THE SPECIFICATION FOR THE QUALIFICATION OF THE AFT COVER FIXATION SCREW OF THE SATELLITES LAUNCH VEHICLE VLS-1 ENGINES

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Abstract. *An understanding of the mechanical properties of metals during deformation over a wide range of loading conditions is of considerable importance for a number of engineering applications. When discussing high strength steel, it is crucial to realise that the definition of so-called high strength depends entirely upon how the steel is to be used. These usages tend to fall into a number of different categories where different combinations of properties are required.*
Being the application in subject, its took place a study to specify and to accomplish assays for qualification of the screw of head six-sided, wrought and laminate, " rolled " thread, type M14x1,5x28,5 mm, used for the fixation of the Back Cover of the metallic rocket engines of VLS 1, made in steel of high resistance AISI 4340, martensitic of low league, which supplies advantageous resistance combinations, ductility and toughness for several applications.

Keywords*: screw, aft cover,VLS1, steel 4340.*

1. Introduction

In this work the mechanical properties and microstructures of AISI 4340 high strength alloy steel, they were taken in consideration for the specification of the screw in subject. There are several well-known structures in steel, such as ferrite, pearlite, bainite, martensite and austenite. Each of them has very different mechanical properties ”(Carlson *et al* 1979)”, “(Callister 1994)”. Therefore, it is possible to obtain the highest strength from any one of these structures and it is likely that the highest strength steel in each of these categories will be of wide application. The mechanical behavior of AISI 4340 steel is quite sensitive to the tempering temperature and holding time. Generally, quenching and tempering are well-established means to produce strengthening in steel which can be achieved mainly due to the precipitation of a fine dispersion of alloy carbides during tempering “(Huang and Thomas, 1971)”. Known for forming the highest level of strength in a steel, the martensite structure is rarely used in an untempered condition because a large number of internal stresses associated with the transformation cause the material to be lacking in ductility “(Briant and Banerji 1979)” , “(Horn and Ritchi 1978)”, however, low-temperature tempering is sufficient to reduce these stresses considerably without essentially changing the basic features of the martensitic structure.

The screws were quenched and tempered to obtain a martensitic structure and submitted to the fracture loads by a testing machine Otto Wolpert, type THZ-200.

2. Material and experimental details

The material employed was the steel AISI 4340 ESR, supplied in form of the bar with diameter of 14,6 mm, with its chemical composition presented in the “Tab. 1”.

Table 1 .Chemical composition analysis of the AISI 4340 alloy steel

Elements	C	Si	Mn	Ni	Cr	Mo	P	S
Wt (%)	0,39	0,24	0,61	1,46	0,67	0,17	0,021	0,006

This low-alloy martensític steel, can be heat treated to obtain a wide strip of hardness and due the utilization, for its production, of to the process called Eletro Slag Remelting (ESR), its concentration of inclusions is considerably reduced.

Under as-quenched conditions, the material has the highest level of strength and hardness, but its ductility is the lowest. This can be explained base on the phase transformation of the steel during quenching processes. It is clear that the ductility of material increases with the tempering terperature and holding time, but that there is then a drop in thoughness and ductility when tempered at 300ºC. This loss in toughness may result primarily from different processes of heat treatment. In the as-quenched state, the thermal instability of interlath austenite after tempering often leads to the formation of carbide films, which is a fairly general cause of tempered martensite embrittlement. In the present case, a loss in toughness after tempering at 300ºC is correlated with the retained interlath austenite and the formation of interlath carbide films that are decomposed from the lath boundary retained austenite“(Horn and Ritchi 1978)”.

Tempering , a process of heating the martensite to elevated temperatures for the material to become more ductile, involves many different basic processes, such as: the precipitation of carbides, the decomposition of retained austenite, and the recovery and recrystallisation of martensite structure.

To produce the screw, the first step was conformed it in a specified geometry and to proceed submitted to the treatments of quench and temper, to reach the conditions of mechanical resistance specified for the steel AISI 4340. The thermal treatment started with a austenisation at 870ºC for 50 min, followed by oil cooling to produce a quenched martensite structure and then the screw was tempered at 580 ºC for 60 min.

The “Figure 1” show the morphologic aspect of the martensitic structure of the steel AISI 4340 after its cycles of quench and temper accomplishes in the conditions of time and above-mentioned temperatures.

