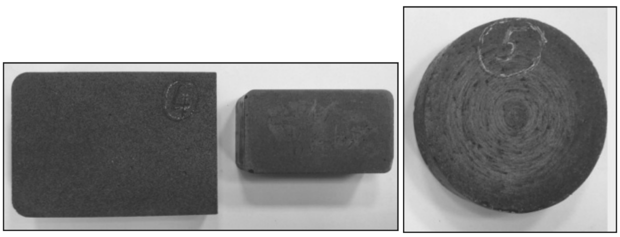

Fig. 4. Composite parts: 3 RFID Chips integrated samples

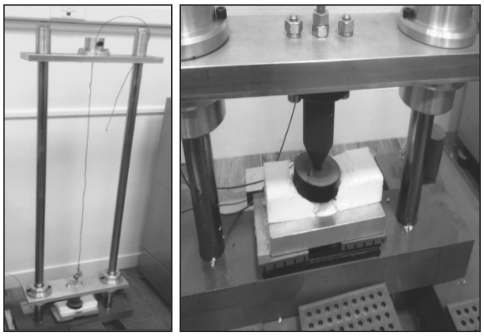

Fig. 5. Drop weight testing for damaging composites parts (Test area: Supmeca/LISMMA-Paris)

To summary the results after industrial applications with real test conditions, an enthusiastic comparison was made between two approaches; conventional production system and new approach by integrating RFID in composite part (Table 2). At the end of analysis, time saving in the production was calculated as 135 minutes (more than 2 hours) by following real data.

By this new approach, we can save all data on RFID chips to eliminate our documentation. Documentation innovation can speed up our Time-To-Customer and time to desired quality. In order to make our process more effective and precise, the process needs RFID Technology. This solution can lower our documentation costs and increase our productivity by providing managers/decision makers access to the right information at the right time. This result drives us to the process excellence. We can apply this approach to other areas of product documentation. It can also be extended to improve the management of engineering documents which play a critical role on the development of all of the product documentation. We can learn through this work how RFID technologies can help us address our product development challenges and gain competitive advantage. As for business process optimization, the most powerful gains for the companies come from process transformation by integrating of RFID into composite parts.

