Cold Welding Based Space Debris Removal System

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Abstract: *Space Debris is a major problem posing a great threat to all the future space travels as well as to all the satellites which are orbiting around the earth. According to a definition by the Inter-Agency Debris Coordination Committee (IADC) “space debris are all man-made objects including fragments and elements thereof, in Earth orbit or re-entering the atmosphere, that are non-functional” [1]. According to J. C. Liou, even if we stop all the space launches the amount of space debris will remain constant up to 50 years but will increase later due to collisions among them [3], [4]. Till December 16, 2019 a total of 20047 objects are on orbit out of which 5370 objects are payloads and 14677 are debris, this means about 73% of the objects in orbit constitutes debris. [2] The rate at which the debris is generated is much greater than the rate at which this debris deaccelerates, leaves the earth orbit and re-enters the earth atmosphere. We can protect the future space missions from huge debris particles that are traceable but the small debris elements pose a major threat. In this paper we propose a technique to remove the small debris particles from Lower earth orbits based on cold welding. Cold welding is the process in which two similar metals stick to each other when there is a metal to metal contact in space. This happens because on the ground these metals have layers of oxides thus, two pure metals never come in contact but in space, due to wear and tear, this layer of oxides get removed irreversibly and as a result, pure metals come in contact and the adhesive forces cause the metals to join. The debris is orbiting around the earth at a speed of 17500 mph [10]. For our system we use a composite material made up of a combination of elements that usually orbit the earth. Since, in relative frames they are stationary by increasing the velocity with controlled amount we can control the impact during contact. We will propel this composite material with the same speed around the earth as the debris, so that in their relative frames it appears stationary. By bringing the debris particles into contact with the composite material, cold welding will take place between them and then, we will send the system to international space station where the captured debris particles are removed from the composite material. By repeating this process, we can remove most of the small debris particles of size less than 10cm which are orbiting around the earth in lower earth orbit.*

Key Words: *Cold Welding, Space Debris, Composite material*

1. INTRODUCTION

Space Debris is the major constituent of the objects currently orbiting around the Earth. Space Debris can be formed in different ways such as collision between two satellites, collision of already orbiting space debris with an active satellite and the remaining parts of the rocket

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stages after they have completed their task such as deploying a satellite. According to NASA, each year we need to remove 5 to 20 space debris particles to stabilize the space environment.

Based on the characteristics of the space debris removal method they can be of two types, namely contact and contactless capturing methods. Contactless capturing methods include Electrostatic Tractor and Gravity Tractor while contact methods include stiff connection and flexible connection methods [5].

This paper deals with a contact capturing method. Contactless space debris removal systems such as Artificial atmosphere and Ion beam shepherd take a long time to deorbit the material.

However, using cold welding we can remove a small space debris particle in one revolution. Figure 1 shows the current status of various objects in the space environment.

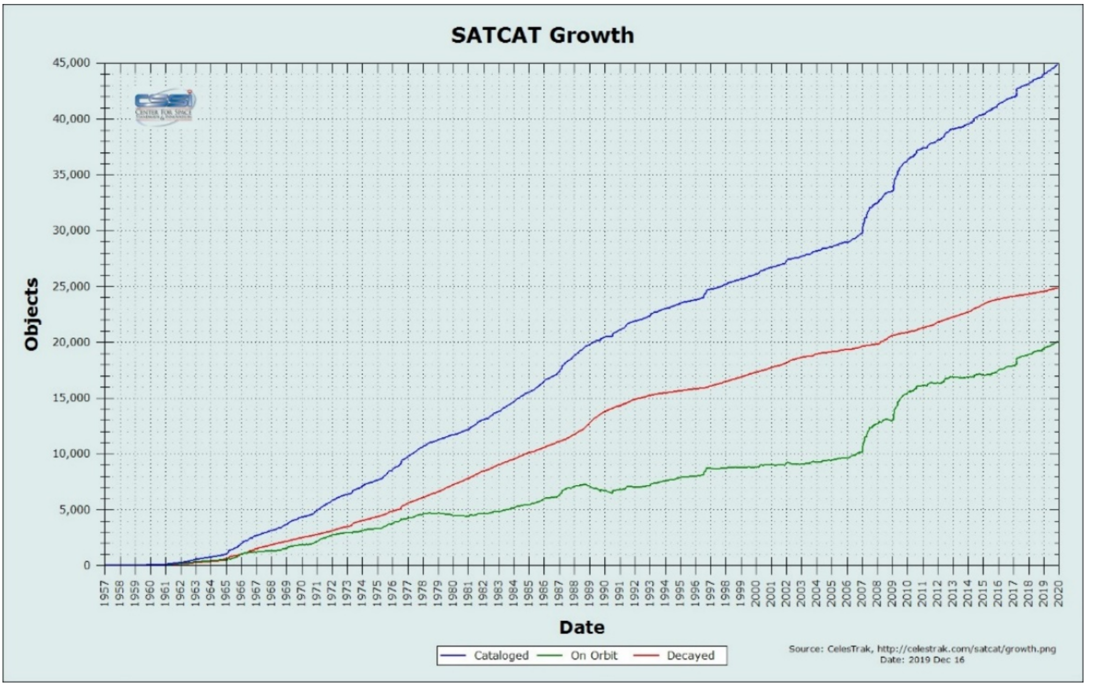

Fig. 1 Figure showing objects in space with respect to year [2]

Now, as stated by Liou in the Low Earth orbit, the altitude close to 800km is most crowded and the altitudes of 600km, 800km & 1000km are the messiest orbits [5].

