Stress-strain analysis of metal butt connection with composite propeller blade

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Summary. Modeling of stress-strain state of metal butt connection with cylinder composite propeller part has been considered based on Composite PrepPost module of ANSYS software. Relations between stress of composite connection and mounting arrangement of tenons butt have been obtained. Application of computer systems allows optimize construction choice has been shown.

Key words: propeller blade, physical-mechanical properties, polymer composite materials, finite element analysis.

INTRODUCTION

Progress aerospace technology over the past 10 ... 15 years led to a significant improvement in the most important parameter of aircraft - weight reduction while maintaining the strength and reliability. A significant role in these achievements is the creation of a fundamentally new structural materials - fiber composite materials that have such a high level of physical and mechanical properties that are virtually unattainable in conventional metal alloys and plastics, as well as the emergence of a number of computational *software* tools that allow for a design stage get all the design parameters of the future material. One such modern computational systems is a well-known software ANSYS. The use of this tandem has made it possible to create structures with desired properties that best suits the nature and working conditions [3-5, 7, 8].

OBJECTS AND PROBLEMS

Fiberglass blade is the main part which laid from fiber glass and connected with her butt made from metal. Preferred are permanent joints (welded, glued, etc.). They have a much smaller than the plug-in connectors, mass construction, less expensive, less time-consuming and have a shorter duration of production cycles. Therefore, the establishment of rational structures of compounds for various types of loading is the actual problem.

The aim is to develop a rational connection the metal butt with composite cylindrical portion of the blade on the basis of analyzing the characteristics of the local mode of deformation using ANSYS [11-14].

Fig. 1 shows the blade of the propeller plane of light aircraft.

To achieve this goal it is necessary to solve the following problems:

- creating a model compound in a medium ANSYS,

- definition of the rational design of compounds of metallic and composite butt (offset and the location of tenons).

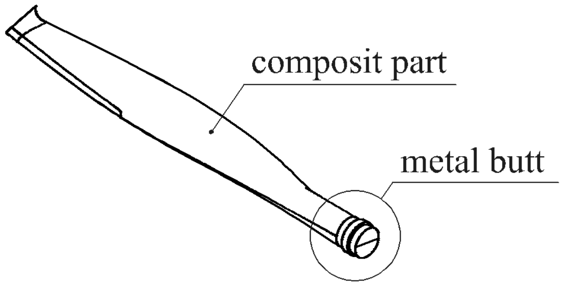

Fig. 1. The composite blade with a metal butt

For a simplified calculation of the strength of the connection is taken into account only the influence of the centrifugal force generated by the work of propeller. Is not taken into account bending and twisting the blade around its own axis of air flow. Centrifugal force is calculated based on the parameters and the operation of the blade shown in Table 1.

Table 1. The parameters of the blade

Parameter	Symbol	Value
Weight of composite blade, kg	m	1
Rotation diameter, m	D	1,8
The maximum allowable propeller revolutions, rpm	ω	3000

Find the centrifugal force acting on the operation of the compound:

$$F_c = m \cdot \omega^2 \cdot R_{cg} . \quad (1)$$

The radius of the center gravity of the blade is taken approximately 1/3 of the radius rotation of the blade:

$$R_{cg} = \frac{1}{3} \cdot \frac{D}{2} . \quad (2)$$

Taking into account the higher resulted parameters centrifugal force is numeral equal $F_c = 750$ N.

Butt is a tube which executed from duralumin. On one side of the butt machined protrusion for fixing it to the hub, on the other hand machined tenons for fastening the composite part of the blade. Butt scheme shown in Fig. 2.

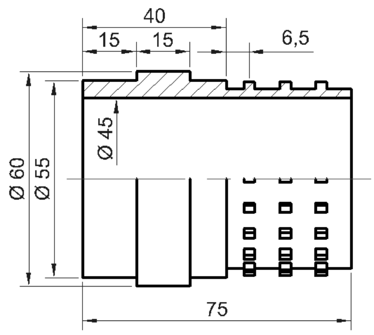

Fig. 2. Scheme butt

In the software package ANSYS produced static loading of the connection, which will allow to estimate the distribution of stresses in the joint. For this was created the model of butt (Fig. 3) and model compounds (Fig. 4) [9, 10].

