International Journal of Scientific Research in Science, Engineering and Technology

Print ISSN - 2395-1990
Online ISSN : 2394-4099

Available Online at : www.ijsrset.com
doi : https://doi.org/10.32628/IJSRSET23103217

Canister Satellite Light Weight Chassis Design using Bio Mimicry of Human Skeleton

Subham Pradhan, Satyam Kumar, Shubham Srivastav

Kalpana Chawla Centre for Research in Space Science and Technology, Chandigarh University, Chandigarh, India

ARTICLEINFO

Article History :

Accepted: 01 Sep 2023
Published: 05 Sep 2023

Publication Issue :
Volume 10, Issue 5
September-October-2023

Page Number :
01-09

ABSTRACT

The design of Canister Satellite (CanSat) chassis plays a crucial role in ensuring the structural integrity, stability, and functionality of the payload during its mission. This research paper proposes a novel approach to CanSat chassis design by drawing inspiration from the biomechanical characteristics of the human skeleton. By mimicking the efficient load distribution, flexibility, and durability observed in the human skeletal system, this bio-inspired design aims to enhance the performance and survivability of CanSats. The paper presents a detailed analysis of the human skeletal system, discusses the fundamental principles of bio mimicry, and outlines the application of these principles to CanSat chassis design. Finite Element Analysis (FEA) and prototyping are utilized to validate the effectiveness of the proposed bio-inspired chassis design. The results demonstrate the potential benefits of integrating bio mimicry into aerospace engineering, fostering innovation in satellite technologies.

Keywords : Chassis, Cansat, Structure, Body, Generative Design, Lightweight, Bio Mimicry.

I. INTRODUCTION

The following paper presents an innovative approach to the design of lightweight chassis for CanSat applications. CanSat is a type of microsatellite that is designed to be launched into the Earth's atmosphere and perform various missions, such as data collection and communication. The design of a CanSat's chassis is crucial as it impacts the overall performance and stability of the satellite during launch and its mission. In this paper, we propose a generative design-based approach to the development of a lightweight chassis for CanSat applications. Generative design is a design optimization method that uses algorithms and artificial intelligence to explore a wide range of design solutions and find the best one based on specific design criteria. This approach allows us to generate multiple design options that meet specific requirements, such as weight and strength, and choose the best one. We use computer-aided design (CAD) software and simulation tools to evaluate the performance of the generated designs and refine them based on the results. The final design is then manufactured using 3D printing technology, which allows for fast and cost-effective production of the chassis. The results of this study demonstrate the potential of generative design as a tool for the development of lightweight and robust CanSat chassis. The proposed design method can be used as a basis for further research in the field of microsatellite design and development.

Paper is organized as follows. Section II describes the design and ideation process involved in the making of CanSat chassis. This section also includes supporting CAD drawings and application of Bio Mimicry. The methodology and the production process of the design are given in Section III. Section IV presents various environmental tests that were used to validate the functional strength of the produced design according to the mission requirements. Finally, Section V includes the conclusion of the Research Paper.

II. DESIGN AND IDEATION

A. Conceptualization With Preliminary Analysis

Every CanSat mission is always bound with certain constraints. Mechanically those constraints can be geometrical as well as volumetric. The CanSat is always built keeping in consideration the dimensions of Launch Vehicle, the rocket airframe. The dimensions of the CanSat as set by guidelines are a maximum height of 400 mm and a diameter of 125 mm. With that in consideration, the initial design was proposed with basic vertical placed components to obtain container telemetry. All the specified systems including parachute ejection system, Sensor Subsystems, Power systems, Payload Release Mechanism should fit into the “Can” enclosure as shown in Fig.1.