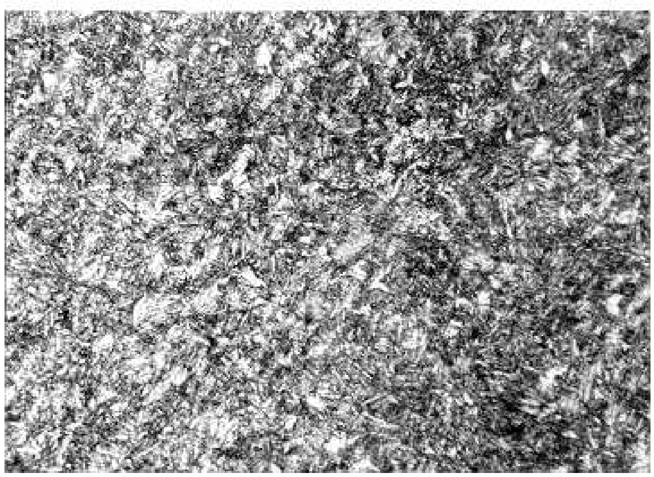

Figure 1. Martensitc structure micrography of the AISI 4340 steel (optical microscope 500 X)
(quenched in oil at 870ºC / 50 min, and tempered at 580 ºC / 60 min)

2.1 Specification of the screw

The “Figure 2” shows the aspect and the geometry of the screw that has the following characteristics:

Material: AISI 4340 high strength alloy steel

Tensile strength - σt = 1200 MPa

Hardness in the nucleus: 37 a 40 RHc

Diameter 14 mm

Thread M14x1,5x28,5 mm.

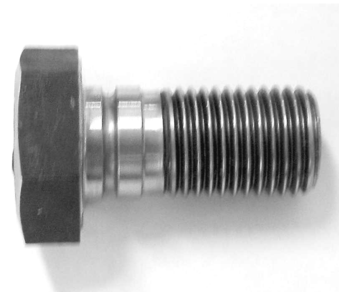

Figure 2. technical drawing of the screw

The screw has a channel that allows to place a o'ring to avoid a possible pressure losses due to a gas leakage during the operation of the rocket engine propellant burn.

The Figures 3 and 4, shows the details of the area of application of the screw and of the mounted aft cover and fixed one of the metallic rocket engines of VLS 1.

Figure 3. Screw application area

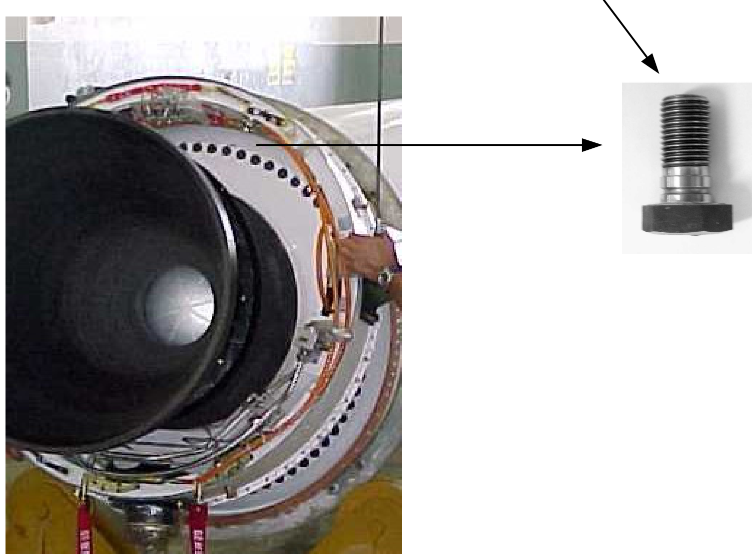

Figure 4. Aft cover fixed in a VLS-1 rocket engine.

2.2 Non Destructive Testing for Magnetic Particles

It was accomplished Non Destructive Testing using the Magnetic Particles Technique in the 170 units, to the detection of superficial and internal discontinuities, being adopted the norm MIL-STD 1907-96 and ASTM E 1444-01 standards. The obtained results described the non detection of discontinuities or cracks.

This test was accomplished to verify the possible presence of internal or external discontinuities, that could interfer in the mechanical tests results, (low values of the resistance).

2.3 Mechanical Resistance Test

Thirty screws (30) were submitted to tension test testing, through a specific device for the test, following a procedure in agreement with the standard ASTM E8 (1987). These were tested in a testing machine Otto Wolpert, type THZ-200, at room temperature with a constant cross-head speed of 0,0083 mm s-1

This test was accomplished with objective of verifying if the mechanical resistance of the screws it is in conformity with the technical specification, which establishes a minimum value Tensile strength, $\sigma t = 1200$ MPa .The “Tab. 2” show the results of the screws submited of the test.

Table 2 .show the results of the Tensile strength of the screws.

IDENTIFICATION OF THE SCREWS	Tensile strength σt (MPa)	Medium value	Standard deviation
1	1468.39	1467.59	8.88
2	1463.73		
3	1473.42		
4	1480.51		
5	1480.53		
6	1461.94		
7	1460.17		
8	1460.17		
9	1465.48		
10	1452.21		
11	1451.32		
12	1464.60		
13	1472.56		
14	1469.02		
15	1469.02		
16	1480.53		
17	1460.17		
18	1480.52		
19	1465.48		
20	1468.40		
21	1461.95		
22	1473.42		
23	1451.32		
24	1461.94		
25	1472.58		
26	1480.52		
27	1480.51		
28	1460.18		
29	1463.73		
30	1473.44		

2.4 Fracture Aspects after Tension Test

The “Figures” 5, 6 and 7 shows the fracture types (A), (B) and (C), observed in the screws submitted to the tension test.

