OPTIONS WELDING PIPE AIR SPACE STRUCTURES MADE OF TITANIUM

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Introduction as the first chapter is followed by the second chapter focusing on the properties of Ti (Titanium) and its alloys. The third chapter focuses mainly on methods of Ti alloys cutting. The fourth chapter describes the methods of welding and the next chapter describes the method of quality evaluation of PSS (Pipe Space Structures) Ti alloys welds. The sixth chapter deals with the weld finishing. The seventh chapter analyses the possibility of applications in the manufacture of Ti alloy welded PSS airframe and helicopter training systems. Practical result of this thesis is calculations and comparison of parameter values for proposed PSS weight trainer helicopter, defined for the material properties of various alloys of Ti and Cr - Mo (Chrome - Molybdenum) Steel.

K e y w o r d s: Tungsten Inert Gas, Laser Beam Welding, Plasma Welding, Electron Beam Welding, Cold Pressure Welding.

1 INTRODUCTION

Problematic in the work result from needs of company TOMARK Ltd. They have to meet theoretical and principal objective of the work. They include the results of implementation of practical aim of the work.

Theoretical goal of the work is partially fulfilled by the description of weld preparation. The preparation is characterized by a commonly used method of cutting Ti alloys' pipe by mechanical means with a reference to the literature [1], [2], by water jet and abrasive jet [2], [3], by plasma [4], by laser beam [5], [6] and by laser technology – MicroJet [7].

Main theoretical goal is fulfilled by description of Ti alloys' welding methods. Specifically, the following methods: cold pressure welding [8], [9], [10], TIG (Tungsten Inert Gas) [11], [12], plasma welding [13], laser welding [14], electron beam welding [15], [16].

The practical goal of the diploma work is design suggestion of PSS support model for helicopter in the environment of Pro-Engineer Wildfire 4.0, including simulation, static strength stress analysis. Verification of its strength is done under specified load conditions. The chapter concludes with the result and the description is already mentioned in the abstract and the particular solution is given in the last chapter.

2 PROPERTIES OF TI AND TI ALLOYS

To do a proposal of suitable structural material for support PSS of helicopter requires expert knowledge of materials in the area. My work is focused on Ti alloys as structural materials suitable for a helicopter, and therefore in this section, that specifically address their material properties.

The purpose of the chapter is to use the information about material properties of Ti alloys to help TOMARK Company, Ltd. to make the right choice for structural material for support PSS of helicopter.

3 TI ALLOY PIPES' PREPARATION

Preparation is done prior to welding. In this work I proceeded with method analysis and the work is written in chronological order. In this chapter the pretreatment of welded construction material is emphasized.

This chapter deals with the importance of Ti alloys preparation before welding. Weld pre-treatment is believed to achieve not only geometrically correct nodes of supporting PSS assembled helicopter, but the cleanliness and quality of welded joints of the structure. This chapter meets a part of given theoretical goal.

4 COMMON METHODS OF TI ALLOYS' WELDING

This chapter is focused on basic welding methods for aviation PSS of Ti alloys. Currently, there are many methods for welding of Ti alloy. The company TOMARK, s.r.o. is mainly interested in the 5 basic methods of welding Ti alloys:

- cold pressure,
- TIG,

- plasma,
- laser beam,
- electron beam.

The purpose of this chapter is to describe mentioned different welding methods in terms of their principles, advantages, disadvantages, welding conditions, and thus fulfill the main theoretical goal of the work.

5 WELD QUALITIES IN AVIATIC PSS MADE OF TI ALLOY

Welded PSS helicopter must meet strength and stiffness safety features. Therefore, in addition to the quality of the material, welds are checked in welding nodes of PSS helicopters.

Verification of the quality of welded joints is provided by non-destructive and destructive tests. Non-destructive testing shall consist of direct visual inspection in accordance with EN 970, capillary test according to EN 571-1 and radiographic examination according to EN 1435. Destructive tests consist of a tensile test according to EN 895, break test according to EN 910, microscopic and macroscopic analysis of welds according to EN 1321 and hardness tests according to EN 1043-1.

