DOI: https://doi.org/10.56738/issn29603986.geo2023.4.38
ISSN 2960-3986
GEO Academic Journal Vol. 4 No. 1 – 2023 series

GEO Global Educators Professional Enhancement International Inc.

Assimilation Process of Design Thinking in the Scarfing Tool Fabrication for Aircraft Composite Repair

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DOI: https://doi.org/10.56738/issn29603986.geo2023.4.38

Abstract

Repairing aeronautical products made of composite materials has been a significant challenge for the aviation industry. Composite materials are used in a variety of aerospace applications. The researchers used a mixed method in the study. They administered a four-point Likert scale survey to students enrolled in the AMT airframe composite laboratory in the first semester of the academic year 2022-2023. The study's results demonstrated the performance of the prototype guiding gadget—interviews with key informants unearthed problems and recommendations for improving the guide tool prototype (KII). KII was attended by five AMT instructors and students in total. According to the study's findings, practitioners require a new tool that would assist them in simplifying repair procedures while still producing adequate results while working on aviation

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composites. Mending composite components is challenging for practitioners of all skill levels, including those with extensive experience and novices. Using specialist instruments is an essential component that plays a significant role in supporting professionals to complete their repair work with self-assurance and successfully deliver the desired outcomes. Students should work with a guide tool prototype when learning how to repair aviation composites. AMT students and faculty members utilize this prototype to improve composites effectively. The organization will profit from having access to this lightweight and reasonably priced directing tool.

Keywords: engineering, aircraft composite repair, design thinking, portable guide tool.

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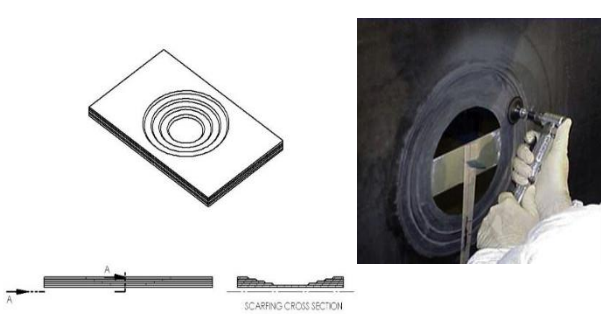
GEO Academic Journal Vol. 4 No. 1 – 2023 series

Introduction

Repairing composite materials has been a critical challenge for the aviation sector regarding aeronautical products. Fixing methods are necessary to replace damaged components without jeopardizing their integrity and function. Inspection, material removal, surface preparation, patch design, manufacturing, application, and post-repair inspection are some of the phases involved in repairing composite materials (Nezhad et al., 2017). In the event of repair, a typical approach entails manually removing composite elements, which is performed using a hand-held router for scarfing (Psarras et al., 2018). Scarfing is a restoration that entails substituting a laminate for broken parts. Layer after layer of laminated materials is removed during the scarfing process until the appropriate depth reaches the damaged fabric. A composite structure's appearance following the scarfing procedure is depicted in Figure 1. With a tool as an aid in this process, this accurate scarfing is more accessible to complete for an entry-level to an intermediate composite material technician and even for professionals. Figure 2 depicts the issue with hand scarfing: unequal labor done during the task.

Figure 1

Composite Structure After Scarfing



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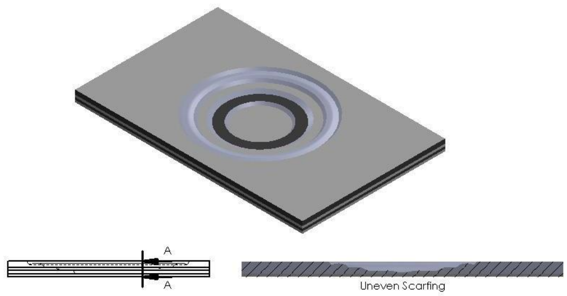
GEO Academic Journal Vol. 4 No. 1 – 2023 series

Figure 2

Composite Structure with Uneven Scarfing



Repairing aircraft structures made of composite materials is a significant issue in aviation maintenance. The method and tools used throughout the maintenance procedure affect the repair's success. For example, one ofthe technologies suggested for aircraft maintenance is an automatic control for laser-based repair (Dittmar *et al*., 2019). The automated device allows the scarfing zone to be disclosed layer-by-layer of composite materials, recognizesthe transition between successive layers, and calculates the various depths.

