Nationaal Lucht- en Ruimtevaartlaboratorium

National Aerospace Laboratory NLR

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Repair of thin walled thermoplastic structures by melting, an experimental research

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Executive summary

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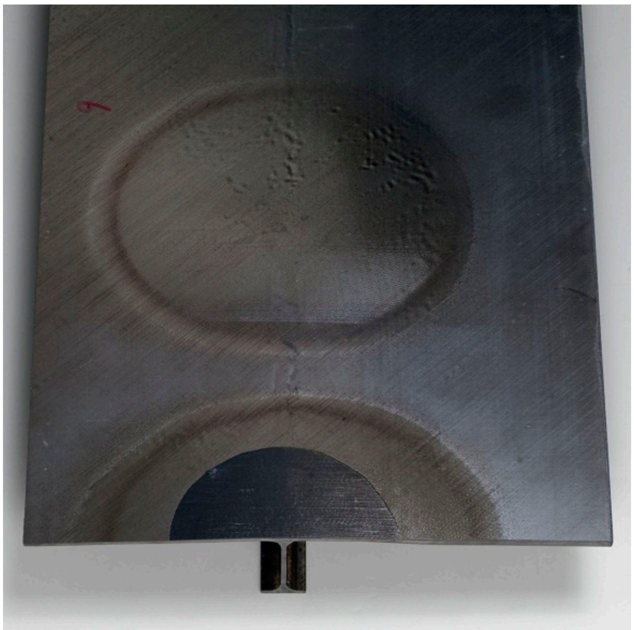

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Report classification
UNCLASSIFIED

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Knowledge area(s)
Constructie- en fabricagetechnologie

Descriptor(s)
Repair
Thermoplastic
PEKK
TAPAS

Problem area
Thermoplastics are tough and low-cost production methods like welding, press forming and co consolidation can be used. Since the arrival of affordable fibre placement machines, the potential of creating more cost effective composite structures with thermoplastic materials even has increased. An important issue for the use of new materials on an aircraft is the reparability. Without a good repair method, operating costs of impact sensitive components, like flaps and rudders will be very high. A major benefit of thermoplastic materials is the possibility to repair a part without adding foreign materials such as adhesives. A thermoplastic material is melt-processable. Damages such as delaminations can be repaired by melting instead of cutting out the damaged area. Patches can be co-consolidated on the original material without adding adhesive materials. Big challenges of a melted repair of thin walled structures are the local thermal expansion of the materials and maintaining the quality of the transition area between melted and non-melted material.

This report is based on a presentation held at the SAMPE EUROPE, Paris, March 11, 2013.

Description of work

The NLR has performed several trials and tests in cooperation with Fokker Aerostructures on PEKK material with AS4D carbon fibers.

This paper describes parts of the investigation done by NLR on repair of thermoplastic thin walled structures with and without butt-jointed stiffeners by melting the base material. A brief overview of the heating methods used and the results is given.

Results and conclusions

The main target was to develop a simple repair method for thin walled thermoplastic structures which can be done on the aircraft. A heat blanket, infrared heaters or a heat gun in combination with vacuum can be used for this task if the damaged area can be accessed from both sides. The heat gun in combination with dead weight can also be used for repair patches without access from the inside. Additional research is required for the repair of delaminations in single side accessible products and a good straightforward solution for applying pressure on a curved product has to be found.

Applicability

Thin walled thermoplastic structures like flaps and rudders.

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Repair of thin walled thermoplastic structures by melting, an experimental research

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Summary

A major benefit of thermoplastic materials is the possibility to repair a part without adding foreign materials such as adhesives. A thermoplastic material is melt-processable. Damages such as delaminations can be repaired by melting instead of cutting out the damaged area. Patches can be co-consolidated on the original material without adding adhesive materials.

The NLR has performed several trials and tests in cooperation with Fokker Aerostructures on PEKK material with AS4D carbon fibres. Big challenges of a melted repair of thin walled structures are the local thermal expansion of the materials and maintaining the quality of the transition area between melted and non-melted material.

This paper describes parts of the investigation done by NLR on repair of thermoplastic thin walled structures with and without butt-jointed stiffeners by melting the base material. A brief overview of the heating methods used and the results is given.