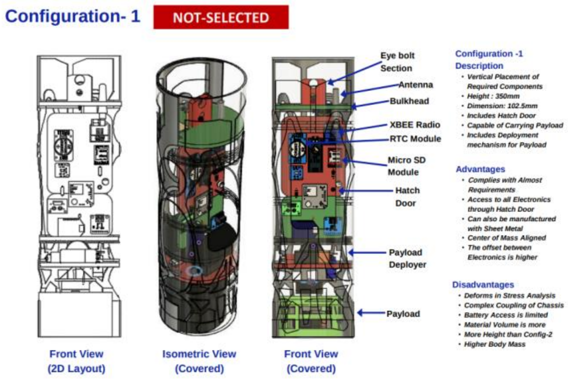

Fig. 1. Concept 1 with Vertical Placement of Components

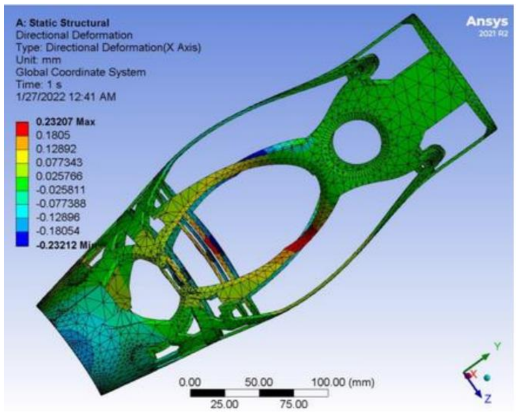

Fig. 2. Deformation of Concept 1 while Thermal Stress Analysis under 500N of Force

The key benefit of this Concept in Fig.1 is that the center of mass is aligned and the space between circuits is small. However, the major drawback with this design is due to the stress analysis of this design. It did not survive the basic requirements while testing under conditions. The structure deformed under 500 N of force. The structure is expected to not only withstand the force but also to maintain its form, so that the components mounted on it are completely safe and functioning even under forces and accelerations caused due to Rocket launches. Fig.2 shows the simulation results of thermal stress analysis of Configuration-1 using Ansys software.

Thus, considering the results of the vertically positioned structure, the second ideation was developed where the components were placed horizontally, which helped to save a lot of volume and hence the height of the structure was also reduced.

And due to less volume occupancy, the weight of the structure was significantly reduced. Fig.3 demonstrates the Configuration-2.

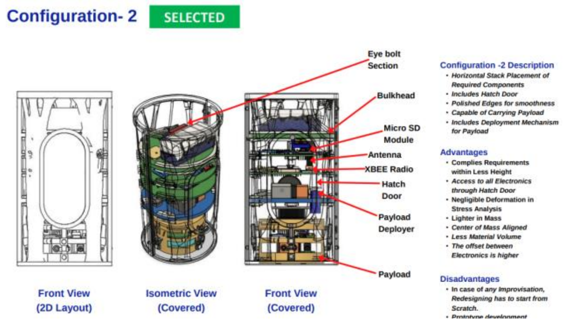

Fig. 3. Concept-2 with Horizontal Placement of Components

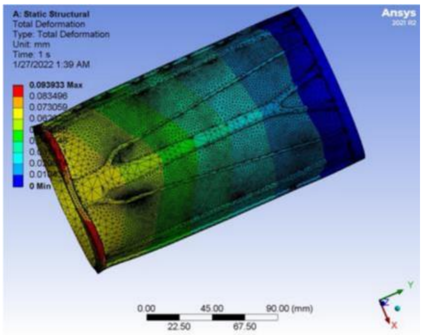

Fig. 4. Behaviour of Concept 2 under Thermal Stress of 500N Force

Configuration-2 performed well under stress analysis in Ansys Simulation software. Fig. 4 demonstrates the stable behavior of Concept-2 under 500N Stress in Z axis, still minor deformations can be seen in the bottom part but it doesn't matter as all the components are mounted on the upper part of the structure.

B. **Computer Aided Design (CAD) Drawings**

The ideation of design can be in one's mind but bringing that to reality may be bit difficult for a freshman. Thus sketching would help you get a rough idea in both 2D and 3D to visualize your concepts. These rough sketches will not only help you visualize but also improvise designs while you go through repeated brainstorming sessions with your team mates. After enough discussions and improvisations, the designs are sketched using CAD software. Now, the dimensions are exact and precise, however one can alter dimensions easily but just for better practice it is worthwhile to have the dimensions pre-defined. The CAD drawings of our design are showed in Fig. 5.