We are going to use our space debris removal system at an altitude of 800 km which is highly crowded to increase the amount of small space debris particles being removed by cold welding.

2. MATERIAL OF THE SPACE DEBRIS REMOVAL SYSTEM

We propose that our system be made up of composite material. Composite materials can be defined as materials made by combining two or more separate materials, each of which retains its own distinctive property [6].

The composite material should have a composition based on the materials form the space debris of small size (size less than 10 cm). Artificial space debris comes mainly from all parts of the spacecraft.

A. Types of Artificial Space Debris

Artificial space debris can be divided into the following types: polymers, non-metals, metals and oxides.

Non-metal space debris mainly comprises of silicon. It is present in the orbit and comes from electronic parts, solar cells, etc.

Metal space debris includes iron and its alloys, copper and its alloys, noble metals, aluminium and aluminium and magnesium alloys and oxides [7].

Thus, the composite material should be made up of iron with minor amount of carbon, chrome and nickel; aluminium and aluminium and magnesium alloy; copper and noble metals.

3. PROCEDURE & METHOD OF SPACE DEBRIS REMOVAL

First, the small space debris particles which we want to remove need to be tracked and their trajectory needs to be observed.

Then, once we have estimated the speeds and the position of the debris particles we are going to launch our space debris removal system which will initially reach the speed at which the debris particles are travelling.

Thus, in relative frames the space debris removal system and the debris particles are stationary.

Then, the space debris removal system shall approach the debris particles and collide with the debris particles such that the impact velocity is sufficient for the debris particles to be cold welded to the system.

Since, most of the small debris particles are in group around the orbit of the earth thus, we can remove a group of space debris particles.

Once the space debris removal system captures space debris particles from a group it will experience more atmospheric drag and by using its propulsion system it will change its orbit to the altitude of the International Space Station where the space debris particles that have been captured are being removed and then, the system is reused.

A. Tracking Targets for Space Debris Removal

We are going to track the space debris particles by creating a 3D model of the space debris around the earth using the data obtained from various observatories on earth and the space. The group of space debris which needs to be removed is tracked, based on the 3D model.

B. Orientation & Control of the Space Debris Removal System

To Control the Space Debris Removal System we shall use the Reaction Control System for changing the orientation and the system orbit.

To determine the attitude of our system we choose the reference axis so that the yaw axis points to the centre of the planet.

The roll and pitch axis are perpendicular to the yaw axis and is defined using the right hand rule.

We are going to use Kalman Filter to get accurate readings of the attitude for our system. For the reaction control system we use canisters of Nitrogen as fuel. For our system, the Reaction Control System is better than the Reaction wheel because it is more suitable for short operation and the weight of the reaction control system is lower.

The Reaction control system will help us for adjusting the orientation, altitude and speed of the space debris removal system.

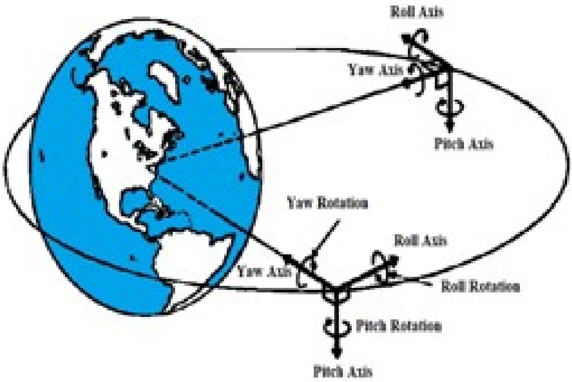

Fig. 2 Yaw, Pitch & Roll Coordinate axis [9]

C. Impact Velocity Determination

On the ground adhesion between metals during impact is extremely rare, as the metals surface is oxidized. However, in space this oxide layer is irreversibly broken.

Therefore, there is metal-metal contact during impact, thus, cold welding takes place [11]. The adhesion forces are the main reason for cold welding. Now, consider the following figure