When performing direct visual inspection of welded joints is important to distinguish the color of the oxide, resulting in the surface. Color of the weld allows us the visual quality check. As shown in

Fig. 1 with a gradual contamination of the weld and the HAZ (Heat Affected Zone). E.g. lack of protective action of the gas stream, there is a change of colors of generated surface oxides.

Poor Ti alloy surface purity is characterized by dark blue, gray, or white coloration of nitric oxide in the weld. If this occurs, welding must be stopped, and oxide must be removed [17].

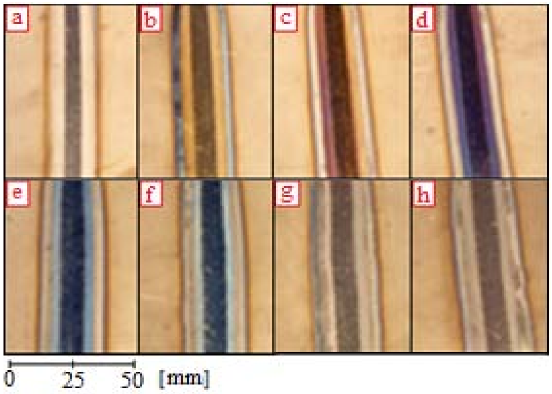

Fig. 1 Patterns of oxide colors on weld surface and in its proximity dependent on contamination of CP Ti (Commercial Pure Titanium). Legend: a - minimal contamination, h – maximal contamination [17].

6 HEAT PROCESSING OF AVIATIC PSS MADE FROM TI ALLOYS

To ensure the quality of welded joints of Ti alloys, it is necessary to eliminate internal stresses. The material is heat-treated after the completion of the welding. High strength welded PSS are obtained by its hardening. Procedures for both methods of heat treatment are described chronologically in this chapter. Theoretical partial objective of the work is completely fulfilled by the content of this chapter and chapter 3.

7 OPTIONS OF APPLICATION TI ALLOYS

The chapter is focused on applications in the manufacture of Ti alloy welded PSS drags and helicopter training systems. There are many possible applications of tubular Ti alloy structures in helicopters. This chapter focuses on some of them, which are used often. In the helicopter, we focused on the application of Ti alloy production in:

- welded carry structure,
- welded Engine bed for piston engine,
- welded skid chassis,
- welded truss structures tail beam,
- welded chassis front undercarriage leg,
- welded wheel chassis,
- welding rod system management,
- welded construction horizontal stabilizer helicopter,
- welded front undercarriage leg,

- welded bed battery helicopter,
- welded construction mounting seat,
- cyclic control lever,
- the foot control,
- tail support.

8 PSS OF THE HELICOPTER

The practical goal of this chapter is to obtain information about the value of weight of bearing PSS Ti alloy prior to its actual production, and it defined the material properties of various alloys of Ti and Cr - Mo steel according to the requirements of TOMARK Ltd. The chapter also verifies the proposed strength design static stress analysis. Other types of stress analysis in this chapter have been addressed.

8.1. Design of bearing PSS of helicopter

Design is executed in Pro-Engineer Wildfire 4.0. In the beginning it is necessary to create a PSS model in that program. Its composition is represented in Fig. 2.

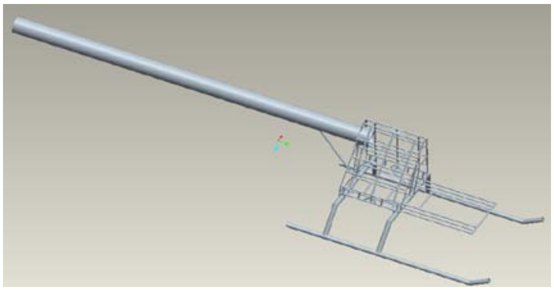

Fig. 2 Model of bearing PSS of helicopter designed in Pro Engineer Wildfire 4.0.

The assembly of proposed PSS helicopter model consists of 31 parts. All the individual parts have been designed according to standard sizes of tubes supplied by a company whose business card is shown in Fig. 3.

Fig. 3 Visit card of Ti Alloys (Deg. 2, 3, 5, 7, 9, 12) dealer [18].