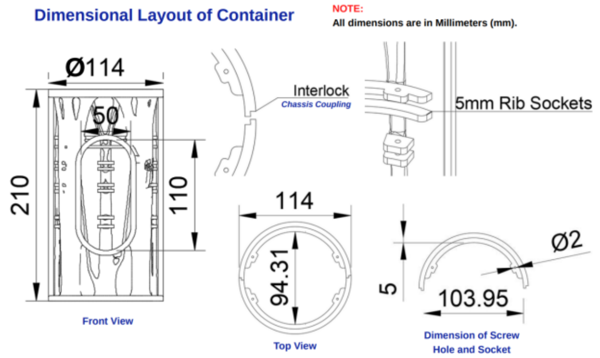

Fig. 5 (a)

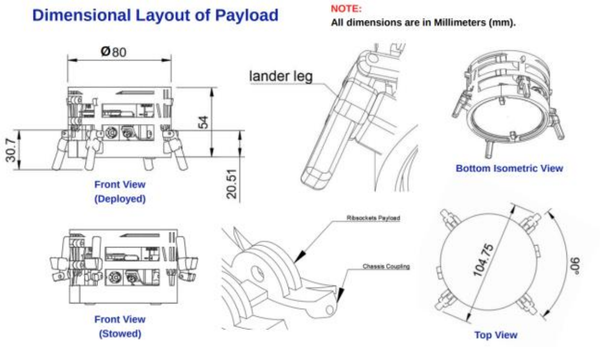

Fig. 5 (b)

Fig. 5. (a) CAD Drawings of CanSat Chassis (b) CAD Drawings of a Scientific Payload which was stowed inside the chassis

C. **CAD Software Selection**

The correct CAD software should be chosen just as carefully as the ideal design. There are many CAD programs in the market, but each one has benefits and drawbacks of its own. For our design needs, we went with Fusion 360. Fusion 360 was chosen because of its cloud compatibility and user-friendly interface. Speaking about cloud capabilities, it's crucial to store your work in cloud because, despite years of advancement, the systems and technology we use could still breakdown due to any hardware malfunction, costing us months of labor and better design.

Fig. 6. Fusion 360's Cloud based Team work named Fusion Team

The Fusion Team facility made it very simple to share resources, designs, and provide team support. As a result, we were able to finish our ideas ahead of schedule even though we were working from home.

D. Generative Design

In every aerospace mission, the projects are always expected to be as much as lightweight as possible but also with reliable structure integrity. But in CanSat design there are so many subsystems and electronics components that could be require a strong and sturdy structure, but this sturdy structure may be heavy and may even exceed the mass budget and hence making the design fail the Flight Readiness and hence disqualifying from getting loaded into the Rocket for a flight Mission.

This situation demanded a technique which would not only use least material but also keep consistent structure strength. Thus the Generative Design Process is selected to design the CanSat Structure.

As shown in Fig. 7, Generative Design is a process of continuous iteration of generating designs under some specific parameters taking in consideration a pre-defined geometry provided by the designer. It uses a sequence of program set to refer the attachment points, the load exerted on the joints and the direction in which the load vector works. These references are entered by user and are called as Load Cases. In every load case, the user can define the forces working on the joints and attachment points.

Fig. 7. Generative Design Example from Siemens PLM

The program then considers the load cases and generates designs according to the different cases of force exertions defined by the user and also preserves the selected geometry as shown in Fig. 7. It keeps on regenerating designs in iterations until maximum materials have been reduced and required forces are distributed according to the design. And hence makes the design lightweight and maintaining the strength.