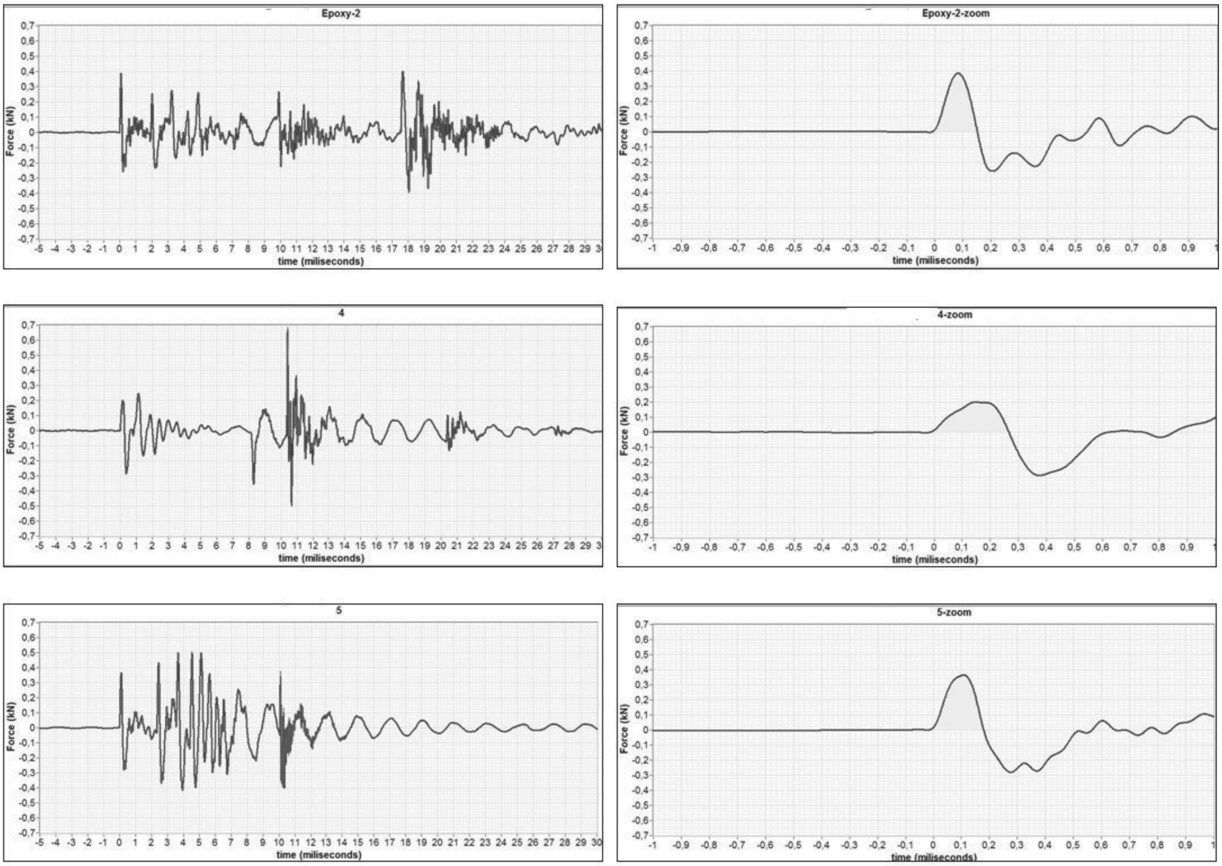

Fig. 6. Maximum damage force as a function of time during drop weight crash test of 3 samples - Scale is fixed +/- 700 N (Test area: Supmeca/LISMMA-Paris)

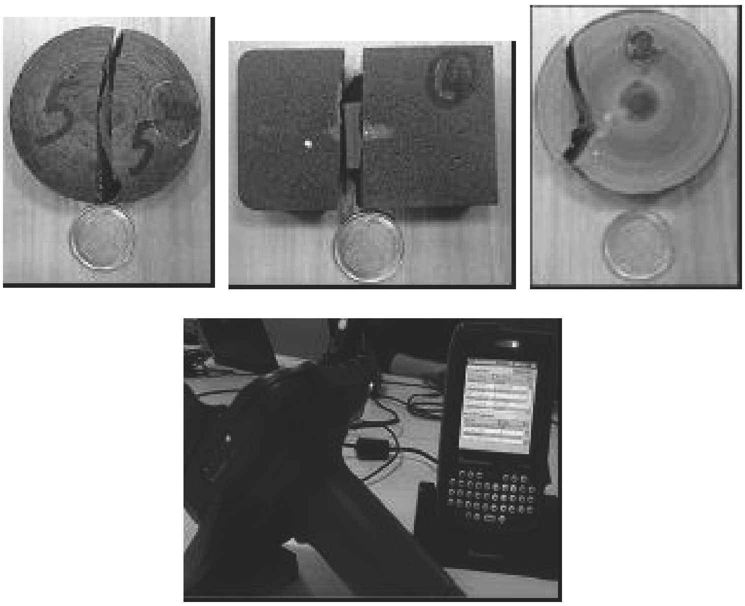

Fig. 7. Damaged composite parts containing RFID chips after crash test (left) and portable RFID chip reader (right)

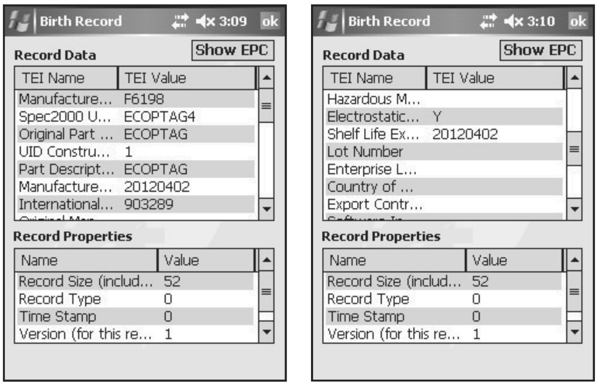

Fig. 8a. Results of composite samples after checking by portable RFID chip reader. Here, sample #4 was shown as an example

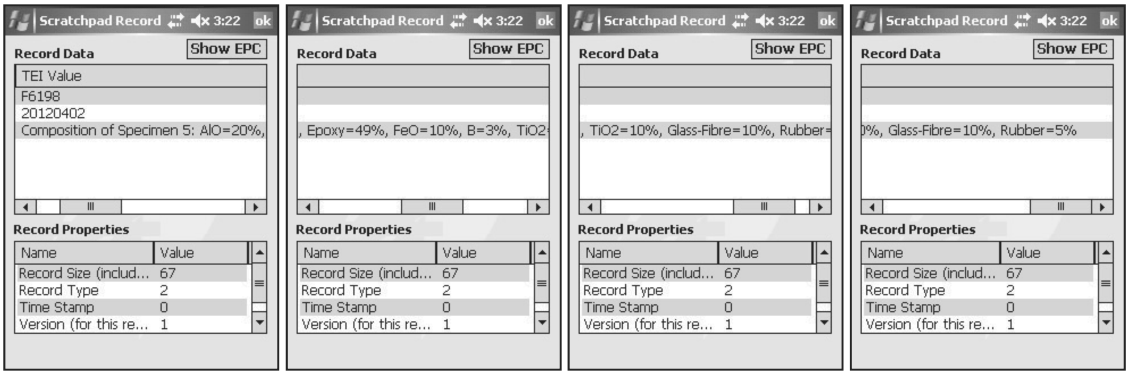

Fig. 8b. Passive RFID tags reader data collector (sample #4)