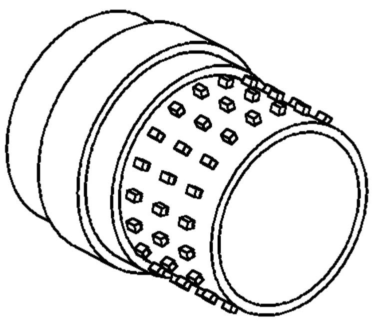

Fig. 3. Model butt

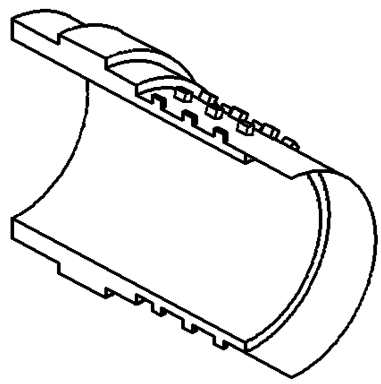

Fig. 4. Model compounds sectional

The composite of the blade in place with butt fixing is a composite package comprising a 4 woven layer impregnated with epoxy resin. All 4 layers are laid along the axis of the blade.

Details of the materials used in the calculation of the loaded state shown in Table 2 [1, 2, 6].

Table 2. Materials parameters

Element (material)	Modulus of elasticity, MPa	Poisson ratio
Butt (duralumin)	71000	0,33
Fiberglass blade (glass fiber fabrics)	45000	0,3

In order to test a compound finger-butt contact between the blade and the composite part is received with a friction coefficient of 0,3. The elements of this model are calculated on the tensile force generated by the rotating screw.

To determine the sound of spikes selected two varying parameter:

- the number of rows of tenons along the radius,
- the number zones of tenons.

Fig. 5 shows the arrangement of studs at the junction of the metal and composite.

The blade is fixed to the hub. For this purpose the projection butt prevent longitudinal and lateral movement of the blade. The scheme of loading and securing the connection is shown in Fig. 6 [15-17, 20].

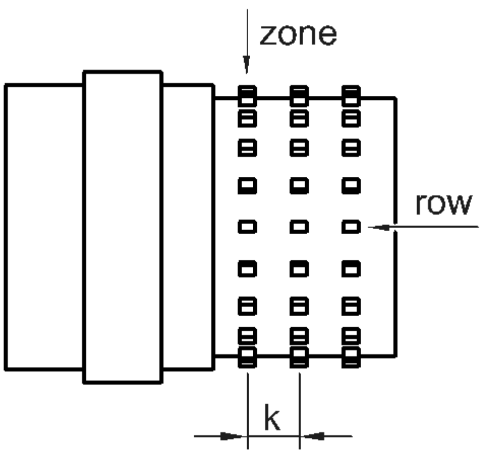

Fig. 5. Arrangement of tenons

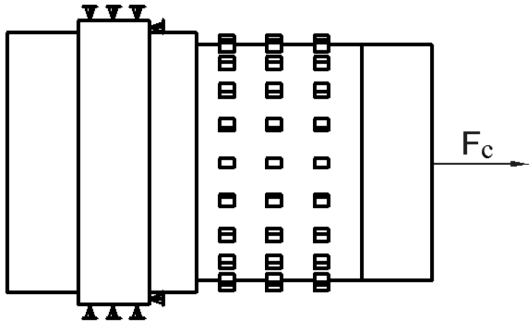

Fig. 6. Scheme of loading

Depending on the number of zones, changing the distance between zones shown in Table 3.

Table 3. Distance between zones

Number of zones	2	3	4
k, mm	15	10	8

To calculate the strength of the connections on the finite element method is used for this program was built automatically finite-element mesh shown in Fig. 7 [18, 19, 21, 22].

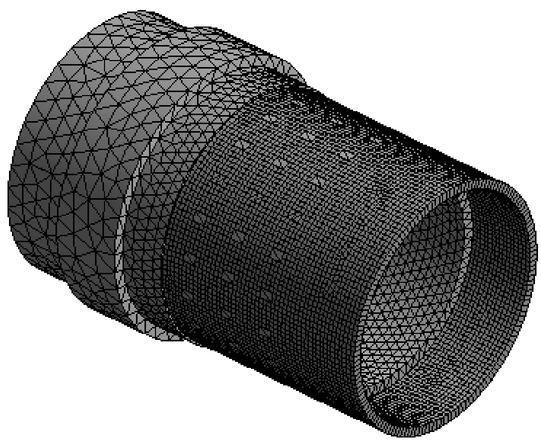

Fig. 7. Finite-element mesh connections

For clarity, depending on the nature distribution of equivalent stresses of the layout tenons, in Fig. 8 and 9 show the extremes of the layout tenons.