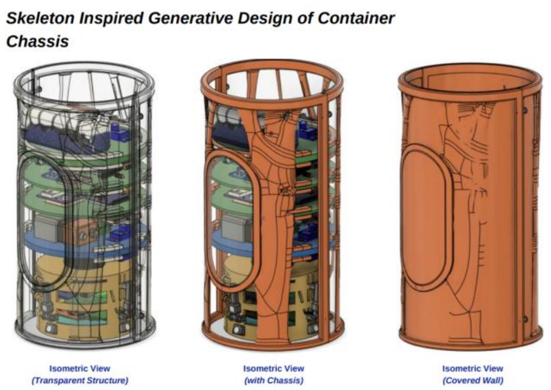

Fig. 8. Generative Design applied to our Cansat Structure

E. Bio-Mimicry

The Nature has always inspired the mankind to design and build things for the betterment of its own race. In every cansat project the conventional way to give a structural integrity to the electronic subsystems is by adding standoffs between the PCBs (Printed Circuit Boards). But the Standoffs themselves add a lot of weight to the Cansat structure and also occupy unnecessary space. An example is shown in Fig. 9.

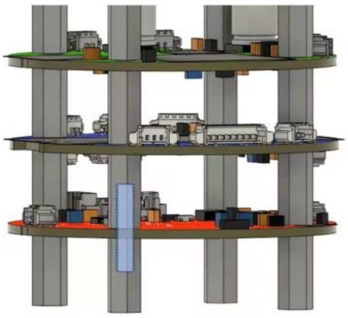

Fig. 9. Standoffs used in Conventional CanSat Stacking

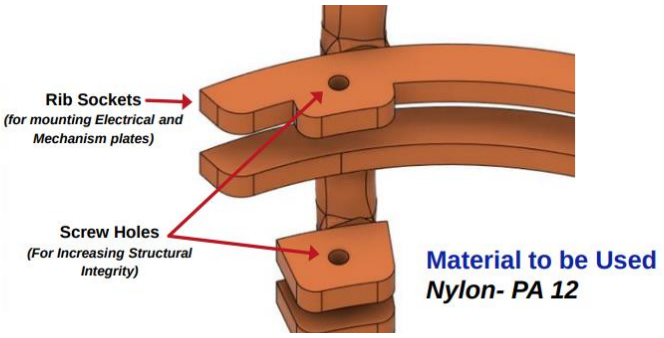

Fig. 10. Rib Sockets stacking inspired from Ribcages of Skeleton

To eradicate this conventional support system and include something that would acquire less space with minimal weight, inspiration from the Ribcages of the Human Skeleton system was utilized to add support structures. Hence the standoffs were replaced with sturdy and lightweight Rib sockets as shown in Fig. 10.

III. PRODUCTION METHODOLOGY

F. Technique

Production technique is always dependent on a lot of factors including the design, the quantity and the finish quality. Even in CanSat mission the cost factor could be limited and thus choosing a right production technique becomes a vital point of discussion. The two types of Production process which were utilized are:

- **FDM (Fused Deposition Modeling)** is a popular and widely used technique where a 3D Printer can move in all three axis consisting of a heated nozzle that could intake Material Filaments, melt them and deposit one layer over another making a model.
- **MJF (Multi Jet Fusion)** is an industrial standard system where powdered material could be used to fuse into different layers giving shape to the design. The technique uses powerful Lasers to fuse powdered material at high temperatures.

Though both techniques are part of Additive Manufacturing, both vary in factor of costing and time to build. MJF has high resolution printing and the density is really low, making the designs lightweight but is very expensive. In Fig. 11 it is shown that, FDM 3D printing was chosen as it is cost-effective and helps to go through a lot of iterations of prints to adjust the tolerances between the designs so that they fit properly with each other.

Fig. 11. First Prototype of 3D printed Cansat Chassis

G. Material

As the CanSat needs to withstand a minimum temperature of at least 60 degree Celsius and will be at an apogee of around 700 meters from ground reference, an analysis of choosing the material for the CanSat chassis was made based on availability and compatibility with the 3D printer.

There were wide varieties available like TPU, PETG, ABS but ABS, PLA+ was chosen as primary consideration due to their acceptable densities. But after several test run it was found that ABS required a lot of temperature constraints and was not user-friendly as that of PLA+. Thus, it was decided to use PLA+ (PolyLactic Acid), since it was quite less demanding with environment requirements as well as cost-effective and widely available, both online and offline. We included “eSun” branded PLA+ Filaments.

