CAE ANALYSIS OF CONTACTS OF FIRST SLOVAK SATELITE skCUBE

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Summary. The paper is focused on CAE analyses of connectors, which are ensuring the connection between solar panels and power system unit in first Slovak satellite skCUBE. The article briefly describes connection between two main electrical parts of skCUBE, possible failure of connectors and the main task of this text is to provide the solution of mechanical failure of this part by CAE analyses. The other aim of this contribution is to assess installer limits of connector SPRING FINGER 3.0 H for skCUBE installation. The last chapter deals with vibration analysis, which is based on real vibration tests in laboratory.

Keywords: satellite, skCUBE, CAE analyses, connector

1. INTRODUCTION

The development of the skCUBE satellite began at 2011 by Slovak Organization for Space Activities (SOSA). It is a small satellite of Cube Sat class with weight of 1056 grams and dimensions 100 mm x 100 mm x 100 mm [1]. Transport of the satellite to the Earth orbit by rocket is accompanied by strong vibrations. Thus, the environmental tests have been done. The tests consisted of vibration test, centrifugal test and thermo-vacuum test. The vibration test has lead to the damage of electric contacts between the one of four solar panels and the power supply unit (PSU). Further analysis has shown that the contacts on the damaged side of the PSU board were soldered in closer distance to solar panel than the contacts on the other sides. Our goal is to determine the limits of pressing of the contact without its damage. The simulations have to be performed to determine the contact soldering tolerance. These simulations depend on material parameters. The Spring Fingers 3.0 H contacts are made of TiCu+Fe alloy by TE connectivity Company. Material parameters specified by the producer are Poassan constant (Poisson's ratio) 0,33, Young modulus 120 000 Mpa, characteristic stress 970 Mpa and failure strength 1100 Mpa [1, 2, 4]. The process of determining of contact soldering tolerance is described in next chapters. All simulations have been performed in the Creo Simulate software.

2. DETERMINATION OF THE CONTACT MOUNTING TOLERANCES

From the measurements and documentations that provided SOSA are known the values of connector installation distances. The front contact surface exceeds 0.8 mm above the edge of contact. The maximal pushing limit is till 0,5 mm, after breaking this value it is probable that the destruction will occur. It is needful to calculate the force that pushes the contact in the mentioned front area by 0,5 mm. This force associated with the frequency band of the vibrations will be also used as the input for the modal analysis in order to possibly determine outer limits of mechanical load for contact. The force acting on the contact is shown in the Fig. 1. As for boundary condition, at the lower section the contact is fixed to the PSU and the front section is touching the inner side of the solar panel. [1]

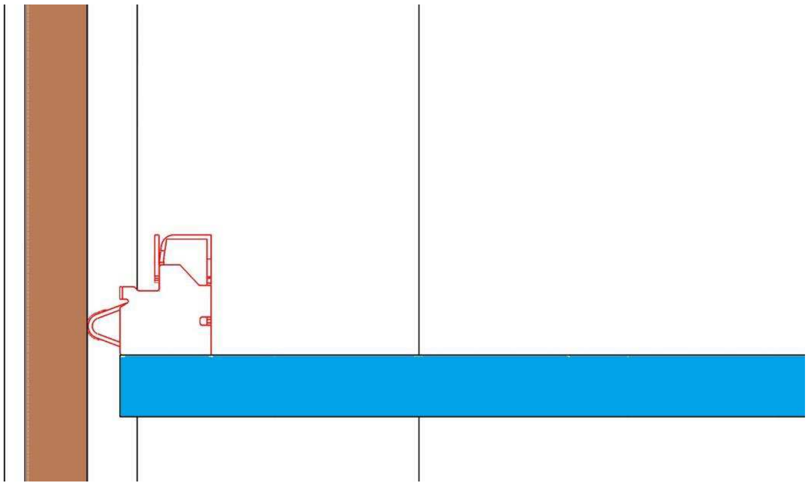

Figure 1 Layout drawing of Solar panel, connector and PSU

2.1. Buckling load factor analysis

The basic assumption for any computations analysis is to know or determine the forces which can cause to exceed the limit distance values in front section of the contact and reach higher values of stress than is allowable. Because the acting forces are not known, it is necessary to determine the value of Buckling load factor (BLF) from which it is possible to calculate critical force analytically.