8.2. Strength / Stress analysis of bearing PSS of helicopter

Stress analysis is made in the environment of Engineer Wildfire 4.0 and is done to verify the strength of the proposed PSS helicopter. The company that commissioned the theme for the solution of this work has identified some of the load conditions, the helicopter must endure in terms of fortification. The carrier must transmit the power rotor 13 000 N and rotor balancing force of 250 N. Other conditions associated with the proposed design load, I determine their own devising. All properly designed and specified loading conditions of the structure are expressed in Fig. 4th.

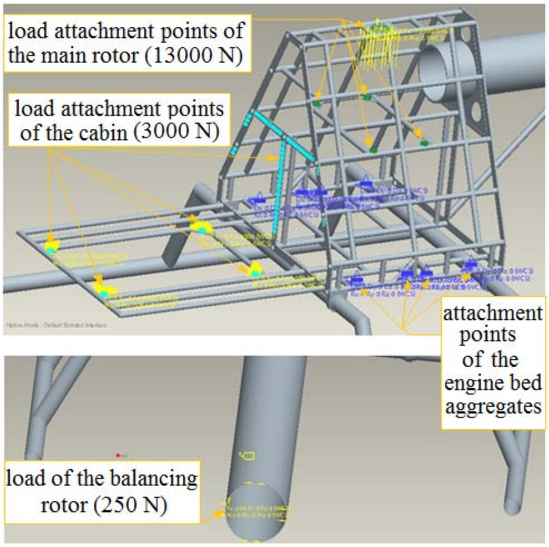

Fig. 4 Conditions of stress load in designed bearing PSS of helicopter.

In following steps we will perform a static stress analysis. Most critical node of stress concentration is shown in Fig 5th.

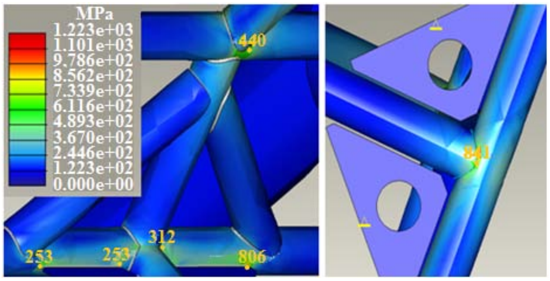

Fig. 5 Locations with strength critical nodes of designed PSS of helicopter (stress values in critical nodes are in MPa).

Static Stress analysis, we confirmed the desired strength of the proposed PSS, for the specified load conditions. In order to make easier construction, we did not attempt to use diagonal elements and that's why some of the nodes are suffering higher stress (Fig.5).

It should be noted that if the proposed PSS helicopter will be installed with engine, auxiliary units, gearboxes, fuel tanks, cabin and other parts of the design, it will increase rigidity and the deformations will decrease because of reducing the tension in the construction. The stress drop is mainly reflected in the sharp edges of the structural nodes, including the strength (stress) of critical structural nodes (Fig. 5).

8.3. Calculation of weight / mass of bearing PSS.

Calculations will be defined for different material properties of Ti alloys and Cr - Mo steel. The value of the density of Ti alloys St. 1, 2, 3, 4, 7, 11, 16, 17, 26, 27 has the same value. This value of density we define the material properties of the proposed model, the following procedure: Analysis / Model / Mass Properties. Unit density, we must specify the units according to preset program t/mm3. The density of the alloys is 4,51.10-9 t/mm3 (Table 1).

Assuming that all of the models are made of the Ti alloys, we define the same density for each set in the table Fig.6. Then the program will calculate several parameters, which include the volume and weight of the model. For Ti alloys St. 1, 2, 3, 4, 7, 11, 16, 17, 26, 27, calculate the volume of the structure of the value of 0.01082554 cubic meters and weight of the structure of the value of 45.47231854 kilograms.

The accuracy of the parameters' calculations is carried out in the program within ± 0.00001.