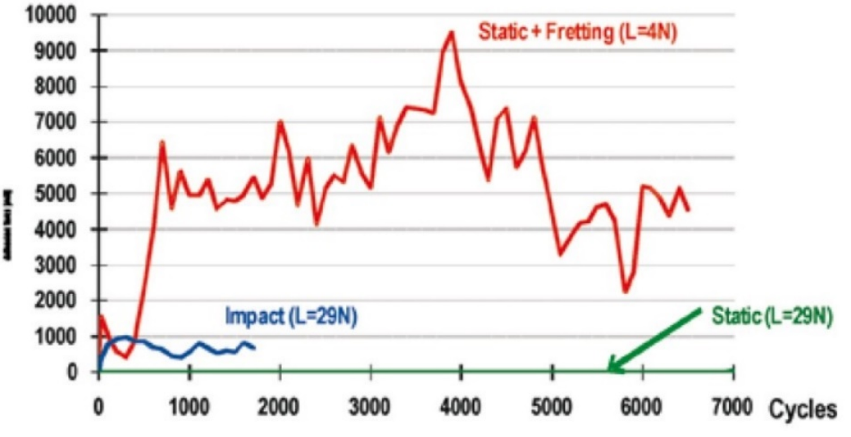

Fig. 3 Adhesion force as a function of the number of cycles & comparison of forces under static and fretting conditions under vacuum [11]

The figure above shows the three plots related to the three contact types of titanium alloy (IMI834) and stainless steel (AISI 440C).

The plots are based on the impact tests carried out by ESA for cold welding; it was concluded that "Under impact the contaminant layers are removed quickly and cold welding takes place quickly as compared to the static contact" [11].

Cold welding has been considered as a major problem in the space travels after the failure of the Galileo spacecraft in 1991, thus, various coatings have been done on metals to prevent them from being cold welded.

Thus, impact is required to have a perfect metal-metal contact. The impact velocity can be determined using the data obtained during the experiments conducted by the ESA for the assessment of cold welding.

As small space debris with a size less than 10 cm has been orbiting around earth for many years, thus, its coating is worn out; to in order to assess the adhesion forces acting over it, let us consider the following figure:

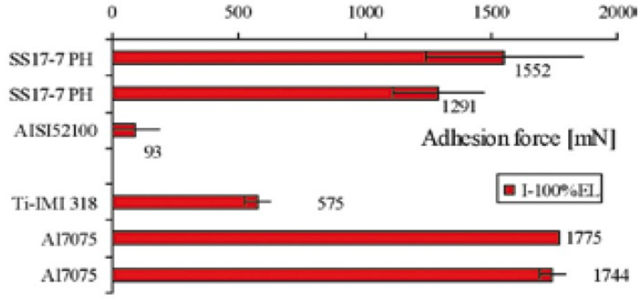

Fig. 4 Adhesion force under impact for materials in contact with themselves [11]

From figure 4, it can be deduced that the highest adhesion force is among aluminium alloys example Al7075 and also among stainless steel SS17-7PH.

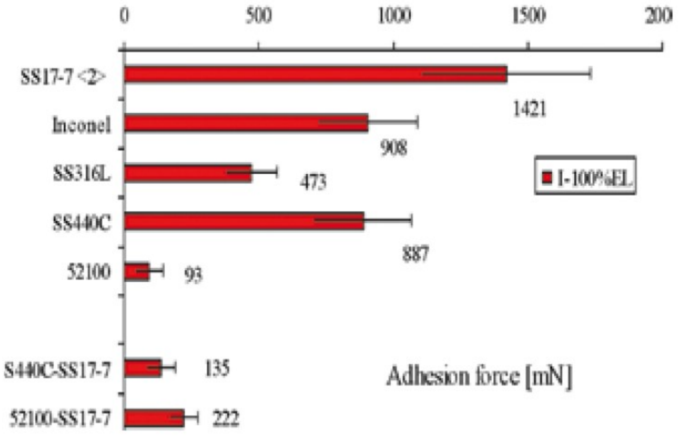

Fig. 5 Adhesion force under impact for different types of steel in contact with themselves [11]

In the figure it is shown that austenite steel and nickel promotes high adhesion as Inconel shows adhesive force of 908mN and SS17-7<2> shows adhesion force of 1421mN. Since, we know the adhesion forces between different elements, we can use it to determine the impact force required to have a perfect cold welding.

D. Deorbiting the Space Debris

After the space debris particles have been cold welded to the space debris removal system, the reaction control system will be used to change the altitude and speed according to the International Space Station, where this system will be captured using the robotic arm and after removing the attached debris to the system. This system can be reused to remove more space debris.

4. ADVANTAGES OVER OTHER SYSTEMS

This space debris removal system using cold welding is of great help in removing small space debris particles as compared to other space debris removal systems in the following ways:

- The contactless space debris removal systems, such as artificial atmosphere, are based on increasing the drag on the space debris particles thus, reducing their speeds and deorbiting them. However, when the space debris particles are small, the resistance from the atmospheric drag is very small, thus, it will take very long time to deorbit these particles. By using the space debris removal system based on cold welding we can remove the small space debris particles in very less time.
- In contact capturing methods, the use of tentacles to capture the satellites are proposed, but it is extremely difficult to capture a small space debris particle using a robotic arm. However, we can capture the smallest space debris particle using the proposed space debris removal system.

5. CONCLUSIONS

The space debris removal system based on cold welding can be used to remove small particles of space debris several times until the systems material completes a desired number of cycles which is calculated taking into account the factor of safety. Further, as compared to the contactless space debris removal techniques such as artificial atmosphere and ion beam shepherd, our system is better because the contactless debris removal takes a much longer time and concentrates on a small amount of space debris particles.

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