Table 2.
Comparison of two approaches in production line: Conventional and new application of RFID chip in Eurocopter-Paris

Conventional production operations		New approach: By integrating RFID in composite part		Time Saving in the production
Operations should be applied after X Ray diffraction test	Time (min)	Operations should be applied after X Ray diffraction test	Time (min)	
Writing production and Quality related data into SAP	60 min	writing production and Quality related data onto RFID Chip	30 min	30
Printing product related data for the next step	30 min	Presenting the data stored on RFID Chips with RFID reader at the next stage on screen.	5 min	25
Preparation of the documents for meeting to take decisions	30 min	Presenting the data stored on RFID Chips at any production step/meeting room on a screen to take decisions.	5 min	25
Taking and Typing the decisions into SAP	60min	Taking and Typing the decisions on RFID Chips	30 min	30
Making these values visible during the next step (printed documents from SAP)	30 min	Making these values visible during the next step (presenting on a screen via RFID Reader)	5 min	25
TOTAL time	210 min		75 min	135 min

5. Conclusion and future perspectives

Main objective of the present work is to measure the resistance of the RFID chips integrated in the composite parts during manufacturing after X-ray diffraction and drop weight crash tests. X-ray diffraction tests must be performed on composite parts after demoulding. X-ray beam is used to help damage visibility in certain composites. Composite parts can be damaged under service condition or during transportation of composite parts integrated with RFID chip across production buildings or country to the customers. Our research application with real test parameters gives very fulfilment satisfaction, we have verified the resistance of the chip after X-ray and drop weight-crash test that the RFID chips keep safely all of the manufacturing information related to the production history.

Our research has shown that new approach with integration of RFID chips in the composite parts can reduce the delivery time significantly and improve quality, and also decrease the course cost due to less lead time and operating time of the products. During the X-ray diffraction test, the results are actually written in paper form and then directly into the System. As we know, these results are very important at the next stages for analyzing and evaluating the results for shifting the product to the next step (painting, assembly, etc.). If we store these results directly on the RFID chip, we will be able to reach to the results in a short time at the next step and also eliminate unnecessary steps (Ex.: paper work, documentation). As a result, the software time will also be decreased, and the decision time shipment time will be reduced drastically and the step of the using and printing of paper will be eliminated. The time that we need to take decisions in "Quality and Production" department will be decreased with a better quality. Instead of analyzing the documents, we will be able to see all important data on the screen live which are transferable directly from production lines to the decision makers from RFID Chips on to a screen. The distance is not a problem; data can also be transferred from RFID Chips via RFID Reader to the SAP System then to another country and so on. The results can be transferred from RFID Chips on to screen board just in a few second to take important decisions in a short time. Data can be obtained on time to assure our on "Target Delivery" and "Targeted Quality". The process will be "LEAN" and "Robust". Data can be acquired on line just with a simple click directly from production area to meeting room. We need always the actual data not frozen data for a strategic solution. This experiment is very important to get the information stored related to the previous production steps. In other case, we should print many pages of papers to gather information. The RFID chips that we use are high memory passive RFID Chips can be used and can keep information 12 years. It is also a big advantage for the traceability. Companies can transform the entire process for providing information from RFID Chips directly to their centralized data source (SAP) to improve service quality, boost customer satisfaction and reduce costs. Process transformation often yields multiple benefits in terms of speed, efficiency, cost, compliance and sustainability.

A vigorous comparison was made between two approaches; conventional production system and new approach by integrating RFID in composite part. At the end of analysis, time saving in the production was calculated as 135 minutes (more than 2 hours) by following real data.

In the next future, manufacturing companies using high technology can transform their engineering and manufacturing processes by applying RFID technology that speed up manufacturing cycle times, maximize efficiency and eliminate unnecessary steps.

As a result, these companies will be in much better position to maximize their productivity and new product/market opportunities as well as efficient product documentation and also production processes. Using RFID technology in production will help companies/customers reduce their operating costs significantly and increase employee productivity, improve compliance, decrease lead time and make faster progress toward their sustainability goals.

Acknowledgements

We acknowledge to the French Aeronautic Companies; Eurocopter-Paris, Airbus Headquarter-Toulouse and we thanks EADS Germany and EADS-England for their valuable collaborations during the applications of RFID chips and permission us their technical facilities.

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