The next step is meshing the 3D model in the Creo Simulate software on which the BLF analysis is carried out.

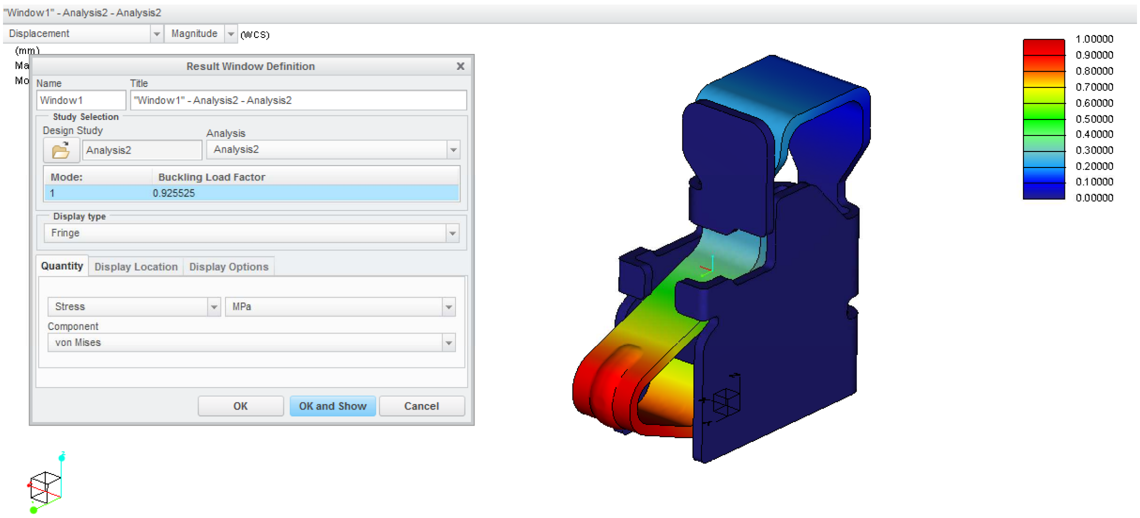

Figure 2 Buckling load factor analysis

The result of BLF analysis is a numeric value that is critical to the component. It is a value by which the deformation of front section is maximal. In this analysis the force of 1 N is applied to the front small surface on the contact and BLF computed Creo Simulate is 0,925525. When the force is calculated by using BLF analysis in Creo Simulate, then it is necessary to divide this value by two and then we get the force of approximately 0,4 N. This calculated force will be used as an input for static analysis, which should show a contact suppression of approximately 0,4 mm.

2.2. Static analysis

As was discussed in previous chapters for a static analysis like this is essential to know the force. Operational load is the force which is known from BLF analysis. So it is possible to carry out the static analysis.

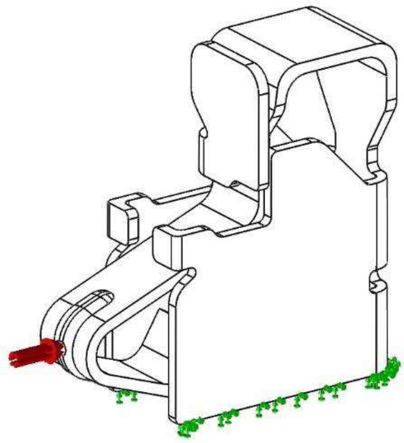

Figure 3 Forces distribution of electrical contact

The computed force from the BLF analysis was applied to the front surface of the contact as shown by the red arrows in Fig. 3. The green arrows are showing fixed connection between the contact and the PSU of the satellite.