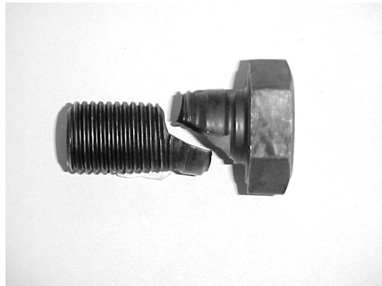

Figure 5. Fracture type (A), that begins in the o'ring channel .

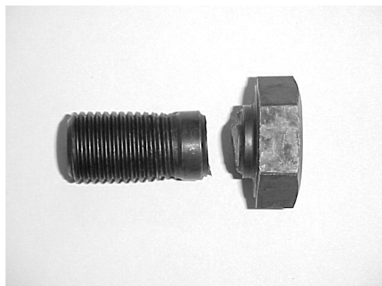

Figure 6.Fracture type (B), that begins in the section of the o'ring. channel.

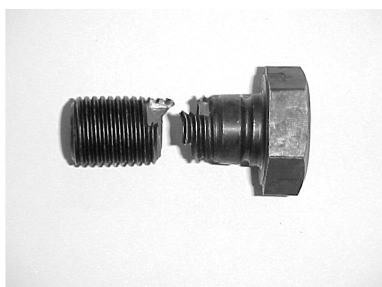

Figure 7. Fracture type (C), that begins in the screw thread

The “Table 3”, correlates the screws (identified with the numbers 1 to 30) with the corresponding observed fractures

Table 3 correspondance between the screw and the observed fractures

TYPES OF FRACTURES	A	B	C
Identification of the screws	3,6,17,21,23,27	2,4,5,7,8,12,13,14,15,16 ,19,20,24,25,26,29,30	9,10,1,11,18,22,28

In agreement with the “Tab. 3”, it is observed that the predominant fractures are of the type B, probably in function of the decrease of the section in the o’ring channel .

2.5 Observation of Fracture Surface

Following the mechanical testing, the observations of the fracture surface for each screw tested are also conducted. The Sections of the fracture surface are removed from the fracture tensile screw and then treated with standard metallographic procedures for microscopic examination. The observation of the topographical features is carried out using a “scanning electron microscope” operated at 2,2 kV.

This observations were made at the fracture surface to help to identify quantitatively the mode of fracture initiation as a function of tempering temperature. For all of the specimens tested, the observations of the fracture surface shows that heavy necking has taken place during tensile loading. The typical ductile “cup-and cone” fracture surface, is a characteristic dominated by the ductile mechanism.

The Figure 8 shows the fracture surface of the schew tempered at 580ºC for 60 min. The features observed on these micrograph, reveal the fine distribuition of voids or “dimples”, showing that the tempered AISI 4340 steel failed with a ductile fracture mode. The voids in these micrographs exhibit a fairly wide variation in size and shape.

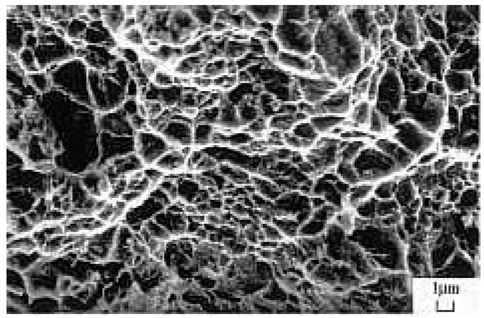

Figure 8. fractoghaphy of the screw quenched in oil (850ºC for 50 min) and tempered at (580ºC for 60 min).

Although AISI 4340 steel is a widely-used low-alloy martensitic steel that provides an advantageous combination of strength, ductility and toughness for the applications of machine part-members, it is susceptible to embrittlement during the tempering procedure at 300ºC “(Kwon *et al* 1988)”.

This analysis of the fracture surface was accomplished with objective of certify that the screws went tempered in to mentioned temperature of 580ºC, avoiding this way the probability of tempered martensite embrittlement occurs, putting in risk the perfect operation of the component, as well as. can be guaranteed the tempered martensite structure for the steel AISI4340, used in the making of the screw

3. Conclusions

The obtained results allow to affirm that the screw attend to the project specification, which establishes a minimum value Tensile strength, σt = 1200 MPa.

The accomplished tests of traction presented values above the specified value, obtaining a resistance average Tensile strength - σt 1467,59 MPa.

It was possible to attest the tempered martensite structure of the steel AISI 4340, under the conditions of quenched at 870ºC/50 min in oil, being followed of the tempering to 570ºC/60 min, through the fractures analysis of the screws fractured in the test.

This analysis allowed to assure that the screws would be exempt of the possibility of they present the tempered martensite embrittlement if the tempering of this material was accomplished at 300ºC, putting in risk the use and the responsibility of this component, once this component is submitted to the high forces that act, due to the high pressure originating from of the process of it burns of rocket engine.

4.References

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