It can be concluded that a heat blanket, infrared heaters or a heat gun in combination with vacuum can be used to repair thermoplastic thin walled structures on the aircraft if the damaged area can be accessed from both sides. The heat gun with dead weight can also be used for repair patches without access from the inside. Additional research is required for the repair of delaminations in single side accessible products and a good straightforward solution for applying pressure on a curved product has to be found.

Contents

1 Introduction

Up to now, the majority of the composite aircraft fuselages are made of thermoset composite materials. During the last years several programs have been started to reduce the manufacturing costs. In the past, studies were based on hand lay-up of thermoset materials. Thermoplastic materials were hard to handle and difficult to process. But since the arrival of affordable fibre placement machines, thermoplastic materials have the potential of creating cost-effective composite structures as well. Thermoplastics are tough and low-cost production methods like welding, press forming and co-consolidation can be used. An important issue for the use of new materials on an aircraft is the reparability. Without a good repair method, operating costs of impact sensitive components, like flaps and rudders will be very high.

A major benefit of thermoplastic materials is the possibility to repair a part without adding foreign materials such as adhesives which, for conventional thermoset composites, have always proven to be difficult to certify. A thermoplastic material is melt-processable. Damages such as delaminations can be repaired by melting instead of cutting out the damaged area. Patches can be co-consolidated on the original material without adding adhesive materials.

The structures technology department of the NLR has performed several trials and tests in cooperation with Fokker Aerostructures on PEKK material with AS4D carbon fibres. One of the big challenges of a melted repair of thin walled structures is the local thermal expansion of the materials and the quality of the hot zone; the transition area between melted and non-melted material. Goal of the trials was to find a straight forward repair which can be accomplished on the aircraft by the end users, using standard tools.

This paper describes part of the investigations done by NLR on repair of thermoplastic thin walled structures with and without butt-jointed stiffeners by melting the base material. The repairs were divided in “one sided accessible” and “double sided accessible” repairs. A brief overview of the heating methods used and the results is given.

2 Heating methods

For melting of PEKK-FC material a temperature of about 365 °C is required for a period of about 30 minutes. During the fabrication of a part, normally an oven or an autoclave is used. For a repair however, a local heat source has to be used. To create a local heated spot, several heating methods can be used. A good overview is given in the reference 1 report.

- Infrared heating
- Microwave heating
- Heated tool
- Resistance heating
- Ultrasonic heating
- Induction heating

Since one of the goals was to develop an easy repair with standard tools, some of the heating methods were omitted on forehand, such as microwave, ultrasonic and induction heating. The following tools were selected for further research within this program.

2.1 Hotbonder with heat blanket

A standard tool for repairing thermoset components is a heat blanket with a Hotbonder (see figure 1). A Hotbonder controls and logs temperature and vacuum. With special blankets, temperatures of 400 °C can be achieved.

Figure 1. Briskheat ACR II Hotbonder used by NLR

2.2 Infrared heater

Infrared heaters are less simple than a heat blanket, but are still relative easy to use and control and therefore included in the present program.

2.3 Heat gun

An even more straightforward tool is a heat gun, normally used to remove paint. Air temperatures of 550 °C are possible, but the size of the heated spot is limited. For larger repairs more heat guns have to be used.

3 Development of repair methods

The tests within this research program were done on a PEKK-FC panel with AS4D carbon fibres, a quasi-isotropic lay-up and a total thickness of 2 mm, which can be compared to the skins of aircraft flaps or rudders and small horizontal tails. For some tests a stiffened panel was used, with a so-called butt-joint stiffener (development by Fokker Aerostructures, ref. 2). For the repair trials, panels were impacted with 25 J to create clearly visible impact damages with delaminations and broken fibres. See figure 2 for details and examples. For a thermoset product, the delaminated area and broken fibres should be removed. For thermoplastic materials the delamination can be repaired by melting the material and small patches can be added to compensate for the broken fibres.

