PREDICTION OF SPRING-BACK DEFORMATION ASSOCIATED WITH AERONAUTICAL COMPOSITE PARTS AFTER CURING PROCESS

BY

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ABSTRACT

The aerospace industry is increasing its utilization of composite-made structures for safety and efficiency reasons but what comes with that is a phenomenon called spring-back which is defined as the deviation of the finished part from the intended design. Thus, there is a critical need for a reliable method to prevent and correct the spring-back problem. The present work employs Finite Element Analysis (FEA) to predict the spring-back behavior of composite structures by modelling the stretching of the first ply of the laminate and integrating it with an interface component between the laminate part and tool. The research study is conducted in 3 phases with pre-impregnated laminates. The first phase is for flat laminates of various sizes and thicknesses. A good agreement was obtained between the FEA simulation results and the experimental data, particularly for the smaller and thinner samples. The predominant mechanism that contributed to the spring-back warpage is found to be the in-plane stress from the ply stretching. The second phase is for curved laminates with the critical parameters identified in the flat phase being maintained with an added mechanism referred to as the Corner Effect. It was discovered that the warpage is due to the in-plane stress contributed predominantly by the corner stretching. The remainder is due to the tool-laminate interface and it has been shown that its properties are independent of the laminate geometry. The third and final phase is to study the effect of angled plies on spring-back behavior. The experimental results showed that the inclusion of angled plies in the laminate significantly raises the severity of the spring-back warpage and that orientation of the deformation is largely aligned by the fiber orientation of the first ply which reinforces the hypothesis from the first phase and overall research. Finally, the scope of the current research study only concerns with predicting the spring-back behavior but as an extension for future study, the author recommends future works focusing more on correcting the spring-back deformation via tool modification by establishing yet again both an experimental and simulation base for validating the FEA model produced in the current study for all 3 phases.

خلاصة البحث

يزداد الاهتمام في صناعة هياكل المركبات الطائرة على استعمال المواد المركبة (composite-made structures) من اجل زيادة الفاعلية و رفع مستوى السلامة, ولكن ينتج عن استعمال هذه المواد حالة تسمى بالارتداد الخلفي (spring-back) الذي يتسبب في عدم تحقيق الاجزاء النهائية للتصميم المنشود, هنا تبرز الحاجة الماسة إلى طريقة موثوقة لمنع حدوث هذه الظاهرة و العمل على تصحيحها في حال حدوثها. العمل الحالي يستعمل طريقة تحليل العناصر المحدودة (Finite Element Analysis) للتنبؤ بسلوك الهياكيل المبنية من المواد المركبة بنمذجة و محاكاة التمدد للصفيحة الاولى و اندماجها مع باقي طبقات التصفيح من خلال الربط بين الجزء المصفح و الأداة. أجريت الدراسة البحثية على ثلاثة مراحل على صفائح معدة مسبقًا. المرحلة الأولى تمت على الصفائح المسطحة بابعاد و سماكات مختلفة. تم الحصول على توافق جيد بين نتائج المحاكاة FEA والبيانات التجريبية ،خاصة للعينات الصغيرة و الرقيقة. و تبين ان الالية لحدوث الارتداد الخلفي هو الاجهاد داخل الطائرة من تمدد الصفائح او الرقائق. المرحلة الثانية اجريت على الصفائح المنحنية مع الابقاء على المعاملات الحرجة و المحددة في مرحلة الصفائح المسطحة مع آلية إضافية تسمى بتأثير الزاوية. تم اكتشاف أن الفتلان الحاصل في الصفائح يرجع إلى الضغط داخل الطائرة الذي يساهم في الغالب على تمدد الزوايا. و تعزى البقية الى أدوات الربط الصفائحي وقد تبين أن خصائصه غير مرتبطة بأبعاد الصفائح. المرحلة الثالثة والأخيرة هي دراسة تأثير الثنايا ذات الزوايا على الارتداد الخلفي. أوضحت النتائج التجريبية أن إدراج الثنايا بزاوية في الصفائح يزيد بشكل كبير من شدة الارتداد الخلفي، و اتجاه التشوه يتماشى إلى حد كبير مع اتجاه الألياف للطبقة الأولى التي تعزز الفرضية من المرحلة الأولى والبحث إجمالا. وأخيرًا ، فإن نطاق الدراسة البحثية الحالية يتعلق فقط بالتنبؤ بسلوك الارتداد الخلفي ولكن كإمتداد للدراسة المستقبلية يوصي المؤلف بأعمال مستقبلية تركز بشكل أكبر على تصحيح التشوه الناتج عن الارتداد الخلفي عبر تعديل الأداة من خلال إنشاء قاعدة تجريبية وقاعدة للمحاكات للتحقق من صحة نموذج (FEA) الذي تم إنتاجه في الدراسة الحالية لكل من المراحل الثلاث.

APPROVAL PAGE

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DECLARATION

I hereby declare that this thesis is the result of my own investigations, except where otherwise stated. I also declare that it has not been previously or concurrently submitted as a whole for any other degrees at IIUM or other institutions.

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Signature …… Date ……..

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This thesis is dedicated to my family for laying the foundation of what I turned out to be in life

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