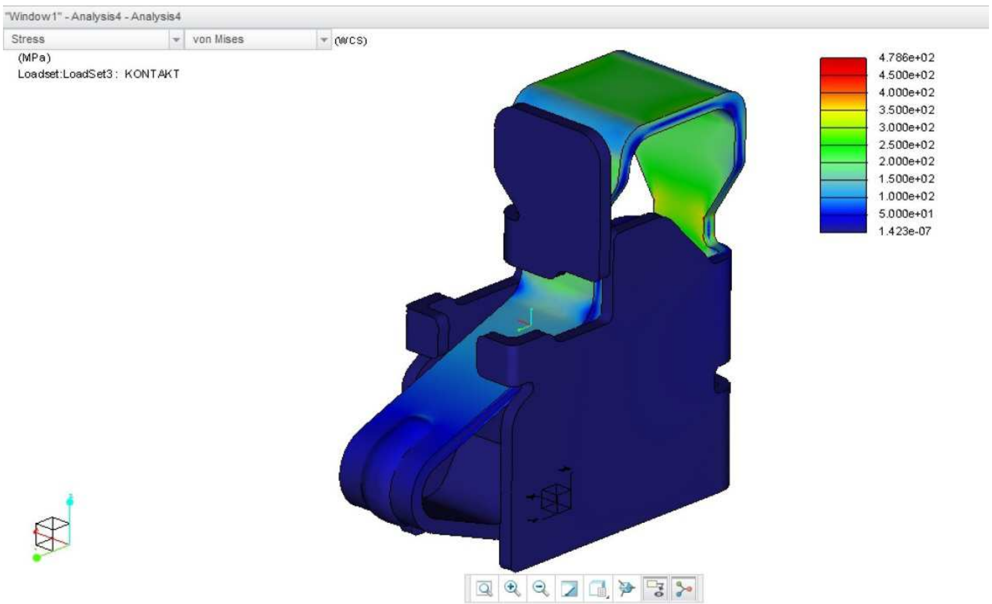

Figure 4 Results of static analysis

The results of the static analysis are presented in Fig. 4, from which can be seen the stress distribution with concentration in the critical section. The maximal value of Von Misess stress is 478,6 MPa. The following figure shows the displacement of the front part of the contact caused by force 0,4 N. The front part of the contact moved slightly more than 0,41 mm, this value is critical and leads to the contact failure.

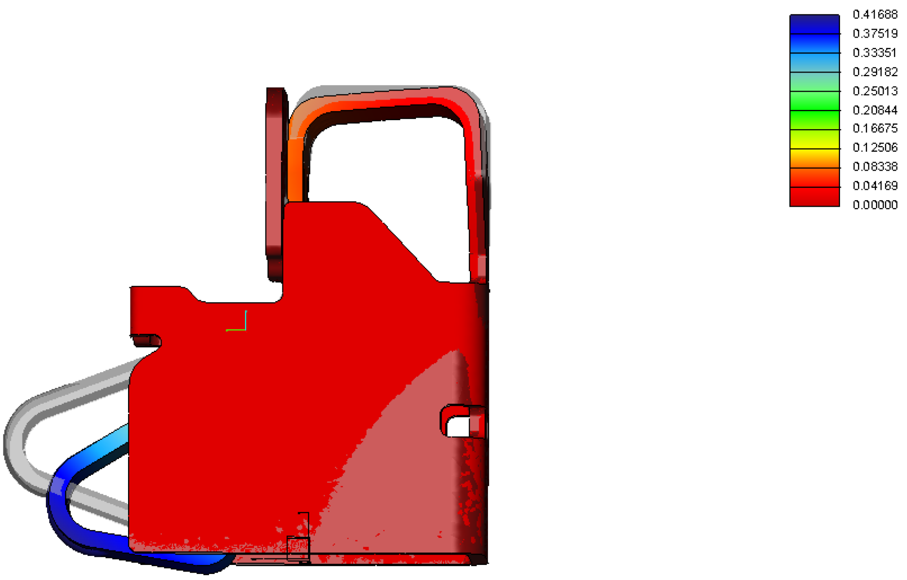

Figure 5 Displacement of skCUBE contact

3. MODAL ANALYSIS

In the introduction were discussed particular tests that were carried out on the skCUBE satellite. One of the tests was the vibration test. A frequency band was set between 5 Hz and 2000 Hz [2]. The results of this test have proved the failure of contacts. Following are presented the results of modal analysis that were carried out in the Creo Simulate. The aim was to find the dangerous vibration area in which the failure of contacts occurs.