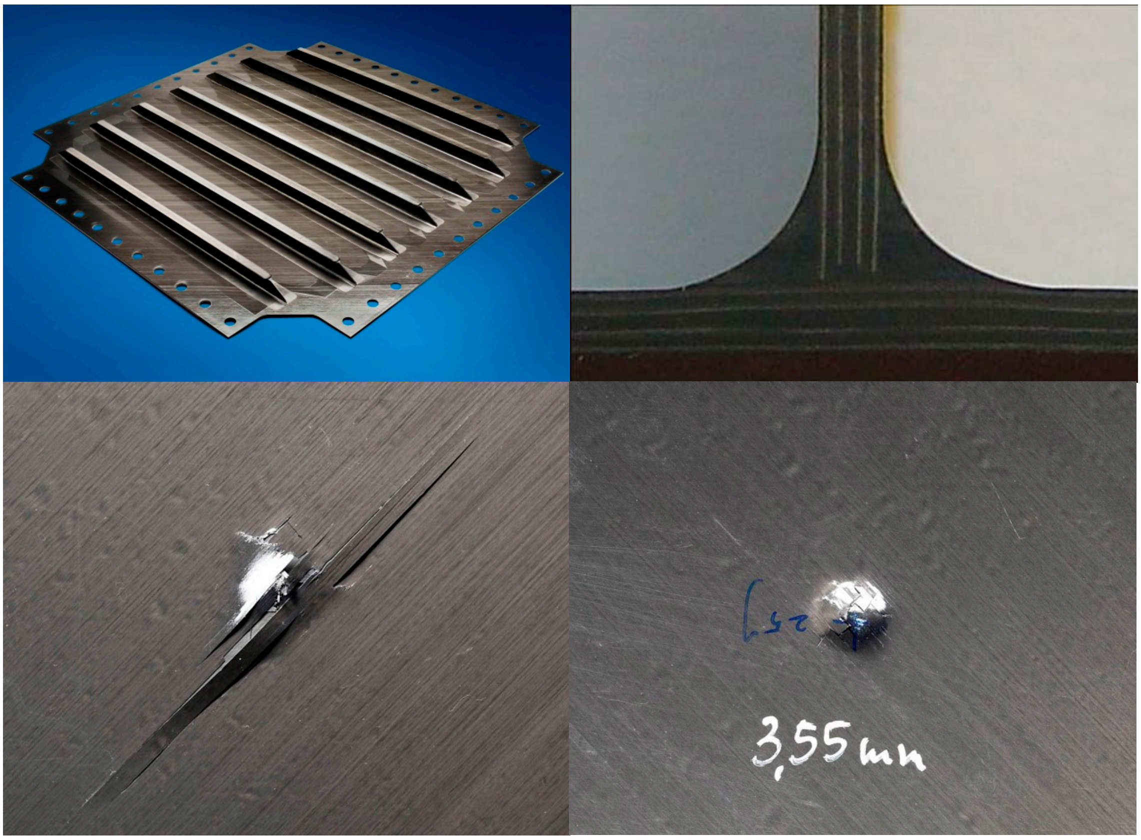

Figure 2. Panel with butt-joints, a detail of the butt-joint and a typical impact of 25 J on a 2 mm thick panel

3.1 Hotbonder with heat blanket

The first tests were done on a flat panel with the hot bonder and a high temperature heat blanket. See figure 3. Tests were done with different caul plates on the upper side (outside) and lower side and vacuum bags on both sides of the panel.