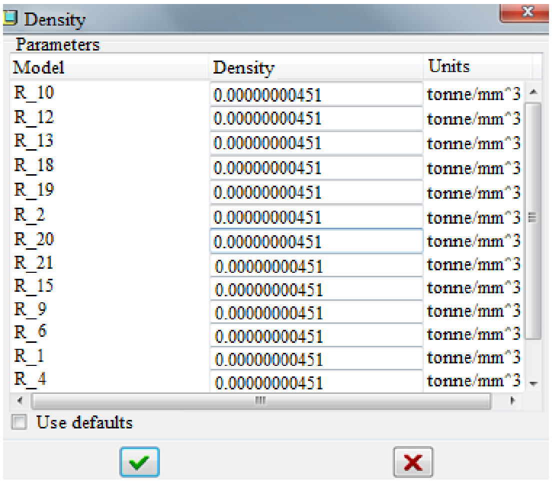

Fig. 6 Entering the values of density, valid for the Ti alloy St. 1, 2, 3, 4, 7, 11, 16, 17, 26, 27, various parts of the assembly model in the program Pro Engineer Wildfire 4.0.

Analogically, according to Table 1, computed for the same model, but for different values of the density parameter of St. Ti alloys, the parameter values and model weights we write to the Table 2.

Table 1 Parameter values Ti alloys densities and Cr – Mo ocele [19].

St. of Ti alloys	Density of Ti alloys	
	kg/m^3	tonne/mm^3
1, 2, 3, 4, 7, 11, 16, 17, 26, 27	4510	4,51.10^{-9}
5, 23, 29	4430	4,43.10^{-9}
6,9, 18, 28	4480	4,48.10^{-9}
19, 20	4820	4,82.10^{-9}
Cr – Mo steel	7860	7,86.10^{-9}

Table 2 Parameter values of mass of simple model calculated for various values of density parameter.

St. of Ti alloys	Weight of the proposed construction from Ti alloy (kg)
1, 2, 3, 4, 7, 11, 16, 17, 26, 27	45,47231854
5, 23, 29	44,66571422
6, 9, 18, 28	45,16984192
19, 20	48,59791028
Cr – Mo steel	79,24887444

The calculated results show that if we build the proposed model of a helicopter bearing PSS from Ti alloys St. 1, 2, 3, 4, 7, 11, 16, 17, 26, 27, will be on:

• 0.80660432 kilograms heavier than the same model, made of Ti alloy St. 5, 23, 29,
• 0.30247662 kilograms heavier than the same model, made of Ti alloy St. 6, 9, 18, 28,
• 3.12559174 kilograms lighter than the same model, made of Ti alloy St. 19, 20,
• 33.7765559 kilograms lighter than the same model made of Cr - Mo steel.

9 CONCLUSION

The thesis is developed for needs of employees TOMARK, s.r.o. engaged in production of small sports aircraft and in this time a helicopter, too. Their goal is apply to helicopters modern materials such as Ti alloys by welding. The most basic and commonly used welding methods of Ti alloys are clearly processed in the core of the work.

Although equipment for welding of Ti alloys using TIG method is the cheapest methods of welding, we suggest using plasma method, because this method requires no weld gaps for welding Ti alloy to a thickness of 3 mm.

Conclusion is simpler preparation of material prior to welding, in terms of its composition and division, and shorten the production time of overall design helicopter.

The only disadvantage of the method is the large heat input, which negatively affects the quality of welded joints. The raw material receives during welding a lot of heat energy resulting in a larger HAZ in weld joint.

The proposed model is verified by static strength stress analysis, under the conditions given by TOMARK Ltd. In the event that the proposed PSS helicopter bearing, as recommended by the manufacture of construction material → Ti alloy St. 5, its mass is 44.66571422 kg. In the event that the proposed PSS helicopter made of a Cr - Mo steel, its mass is 79.24887444 kg (Table 2). The difference in weight is 34.58316022 kg.

If we have other load criteria (specific data) by company TOMARK, s.r.o, is possible on the base proposed model, simulate additional analysis, for example modal or fatigue analysis. These analyzes are simulated in order to detection life of construction.

Dimensions of proposed construction are displayed in annex F, which is part of the work. The dimensions of proposed construction are typical for two-seater helicopter.

Considering maximum and minimum strength values of the density of Ti alloys we recommend to use a particular Ti alloy Deg. 5 as construction material for PSS production helicopter.

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