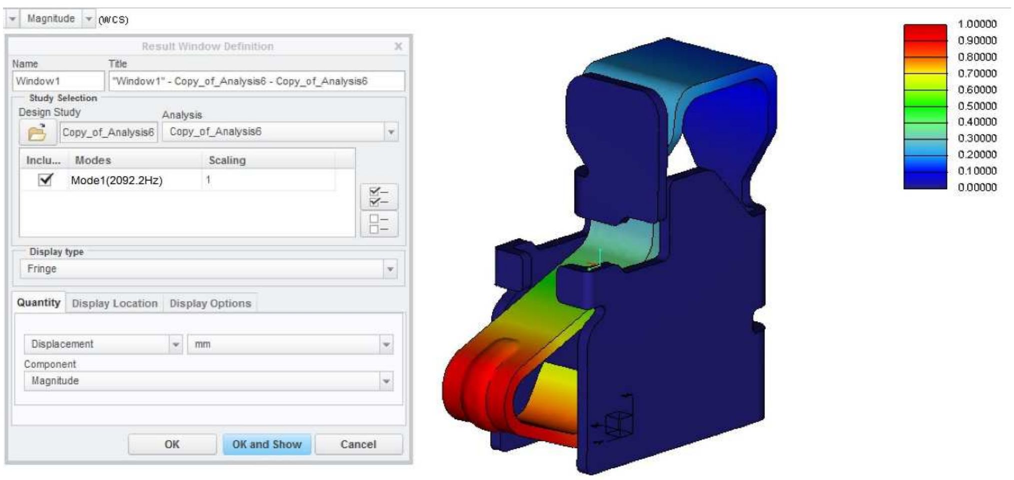

Figure 6 Results of modal analysis

The outcome of the modal analysis is in the figure 6. First Eigen frequency has value 2092,2 Hz as we can see in the table (Fig. 6). It is one of the natural resonant frequencies of the contact [5]. And the shape in this frequency is the same as in real conditions. It can be seen that the front part of the contact will move towards solar panel in the Y axis direction.

3.1. The Dynamic frequency analysis

In a dynamic frequency analysis is created the measurement point which is applied on the front surface of the contact as we can see in the picture below (Fig. 7). This measurement point is shown in red and with sign Measure1. In this analysis was observing moving of the measuring point depending on the frequency.

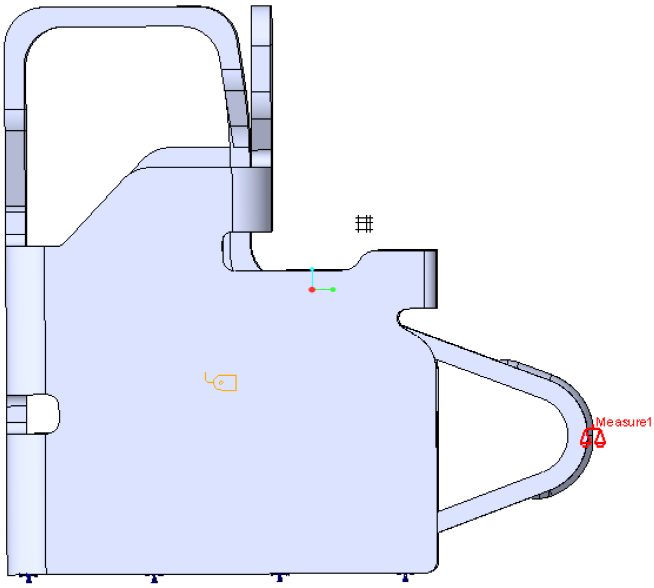

Figure 7 Definition of meassure point for dynamic analysis

The analysis results are shown in the figure 8, where the x-axis is a frequency spectrum from 0 to 2500 Hz and the y-axis is the amplitude. The graph clearly shows that the 2000 Hz frequency is the critical value. In the frequency spectrum the range 0 Hz to 1900 Hz is no significant displacement of the measurement point observed. After crossing this limit at the frequencies just above 2000 Hz the amplitude gains a high value and moves the measuring point up to 0,55 mm. Pushing this front section of the contact leads to its destruction as a result of exceeding the limit value.