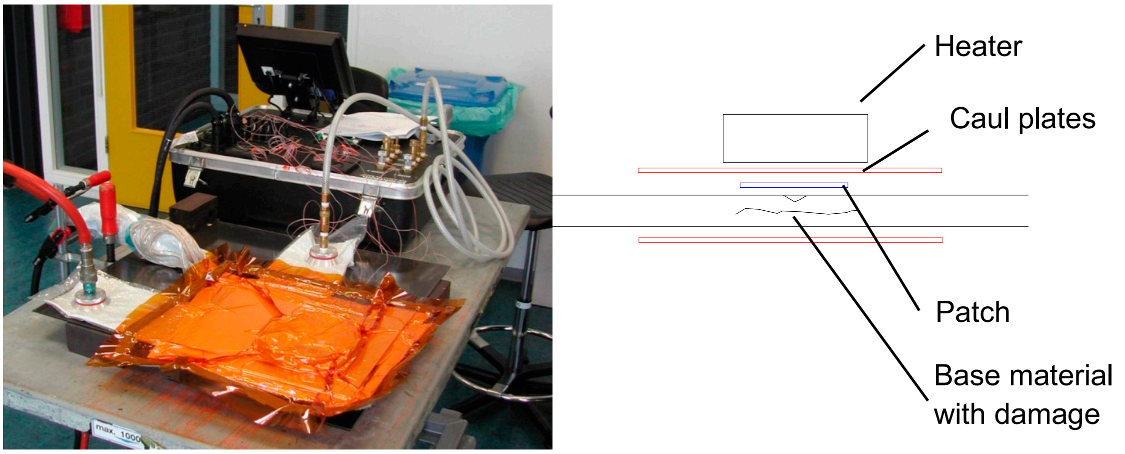

Figure 3. Repair with Hotbonder and heat blanket

The caul plate between the heater and the base material was used to create an equal temperature distribution and a conformal surface. The material, size and thickness of the caul plates were varied during the trails to create a situation where the temperature in the damaged area was above the melting temperature and on the outside of the caul plate below. By use of a vacuum bag, the hot zone (i.e. the transition area between melted and non-melted material) is always pressurized. A problem with the repairs on flat sheets is the thermal expansion of the caul plate but also of the PEKK material itself. By heating from one side, the upper side is warmer and the expansion is larger. By this, the caul plates bulge during the repair and the final repair is slightly curved. To prevent this, thinner caul plates of 0.3 mm were tried and even combinations were used. The best repairs were made with a CRES 2 mm caul plate on the upper and lower side of the panel and a 2 mm aluminium panel between the heater and the upper CRES caul plate for an equal temperature distribution. The quality of the laminate after repair was good but the repair was always slightly curved. With this heating concept also specimens with scarf joints were made using a 500 mm long rectangular heater. The specimens were tested statically and dynamically in tension with good results (> 3000 microstrain in fatigue).

3.2 Infrared heater

Using the heat blanket, the required time to heat up the panel was relative long, which made it difficult to keep the temperature on the edges of the caul plate below the melting point of the base material. Therefore an infrared heater was tried without a caul plate on the upper side. A rectangular heater was used and the size of the hot area was manipulated by using aluminium/airweave isolation foils with a defined hole size. A caul plate of 2 mm CRES was used on the lower side of the panel. Several trials were done with half hard aluminium, combinations of 0.8 and 0.2 mm thick CRES and 0.8 mm thickInvar caul plates to prevent wrinkling of the panel. The results with an Invar caul plate were the best, but still a slightly curved repair was created.

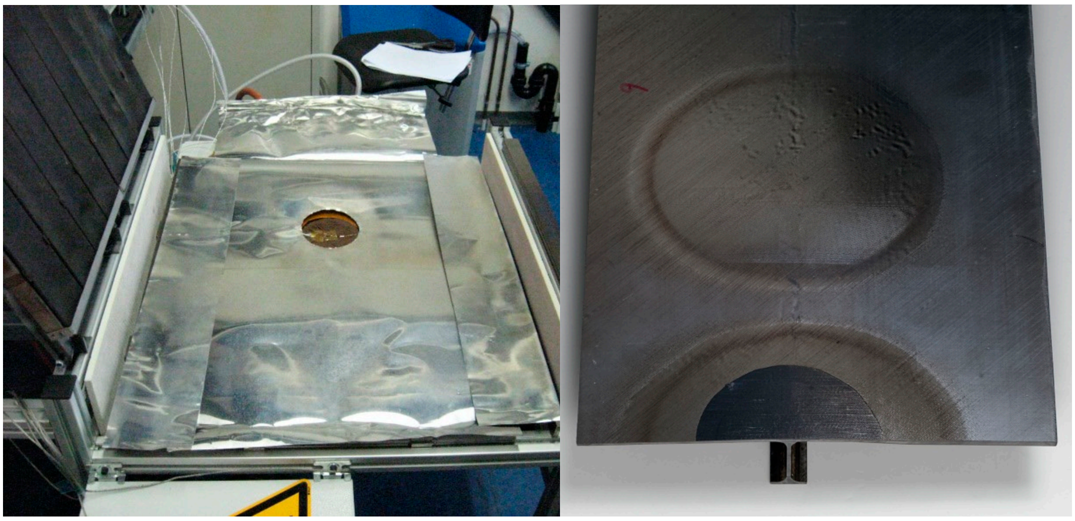

Figure 4. Repair with infrared heater (left) and a repaired butt-joint panel (right. Two repairs are shown, one with and one without patch)

