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Expert system for process planning of pressure vessel fabrication by deep drawing and ironing

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Abstract

The fiber reinforced composite material is widely used in the multi-industrial field where the weight reduction of the infrastructure is demanded because of their high specific modulus and specific strength. It has two main merits which are to cut down energy by reducing weight and to prevent explosive damage proceeding to the sudden bursting which is generated by the pressure leakage condition. Therefore, pressure vessels using this composite material in comparison with conventional metal vessels can be applied in the field such as defence industry, aerospace industry and rocket motor case where lightweight and the high pressure are demanded. In this paper, for non-linear finite element analysis of E-glass/epoxy filament wound composite pressure vessel receiving an internal pressure, the standard interpretation model is developed by using the ANSYS, general commercial software, which is verified as the accuracy and useful characteristic of the solution based on AutoLISP and ANSYS APDL. Both the preprocessor for doing exclusive analysis of filament wound composite pressure vessel and postprocessor that simplifies result of analysis have been developed to help the design engineers.

Keywords: ANSYS APDL; Autofrettage; Composite material; Filament winding process

1. Introduction

The FRP (fiber reinforced plastic) being spotlighted as new material is widely used in the multi-industrial field where the weight reduction of the infrastructure is demanded because of their high specific modulus and specific strength [1]. Filament winding method using specific stiffness and specific strength such as fiber glass, cable, and carbon fiber in manufacturing a symmetric or revolutionary composite material-fabric is more suitable in view of cost of manufacturing, time to be used, and mass production [2]. Filament wound composite pressure vessel has in view of analysis non-linear problems complicated such as the contact between steel liner and laminate, the residual stress by autofrettage process, transient analysis of load changed according to time, and mechanical strain by high pressure gas. In order to solve and analyze above items, it needs empirical results and the empirical knowledge of field experts to the designers.

This study focuses on the development of standard analysis model using a commercial software ANSYS, which is verified to its exactness and usefulness, to carry out non-linear FE analysis of E-Glass/epoxy filament wound pressure vessel. The steel linear is pressurized as a part of it and manufactured by first drawing using tractrix die and the DDI (deep drawing and ironing) process. And also this paper concentrates on the development of an automated design system of filament wound CNG composite pressure vessel, which is able to carry out analysis as only inputting design parameters such as winding pattern, winding thickness, and fiber angle, and pressure to the analysis module of the system based on AutoLISP and ANSYS APDL (ANSYS parametric design language) [3,4].

2. Structure of the system

The system in the present study is composed of product thickness, input and shape treatment, production feasibility check, process planning, autofrettage process, data conversion, preprocess, and postprocess modules. It is accomplished in one operation and each module holds rules and

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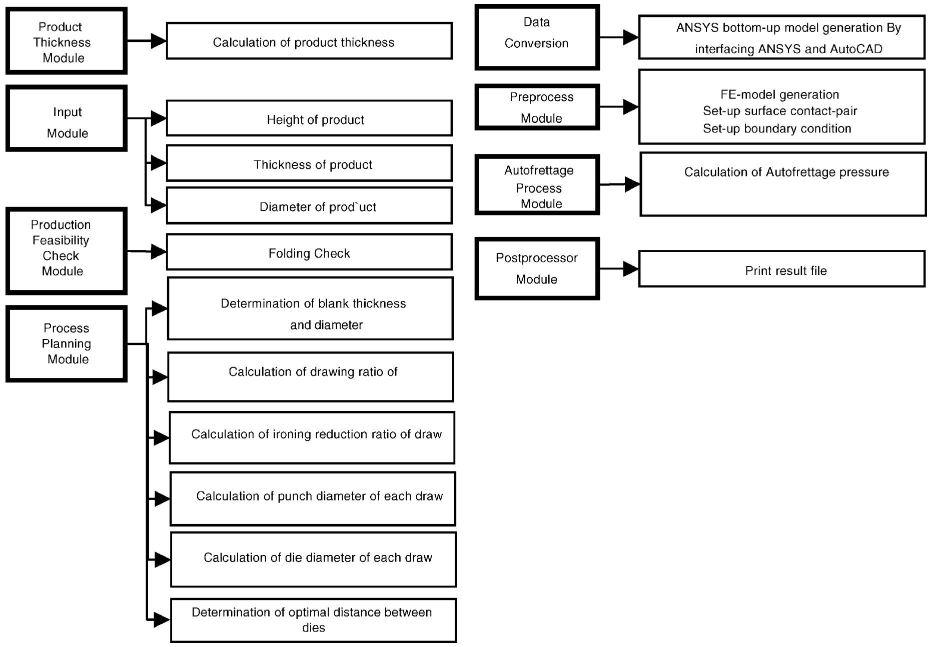

Fig. 1. Modular structure of the system.

database in common. The modular structure of the system can be seen in Fig. 1.

2.1. Product thickness module

In this module, minimum thickness is calculated to endure 2.25 times of 2.11 kgf/mm^2, which is the working pressure, according to the safety control standard of high pressure vessel.

2.2. Input and shape treatment module

When users input height, outer diameter of the final product, and the thickness calculated in the product thickness module to DCL dialogue window of AutoCAD, this module transforms the shape data into numerical list data for the shape recognition of the product.

2.3. Production feasibility check module

This module provides feasible design data through folding check diagram. Drawing ratio is determined to prevent folding phenomena through the folding check diagram with the ratios of punch diameter and blank thickness, and that of blank diameter and blank thickness regarding the final product.

2.4. Data conversion module

The data conversion module converts shape data into a pattern of matrix needed in ANSYS analysis and automatically regenerates FE model by only clicking operation because the shape data of the CNG vessel generated in the AutoCAD is integrated with ANSYS using AutoLISP.

2.5. Preprocess module

The preprocess module which performs modeling to analyze a CNG composite pressure vessel makes log files needed in ANSYS analysis been “Macro” and carries out automatically transient analysis regarding load being changed according to the time. Process parameters such as drawing ratios of each process, bursting of material according to the draw ratio and ironing reduction ratio and forming defects are verified in this module. Under graphic user interface by inputting data and clicking the button, modeling of the composite pressure vessel is generated by AutoCAD and AutoLISP. Because it based on ANSYS APDL (parametric design language).

2.6. Process planning module

In this module, the number of feasible draws from the blank diameter to diameter of the last punch which is the same as the inner diameter of the final product is determined by design data obtained from the production feasibility check module. Distance between dies is determined to lower maximum load of deep drawing and ironing or ironing and ironing successive process.

2.7. Autofrettage process module

Autofrettage process is performed to improve fatigue limit and structure strength of the vessel finally manufactured, and compressive residual stress remains in the vessel due to