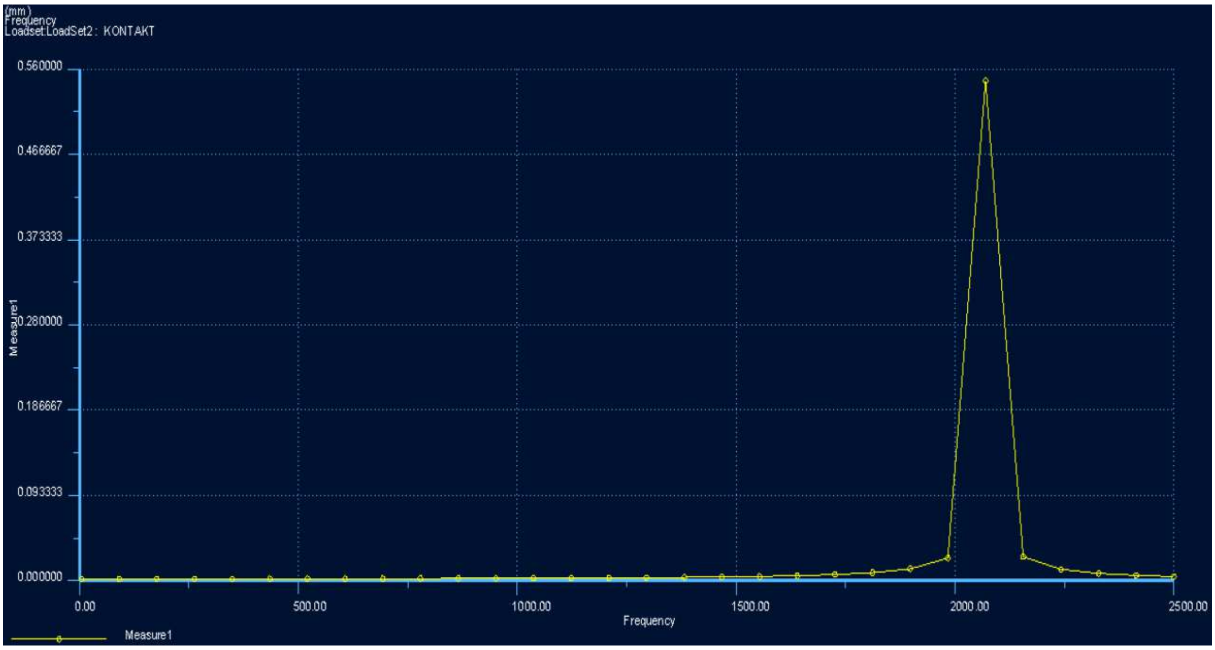

Figure 8 Results of dynamic modal analysis

The dynamic modal analysis confirmed the fact that if the contact pressing limits are exceeded above given values, the resonance will occur and it leads to the contact destruction. That is why during the installation of the contacts is necessary to ensure that the contact is not placed within the tolerance limits. The failure of such an important component of satellite could lead to power supply failure on skCUBE satellite in its orbit.

RESULTS AND DISCUSION

The results of vibration tests on skCUBE satellite have shown the damage of contacts between single solar panel and PSU unit. The goal of performed analyses was to determine the safety working load of contact. Critical values of load when the contact is damaged were determined.

In no-load status the contact blade overreaches the contact body by 0,8 mm from tip of the blade. Static analysis has shown the damage of the contact at contact blade press by 0,41 mm. The acceptable press of the contact blade is 0,2 mm, when all stresses are under the critical limits in all parts of the contact construction.

The modal analysis has determined self-resonant frequency of contact to 2092,2 Hz. At this frequency the contact blade oscillates and pressing the contact more to the solar panel. Dynamic analysis of the contact in range from 0 Hz to 2500 Hz has shown increase of the oscillation amplitude to 0,55 mm. Former static analysis has shown that such press of the contact blade will result in its damage. From the dynamic analysis it can be seen that the critical range of vibration is from 2000 Hz to 2200 Hz.

Analysis noted above that the press of contact blade has the influence on its reliability. Mounting the contact with static press of 0,4 mm does not result into the contact damage. But when the vibrations are present, the design should be made in such way that it prevents the creation of vibration in the range from 2000 Hz to 2200 Hz. The safe and reliable operation of the device can be obtained by fulfilling these two limits.

Acknowledgement

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