With the infrared heater also a butt-joint panel was repaired, see figure 4. The stiffener prevented the deformation of the panel. With the infrared heater, a fast and good repair could be made, but the equipment is less widely available. With the infrared heater also trials were done to repair a panel from one side (for example for a closed rudder repair). Unfortunately, in all trials, wrinkling of the lower surface occurred.

3.3 Heat gun

Small repairs can be made by using a heat gun. Caul plates of CRES were used on both sides of the panel, similar to the hot bonder repair. With the heat gun also trials were done to melt repair patches on the base panel from one side, to simulate one sided accessible repairs. The heat gun was used directly on a vacuum bag, using vacuum as pressure source, but also via a thicker metal disk of 5 mm, using the heat gun for heating and dead weight as pressure source (approximately 0.5 bar). See figure 5. The vacuum method and the dead weight method both worked, but for impacted areas, a single sided vacuum bag will not function. A problem with the steel disk is the shape of the product. If a curved product has to be repaired or the panel bends too much, an exact curved disk has to be used, which makes it more complicated.

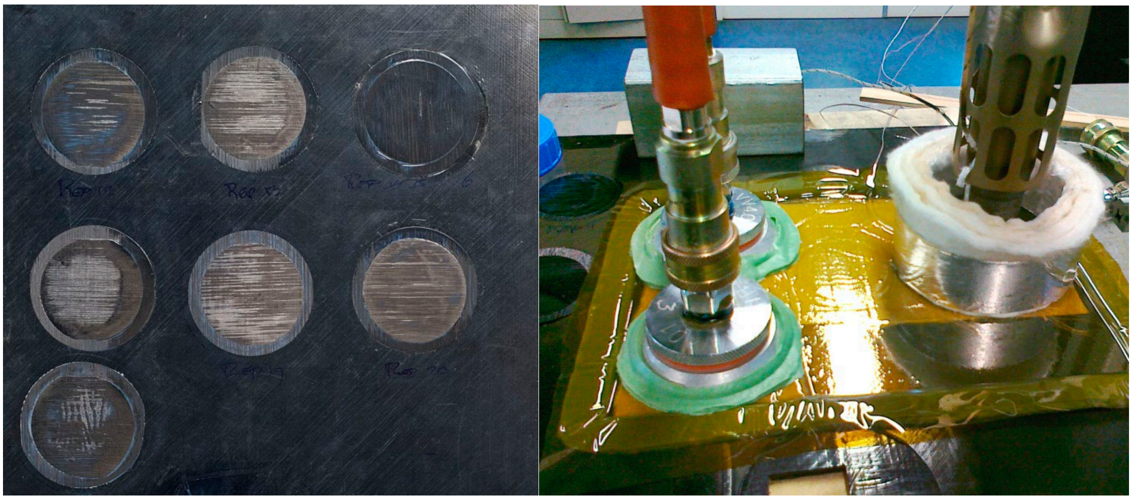

Figure 5. Repairs with heat gun

4 Conclusions

The main target was to develop a simple repair method for thermoplastic thin walled structures which can be done on the aircraft. A heat blanket, infrared heaters or a heat gun in combination with vacuum can be used for this task if the damaged area can be accessed from both sides. The heat gun with dead weight can also be used for repair patches without access from the inside. Additional research is required for the repair of delaminations in single side accessible products and a good straightforward solution for applying pressure on a curved product has to be found.

Acknowledgement

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References

1) Report: Roger Vodicka, DSTO-TR-0424 (1996), Thermoplastics for Airframe Applications. A Review of the Properties and Repair Methods for Thermoplastic Composites.

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