The study of different parameters on the failure of pin joints prepared from composite laminates

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Abstract: The aim of this paper is to study the various parameters investigated by researchers to analyze the failure load of the composite laminates. They studied the various parameters like fibers used to make composites, orientation of fibers and number of laminates. The further study has been extended on the joining of the composite laminates. Th most common method of joining of two plates is with the help of pin/bolt joint. The same approach can be used to study the effect of joints in the composite laminates. To optimize the various parameters discussed are to be optimized which can be done with the help of design of experiment. The same approach, parameters and failure methods can be used to investigate the failure load of the composite laminate with multi pin joints.
Keywords: Failure analysis, Multi hole joints, Composite laminates.

Introduction

In the contemporary world the composite materials are widely replacing the traditional materials on most of the engineering applications. The various engineering applications in the field of automobiles, marine components, aerospace applications, structures and other engineering components are working to make these applications lighter and to increase the strength of these applications. The composite materials are widely used in most engineering applications because of their strength over the most extensively used material steel and aluminium. The components made from the composite materials are lighter and provide the strength equivalent to these traditional materials. Most of the researchers are focused and are working on to find the new materials which can replace the heavy materials like steel. The major challenge is joining of the materials. The metals are joined either by welding process which is a permanent joint or with the help of temporary joints like rivets and bolts. Most of the researchers are working in the field to find ways that how to join two composite plates. The strength provided by majority of the composite materials are equivalent to traditional materials but when holes are drilled in these composite materials the mechanical properties like strength are different than the strength provided by the materials without holes. In this paper we are going to study about the work done by researchers so far in the field of holes drilled in the composite laminates. We will study the various parameters which will affect the strength of the composite laminates.

Literature Review

Chen *et al.* [1] proposed a new finite element technique to study the stress analysis of composite laminate when hole is drilled in the composite laminates. In their study the composite prepared were graphite-epoxy laminate and glass-polyester laminate. They studied the effects stacking sequence of plies, friction and clamping of the bolt and the stresses thus generated were examined experimentally and theoretically based on the proposed technique. They found that the results from the proposed technique and from experimentation are in good correlation.

Okutan *et al.* [2] studied the failure of glass-epoxy laminates because of the pin joints. In their studied the various parameters for the failure of the composite material. They also proposed that the unidirectional fibers used for the failure analysis give different results in different samples. They studied the effect on glass-epoxy composite. The fibers used to prepare the samples were in woven form. The width and the edge distance were varied for given hole diameter. In their study the type of fiber, orientation of fiber and stacking sequence of the fibers were also investigated. The edge to diameter (E-D) ratio and width to diameter (W-D) ratio was varied from 1 to 5. From the results it was found that the bearing strength increases for E-D ratio up to 2 and then it decreases whereas the strength increases up to 3 for W-D ratio.

Sayman *et al.* [3] investigated the mechanical properties of the glass-epoxy composite laminates. They studied the effect of stacking sequence of plies, E-D ratio, W-D ratio and the preload moment on the joints. In their study they varied E-D ratio from 1 to 5 and W-D ratio from 2 to 5. Four plies were stacked in particular orientation for preparing the glass-epoxy composite samples. From the results it was found that the E-D when equal to 1 shows the weakest result when W-D is kept constant. It was also observed that the strength increases with continuous increase in E-D and W-D ratio. The stacking sequence when the fibers are oriented at 90° to each other gives higher strength than other orientations.

Ozen and Sayman [4] investigated the mechanical properties like failure load and bearing strength was analyzed for glass-epoxy composite. The study was made on the pinned joint in composite material. They drilled two holes on the composite laminate and studied the effect of E-D ratio, W-D ratio and center of hole to hole diameter (H-D) ratio. Also, the effect of preload moment of 3Nm and 6Nm was analyzed. To find the failure load in the material Tsai-Wu failure criteria was applied to predict the result with the help of finite method technique. From the experimental study and results obtained from numerical study it was found that the increase in preload moment and E-D, W-D and H-D ratio, increase the failure load.

Singh *et al.* [5] investigated on new study to analyze the strength of the glass-epoxy composite when nanoclay was added to these composite laminates. The various parameters like effect of ply orientation, variation of nano material (1 – 5 wt%), E-D ratio, W-D ratio for single pinned joint was analyzed both experimentally and numerically. To predict the failure load in the pinned joint of composite laminate Tsai-Wu failure criteria and characteristic curve method was applied. From the results it was found that with the addition of nanoclay the strength was increased by 15 – 20% up to 3% by weight after that it decreases. The net tension and shear out failure occur immediate in the composite laminate without any warning. Also, the results obtained numerically and experimentally are in good correlation.

Singh *et al.* [6] studied the mechanical properties of the glass-epoxy composite laminates. The fibers used to make laminates were unidirectional. They also investigated the effect of variation of nanoparticles varied from 1 – 5% by weight. The mechanical properties were tested on the samples with E-D and W-D ratio varying from 2 – 5. From the results it was found that up to 3% of nanoclay the strength increased by 20% as compared to samples without nanoclay. The bearing strength also increased by 15% for the laminates with nanoparticles. As the bearing of the laminates is most common because of the hole drilled in the laminates.

Singh *et al.* [7] applied the design of experiment approach to optimize the parameters for the hole drilled in the laminates. The laminates prepared were made up of glass-epoxy with the addition of nanoparticles. They varied the percentage of nanoclay from 1 – 5 % by weight. They investigated on four parameters which are E-D, W-D, H-D and side width to hole diameter ratio (S-D). Taguchi method was used to optimize these parameters. They also proposed that for serial and parallel double pin joint E-D is the most significant parameter to increase the strength of the joint. To experimental results were compare with the numerical results obtained from finite element technique using Tsai-Wu failure criteria.

Singh *et al.*[8] aimed to increase the failure load of pin joints by addition of nanoparticles and by inserting metal inserts to give additional strength to the composite laminates. The laminates were prepared from glass-epoxy in which the nanoclay was varied fro 1 – 5% by weight. The E-D and W-D ratio was varied to analyze the failure criteria. The Hashin failure criteria was used to compare the results numerically and experimentally. From the results it was clear that with addition of metal inserts the results are improved considerably and the strength is more than the laminates without metal inserts.

Summary

From the current study it is found that the researchers have worked on the failure analysis of the joints with single and double pin holes. They also studied the effectof nanoparticles on the composite laminates. From this study it is proposed that the above discussed methods and approaches can be applied to study the composite laminates with multi pin joints. In most of the engineering applications the components are joined with the help of pin or bolt joints. The study made so far is only for single pin/bolt or double pin/bolt. Very few researchers have worked on the study of multi pin joints. The parameters like ply orientation, stacking sequence and effect of nanomaterials can be studied. Also, the researchers have worked on glass-epoxy composite. The above-mentioned study can be performed on the composite laminates which can be prepared from carbon fibers. The carbon fiber provides more strength than glass fibers. This factor can help that the investigation on carbon-epoxy laminates with pin holes can give better strength.

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