Initial tests’ test plan

Twardowsky 2 propulsion

Bartosz Hyży

1. **Introduction**Within this document, the test plan regarding initial qualification tests of the propulsion system will be presented. Initial qualification tests are understood as tests, that verify readiness of individual subsystems and its elements for functional tests in conditions specified within project requirements. Main goal of this testing phase is to make sure, that assumptions and calculations accepted during mechanical model creation are compliant with reality, particularly with regard to the stress calculation of components and the design of subsystems’ seals. After that phase of testing, the next step is to begin functional tests campaign which consists of cold flow and hot fire tests.

Obraz zawierający tekst, zrzut ekranu, Czcionka, linia

Opis wygenerowany automatycznie

Fig 1. General scheme of qualification test campaign

In order to make sure, that conducted tests will be performed in safe way in accordance with stated requirements, each must be performed in conformance with pre-prepared checklists or test sheets which later have to be stored as a prove, that test took place. For safety reasons, tests involving pyrotechnic materials (gunpowder or solid propellants) require particular attention in the procedure. The integration of pyrotechnic components must always take place under the control of a person experienced in this field.

Obraz zawierający tekst, diagram, Plan, linia

Opis wygenerowany automatycznie

Fig 2. Initial tests’ campaign

The initial tests consist of several steps, the defined sequence of which must be followed. In addition, due to the different functionality of the subsystems, each has to go through a different route in the verification process. The components and subsystems concerned by the initial tests are listed below:

* Tank
* Main valve
* Vent valve
* Plug assembly
* Combustion chamber

**2. Tank**

Due to its role in the propulsion system, tank is critical component when it comes to pressure and leakage proof testing procedures. Its durability is determined by the weakest spot in its structure, which is the weld that joints the tank body with its ends. Tank has been welded using simple TIG method, which was chosen for it accessibility and based on previous experiences in Twardowsky project, where welding technology was particularly problematic. Tank leakage test is included in test plan, due to possibility of leakages on weld itself, in case when it was manufactured without cleaning precautions. The test is important because there may be holes in the weld of such small dimensions that pressure tests utilizing water will not detect the leak due to the low compressibility of the medium. For this reason, the fact that the leak test is carried out using air, a compressible gas, is crucial. In the case of target engine operation or when performing cold flow and hot fire tests, the medium that will fill the tank will be partly in the gas phase, which can lead to uncontrolled leakage at the weld.

The test should take place with a gaseous medium, the pressure of which can be easily controlled once the tank is full and can reach maximum pressures in the region of 1 MPa. Carrying out leak tests with higher pressure gases is not recommended for reasons of test safety. A compressible gas, unlike an incompressible liquid (e.g. water), stores much more kinetic energy during compression, which, if the tank is destroyed, can lead to a risk to the life or health of the test participants. At the time of writing, it is assumed as standard, to use a compressor with a maximum operating pressure of 8 bar for this purpose. A compressor with such parameters has been used on numerous occasions during the tests of the Twardowsky 1 engine.

Then, when the tank is found to have passed the test, it should proceed to the pressure test stage. As required, pressure testing of any tank that is part of the rocket must pass the pressure test given a nominal design safety factor of 1.5. The tank's destruction safety factor is 2, but at the time of writing, no tank destruction test is assumed. The nominal tank pressure is 58 bar, so a pressure test must be carried out bringing the tank to a pressure of 87 bar with an accuracy equal to that of the available pressure indicator. For pressure testing the compressed medium is water, preferably demineralized water should be used here to reduce the risk of mineral deposition inside the tank. Water, as a liquid, is an incompressible medium which is preferred for pressure tests. Because of this fact, if a tank is damaged during the test, the kinetic energy that will be imparted to the debris will be much lower than if a gas-filled tank is destroyed. Nevertheless, special safety measures and personal protective equipment, such as safety goggles or protective headphones, must be observed here. According to the requirements set, the predefined pressure must be maintained for one and a half times the maximum time allowed for the tank filling process, so the time during which the pressure must be maintained is 90 minutes. During this time, the pressure reading must be checked every 20-30 minutes or so and changes recorded. After this time has elapsed, or if a partial failure of the tank is detected, or if leaks are detected, the set pressure should be released completely before the test participants approach the tank. During the test, the tank should be immobilised and the bottoms protected against damage in case of weld rupture.

**3. Main valve**

Testing valves is more problematic and requires more steps, than in case of vessels’ tests. The valve qualification process consists of four stages:

* Static leakage test
* Static pressure proof test
* Dynamic test
* Dynamic pressure test

Static leakage test is simple and similar to other leakage tests. In this case, the main goal of this test is to verify, weather the sealants for the main valve piston were chosen properly. The test should be performed, when the valve is in the closed position, using gaseous medium. As described in the Tank tests description, the standardized device to produce the pressure here is the compressor with maximal pressure of work of 8 bar. During this test, the valve assembly should be immobilized and nobody should stand in the axis of piston movement.  
After it is confirmed, that the system passed the leakage test, the static pressure proof test should be performed. It should be followed