Table 4 displays the stresses arising under various schemes of tenons arrangement. Unit of measure stress – MPa.

Tabular data plotted in Fig. 10.

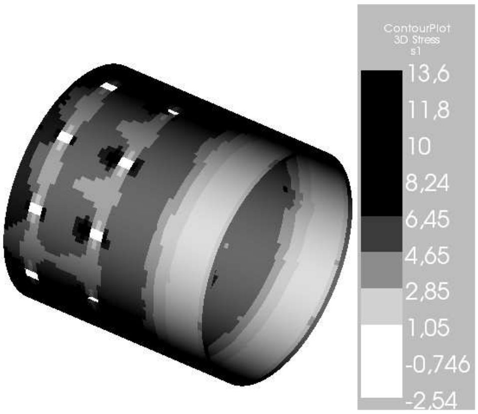

Fig. 8. Scheme: 2 zones, 10 rows

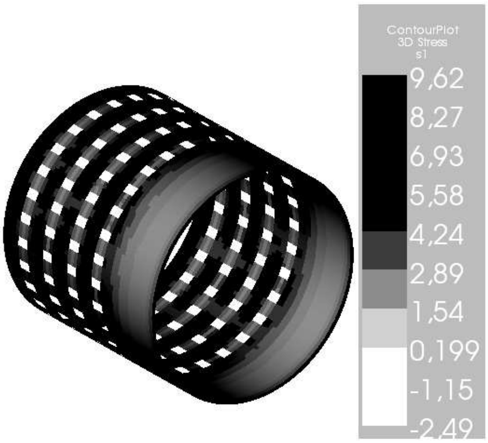

Fig. 9. Scheme: 4 zones, 30 rows

Table 4. The stresses arising under various schemes

Number of zones	Number of rows		
	10	20	30
2	13,6	9,3	9,2
3	12,2	9	9,3
4	11,2	8,9	9,6

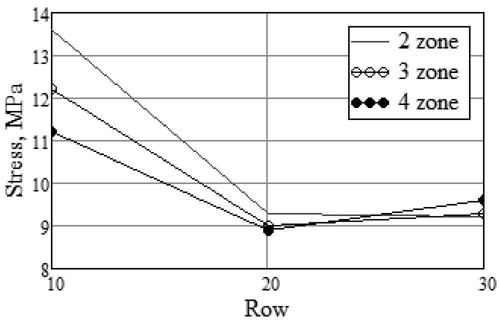

Fig. 10. Graph of the distribution stress, depending on the layout of thorns

The optimal mounting arrangement of tenons butt is an arrangement of 4 belts and 20 rows based on received results. However discrepancy between close result of 3 belts and 20 rows is up to 1.1% (mash error) but the first option of 4 belts and 20 rows is more expensive.

Hence, optimal mounting arrangement of tenons is arrangement of 3 belts and 20 rows. It may be inferred that a few mount of tenons doesn't secure uniform load distribution (Fig. 8) and vice versa a lot of tenons of first row restrict load transmission to other belts that are shown in figure 9.

There is divergence of results of numerical experiment and full-scale experiment due to difficult non-linear physics characteristics of materials.

CONCLUSIONS

1. The optimal mounting arrangement of tenons butt of 4 belts and 20 rows has been determined based on finite element analysis using ANSYS.

2. Engineering time has been reduced and consequently consumptions of constructions design have been decreased according to required strength characteristics.

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АНАЛИЗ ХАРАКТЕРИСТИК ЛОКАЛЬНОГО НАПРЯЖЕННО-ДЕФОРМИРОВАННОГО СОСТОЯНИЯ СОЕДИНЕНИЯ МЕТАЛЛИЧЕСКОГО КОМЛЯ С КОМПОЗИТНОЙ ЛОПАСТЬЮ ВОЗДУШНОГО ВИНТА

Игорь Малков, Геннадий Сыровой, Игорь Непран

Аннотация. В статье рассмотрено моделирование напряженно деформированного состояния соединения металлического комля с композитной цилиндрической комлевой частью лопасти с применением специализированного программного приложения ANSYS и его модуля Composite PrepPost. Получены зависимости напряжения в композитной части соединения от схемы расположения шипов комля. Показано, применение современных вычислительных комплексов, позволяет оптимизировать выбор варианта конструкции.

Ключевые слова. лопасть воздушного винта, физико-механические свойства, полимерные композиционные материалы, метод конечных элементов.