

1 Introduction

With the increase of flight distance and the extension of working time on deep space exploration mission, the traditional spacecraft which relies on the reaction propulsion will need to carry more fuel and energy, which largely increases the payload of the spacecraft and thus limits its maximum speed.

In recent years, solar sail as a new type of spacecraft has attracted much attention. It can be powered by solar pressure without having to carry a large amount of fuel. Therefore, it has been widely used in interplanetary navigation and deep space exploration.

The advantages of solar sail spacecraft is that it does not need to carry a large amount of propellant. Although the solar radiation is very small, but the continuous acceleration from the large, ultrathin mirrors can harness the faint pressure of the sun's reflected light to move through the vacuum of space and reach a considerable speed which is about 5-10 times faster than traditional spacecraft, suitable for deep space exploration.

In this paper, we studied the ***** of solar sail, gave the differential equation of *****, and designed the *****. Finally, we obtained the optimal flight plan of solar sail with the realization of the shortest transit-time and the maximum payload.

2 Problem statement

The spacecraft can reflect the sunlight by carrying a large, lightweight reflective surface that exerts a pressure equal to twice its energy density, thus gaining impetus. This impetus is related to the acceleration of the spacecraft, and its acceleration is influenced by the attitude of the spacecraft. When the attitude angle α of the spacecraft changes, its trajectory will change accordingly.

When the distance between Earth and Mars is the closest, a rocket will launch a total mass of 2000 kg (sail plus payload) to escape velocity from Earth to Mars, and the spacecraft must have a relative velocity of no more than 9 km/s to ensure a safe landing close to Mars. Assume that the sail is made of material of mass 7 g/m^2 , we need to design a flight plan for the solar sail spacecraft in order to find the optimal size of the sail so that to maximum the payload and to reduce transit time.