Literature Review

According to Rito et al. (2017) 's study on health inspection monitoring of composite patch repairs using sensors, a sensor will be inserted into the bond line to monitor the state of a composite patch repair. The sensor's job is to forecast the delamination fractures (disband) that will appear in the repair patch. This technique is used to research the properties of composite repair patches so that a new repair process may be developed.

Safai et al. (2019) developed a remote advance repair guidance that allows an off-site

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GEO Academic Journal Vol. 4 No. 1 – 2023 series

expert to communicate with an on-site technician while a composite structure is being repaired. The system and procedures will provide direct visual guidance, feedback, and out-of-plan alerts for human or automated scarfing and other activities during composite structure repair. Safai et al. (2019) claim that the repair procedure includes optical three-dimensional surface measuring with at least one visible, ultraviolet, and infrared light illumination. The composite repair will be tracked step-by-step using the projected light. The guiding systems can map the damage and establish the thickness of each layer. The system is also capable of offering process control for composite structural repair.

According to Takita et al. (2020), a router guide device called A Guide Device and Scarfing Surface Forming Technique directs a router device through the surface shape of a scarfed surface forming method to create a circular scarf surface in a workpiece. This will provide a reference groove to construct the scarfing step into the desired precise depth. However, the device's increased manufacturing cost prevents it from being widely used in limited damage zones.

The researcher's study will draw on helpful information, including the patented tools and suggested experiments. It may support the idea of creating a scarfing guidance tool that is simple, portable, effective, and reasonably priced for end users. The scarfing guidance tool is helpful for aviation, particularly for students undergoing composite manufacture and maintenance training. The design prototype is created by considering several aspects from earlier publications.

Methodology

Methods of Research

This study employed an embedded mixed methodology. The design thinking approach to

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GEO Academic Journal Vol. 4 No. 1 – 2023 series

the data collection incorporated a sequential stage alternating between qualitative and quantitative methodologies (Kimmons, 2022).

For the qualitative method, a critical informant interview (KII) was conducted to gather information about the empathy phase of the design thinking approach. For this phase, it was necessary to evaluate the challenges in creating the proposed prototype and determine the outcomes of utilizing it during the testing phase to make improvement recommendations.

A structured questionnaire was utilized to collect quantitative data to assess the effectiveness of the prototype. The questionnaire design was based on the requirements for the design prototype as modified from the study of Berones (2021).

According to Steinke et al. (2017), the design thinking process idea is a framework that focuses on creating prototype solutions after defining and focusing on the problem. Figure 3 illustrates the five steps of this process: (1) Empathize, (2) Define, (3) Ideate, (4) Prototype, and (5) Test.

1. Empathize – In this phase, the scarfing issues in the PATTS College of Aeronautics composite training shop were identified.
2. Define – Based on the knowledge from the empathize phase, the prototype requirements were formulated.
3. Ideate – The prototype design was drawn using the Solid Works application to envision potential solutions to the problem as stated in the define phase.
4. Prototype – During this stage, the initial design of the prototype was fabricated.
5. Testing – The composite training subject's teachers and students tested the initial prototype at this phase. This enabled the participants to use the prototype and provide inputs for design

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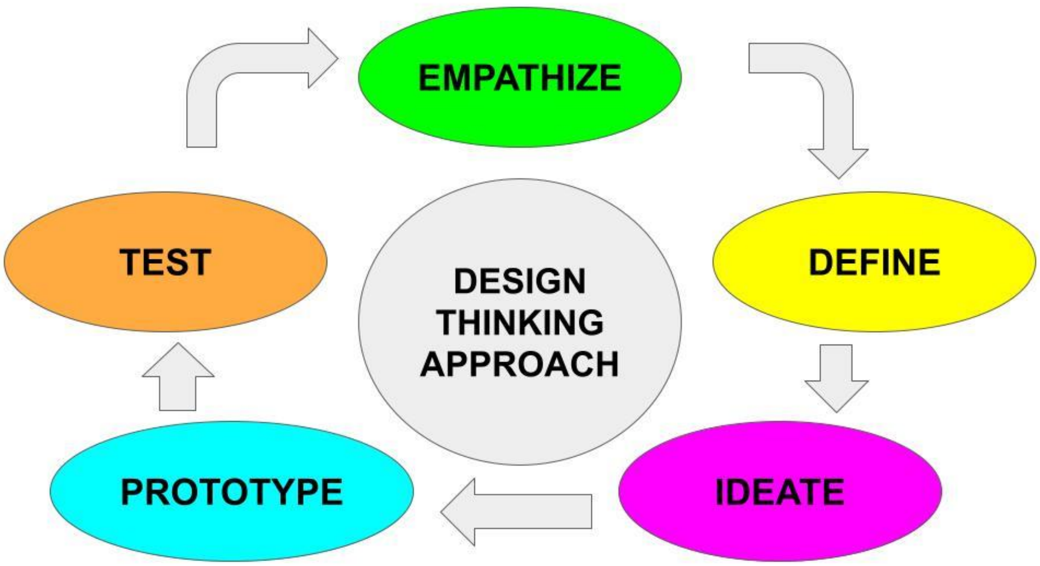
ISSN 2960-3986
GEO Academic Journal Vol. 4 No. 1 – 2023 series

upgrading.

Figure 3

The Design Thinking Process Approach



Participants of the Study

Ten individuals were included in the key informant interview (KII): five students enrolled in the course during the first semester of the academic year 2022–2023 and five faculty members who oversee it. Both interviews were captured on tape and written down. The average interview lasted from 10 to 20 minutes. To assess the effectiveness of the suggested design, a class of 18 students in the composite training shop was surveyed online.

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Data Gathering Instrument

The efficiency of the portable scarfing guidance tool was evaluated using a 4-point Likert scale. The survey questions were modified to reflect some of the indicators in the study of Berones (2021), which focuses on the efficiency of the portable scarfing guidance tool. The concerns with the scarfing technique utilized for composite repair and the impact of utilizing the prototype on end-users were defined via key informant interviews. To create and distribute the online survey. Questionnaire surveys in google forms were employed. Key informant interviews were also done online.

Data were gathered from the KII as part of the design thinking phases for empathy and testing. Thematic Analysis was used to extract codes and themes from the interview data. The steps of the coding method are as follows: familiarization of the data, creation of preliminary codes, and extracting themes throughout the data (Braun et al., 2006).

1. Statistical Treatment of Data

a. Likert Scale: This measurement was used to determine the effectiveness of the portable scarfing guide tool as perceived by the students and instructors in PATTS College of Aeronautics using non-rational models with its verbal interpretation by Gujarati (2003).

b. One-way Analysis of Variance (ANOVA): It tests the hypothesis of two means. First, it evaluates the importance of one or more factors by comparing the response variable at the different factor levels. The null hypothesis states that all population means (factor level means) are equal, while the alternative hypothesis states that at least one is different. For example, one fixed factor

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GEO Academic Journal Vol. 4 No. 1 – 2023 series

(levels set by the investigator) can have either an unequal (unbalanced) or equal (balanced) number of observations per treatment combination.

c. Thematic Analysis: It is a method for analyzing qualitative data that entails searching across a data set to identify, analyze, and repeat patterns (Braun & Clarke, 2006). Thematic Analysis was used to analyze the key informant interview data qualitatively.

Results and Discussion

The data gathered from the survey conducted by the researcher has undergone statistical treatment—the tabulated data corresponding to the problem statement's research purpose and specific questions. The analytical tables were presented according to the questions, followed by interpretation and analyses.

1. The problems in creating scarfing in composite repair in Fundamentals of Composite Training at PATTS College of Aeronautics.

In the Fundamentals of Composite Training course at PATTS College of Aeronautics, the existing problems with scarfing in composite repair were the procedures, output quality of scarf profile, tool requirement issues, and the need for a new tool. Additionally, there was a necessity for the production of a new tool.

2. The initial prototype design of the portable scarfing guide tool.

Given the issues, an initial prototype was designed in Solidworks during the ideate phase. From the design, as seen in Figure 4, the essential functions and features were incorporated into the prototype assembly. Design considerations were reviewed before actual prototyping. During the testing phase, the initial effectiveness level was determined.

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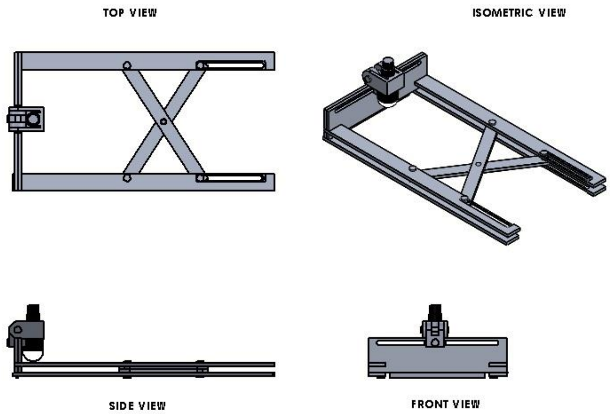
GEO Academic Journal Vol. 4 No. 1 – 2023 series

Figure 4

Initial Design of the Portable Scarfing Guide Tool



3. The level of effectiveness of the portable scarfing guide tool prototype.

Regarding its function, the survey results showed that both Stability and Asymmetric Profiling were Moderately Effective. On the other hand, the Adjustability was Partially Effective. In terms of its features, both Portability and Aesthetics were Moderately Effective. On the other hand, both the Reusability and Durability were Highly Effective. Adjustability received the lowest general weighted mean for functionality and was the focus of the upgrade.

Based on the thematic Analysis, the following core themes emerged: Improvement of Tools and Ease of Use. The participants desired a convenient feature for inspecting scarves and user-friendly, even for novices.

4. The recommendations on the upgraded design of the portable scarfing guide tool.

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The recommendations for design improvement that were raised during the testing of the initial prototype design were as follows:

a. Provide an adjustable light source – Because it possesses this feature, the scarfing guide tool can cover a larger region when checking for anomalies in the scarf profile. It also helps users determine scarf profile symmetry.

b. Provide an adjustable mounting. It is vital to have a mounting that can be adjusted to reach the needed proximity of the light source to achieve the desired level of light source adjustment.

c. Improvement of stability and aesthetic. The tool needs to be stable.

When placed on the structure, it should not make any needless movements. This will provide a clearer view of the result of the scarf profile. Physical features should be simple to operate.

d. Improvement of durability. The lightweight and durable material of the prototype assembly should be able to operate in any environment without compromising its integrity. Since the prototype is portable, the user must be confident not to break it.

5. The upgraded design of the portable scarfing guide tool.

The scarfing guide tool prototype has an arm for mounting the light source. Since the arm is placed horizontally, its forward and backward movements increase the light depth. The arm's flexibility extends not only to flat surfaces but also to curves once they are formed.

6. ***The significant difference in the level of effectiveness of the initial portable scarfing guide tool prototype to the upgraded one as to functionality and features***.

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According to the study's findings, there is a noticeable difference in the level of effectiveness between the initial and the upgraded prototypes. The function of the prototype was improved for better stability and accuracy with the attachment of the arm mounted to the light source. The user can have a clearer perspective of the scarf profile with the help of the portable guiding tool, which can now be used on any surface of the composite construction. Since the participants are only interested in the tool's intended use, adding the arm does not substantially affect the tool's characteristics. According to the results of the thematic Analysis, it was found that when all of the participants used the improved prototype, they all agreed that there was an improvement in the tools' output because they were able to get a better visual of the scarf profile while they were using the tool.

Conclusions

No specialized tool is available to establish the symmetry and correctness of the scarf profile, which presents a challenge for conducting scarfing processes in aircraft composite repair in the Fundamentals of Composite Training course at PATTS College of Aeronautics. The management may consider developing or acquiring new tools to better assist teachers and students in scarfing during composite repair. Investing in a composite repair guide tool may make teachers and students more knowledgeable about their scarfing processes. They can also put into practice more accurate methods of carrying out jobs from the very beginning of their training.

The design thinking approach of developing a prototype is an excellent developmental paradigm for creating prototypes to solve problems in study. The systematized approach to dealing with issues is to find a better solution and then test it during experimentation.

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GEO Academic Journal Vol. 4 No. 1 – 2023 series

The level of effectiveness of the initial prototype was concerned with improving the adjustability function, where it must be capable of adjusting from any scarfing area.

The participants recommended that, in terms of functionality, the prototype must be more stable and adjustable for its light source for a broader range of scarfing detection.

The upgraded portable scarfing guide tool has improved functionality in assessing stability, asymmetric profile, and adjustability due to adding the arm to the prototypes. The arm also makes the portable scarfing guide tool more flexible. The prototype of the scarfing guide tool contains an arm that can be used to mount the light source. Because the armrests are horizontal, the light depth can be adjusted in both directions. The arm's flexibility can be applied not only to flat surfaces but also to curved surfaces once it has been constructed. This makes it possible to make more efficient use of the scarfing guidance tool while performing scarf inspections on composite constructions to be inspected.

Re-designing the prototype tool after the experimentation process takes a lot of considerations, such as performance analysis using conducted surveys and recommendations for Improvement. This given data helps to improve the functionality of the portable scarfing guide tool in terms of stability, asymmetric profile, and adjustability.

Recommendations

Based on the results of the study, the following are recommended for the development and usage of the portable scarfing guide tool for aircraft composite repair:

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GEO Academic Journal Vol. 4 No. 1 – 2023 series

It is recommended that a portable scarfing guide tool be used in the Fundamentals of Composite Training course offered by PATTS College of Aeronautics. This tool will assist the instructors and students in learning how to correctly repair composites. Utilizing this guide tool will benefit the organization because there is no other specialized tool that is both portable and less expensive than other advanced tools available on the market.

Several recommendations should be considered in the upgraded prototype: adjusting the tool's base for more stability, using a different light source, and adding an extra attachment for marking purposes.

Acknowledgments

This research was created as part of the requirement for my master's Degree in the Philippine State College of Aeronautics and was supported by the management of PATTS College of Aeronautics.

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ISSN 2960-3986
GEO Academic Journal Vol. 4 No. 1 – 2023 series

References

Berones, C. (2021). Development Of an Arduino-Based Gyroscope Guide Tool Mounted on A Motorized Power Drill for Aircraft Maintenance Personnel.

Braun, V., & Clarke, V. (2006). Using thematic Analysis in psychology. Qualitativeresearch in psychology, 3(2), 77–101.

Dittmar, H., Jaeschke, P., Suttmann, O., Kaierle, S., & Overmeyer, L. (2019). Automatic control for laser-based repair preparation of composites by fiber orientation detection and short coherent interferometry—Journal of Laser Applications, 31(2), 022204.

Kimmons, R. (2022). Mixed methods. Education Research.

Nezhad, H. Y., Wang, X., Court, S. D., Thapa, B., & Erkoyuncu, J. A. (2020). Development of An Augmented Reality Equipped Composites Bonded Assembly and Repair for Aerospace Applications. *IFAC-PapersOnLine*, *53*(3), 209-215.

Rito, R. L., Crocombe, A. D., & Ogin, S. L. (2017). Health monitoring of compositepatch repairs using CFBG sensors: Experimental study and numerical modeling. Composites Part A: Applied Science and Manufacturing, 100, 255-268.

Safai, M., & Georgeson, G. E. (2019). Remote advanced repair guidance.

Steinke, G., Al-Deen, M., & LaBrie, R. (2017, March). Innovating information system development methodologies with design thinking. In Proceedings of International Conference on Applied Innovation in IT (Vol. 5, No. 1, pp. 51- 55). Anhalt University of Applied Sciences.

Takita, Y., & Ito, K. (2020). Guide device and scarfed surface forming method.

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ISSN 2960-3986
GEO Academic Journal Vol. 4 No. 1 – 2023 series

Bionote

Engr. Jabes A. Isoli is the Program Chairperson in the BSAMT Department, PATTS College of Aeronautics. His journey is characterized not only by his administrative responsibilities but also by his unwavering commitment to continuous learning. Currently, he is pursuing a Master of Education in Aeronautical Management at PhilSCA Institute of Graduate Studies in the Philippines. His impact extends beyond the confines of the classroom. He co-authored the "Aircraft Sheet Metal and Non-Metallic (Composite) Structures – Shop Workbook." Published by Books Atbp. Publishing Incorporated in November 2018 and "Enhancement of Project-Based Learning on Airframe Composite Laboratory in Limited Face-to-Face Classes for the New Normal", in 2019. In essence, Engr. Jabes A. Isoli's narrative is one characterized by his steadfast commitment to education, his multifaceted contributions to aeronautical knowledge, and his endeavors to adapt and innovate in the ever-evolving landscape of education.