Fig. 12. PLA+ Filament from eSun

H. **Importance of Slicing in 3D Printing**

Slicing is a process of converting (.stl) file into a (.gcode) file in which the whole design is sliced into layers which 3D printer would use as an instruction set to apply the FDM process. The 3D printing process is a layer-by-layer process. If the design is having lots of joints and attachment points, the angle of slicing must be taken care of. It is mostly done that the slicing axis should always be perpendicular or different than the axis of joint. Otherwise, when force is exerted on the joint it would have high chances of breaking away easily.

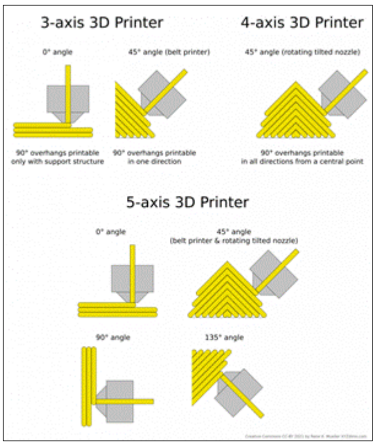

Fig. 13 (a)

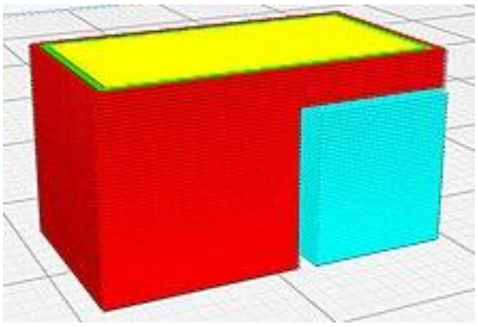

Fig. 13 (b)

Fig. 13. (a) Different Angle of Slicing and 3D Printing axis (b) Support structure (in blue) generated by Cura software

You can see different types of slicing and 3D printing in Fig. 13(a). Slicing also takes care of other aspects of printing, Support structures are one of them. Suppose there is a free structure that had no support structure from bottom, it would be hard to print it on air and form a solid bond. Thus Temporary support structures are printed along with the Main design as shown in Fig. 13(b) and after the print is complete, the support structure is removed.

Another attribute of Slicing is Infill. Infill handles the volumetric concentrations of the 3D print as shown in Fig. 14. It can be inferred that higher the infill, higher the density and hence higher the mass of the print, and lower infill means hollow structures. Lower Infill creates corrugated structures inside the Object to keep it strong while slicing.

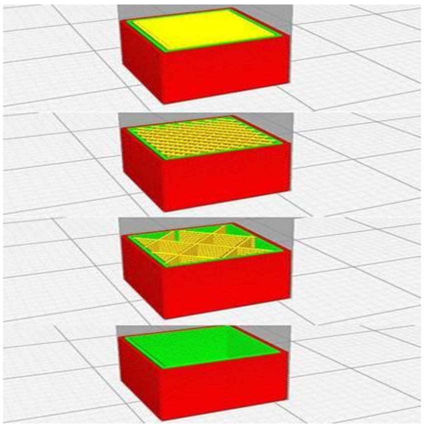

Fig. 14. Different densities of infill (in yellow), as generated by Cura slicer, from solid to hollow (up to down)

IV. ENVIRONMENTAL TESTS

I. Thermal Test

The structure must perform well under temperature pressure conditions, and thus required to be tested under controlled temperature condition. The goal of the test is to ensure that no materials fail to perform, weaken, change their properties, or deform at temperatures up to 60 degrees Celsius. The CanSat would be warmed at exactly 60 degrees Celsius. Once the temperature reaches 60 degrees Celsius, the telemetry will be reviewed. Because of the metallic wall barrier in the oven, the temperature will be maintained for two hours while telemetry is analyzed using onboard data storage. Following the test, systems and structures were evaluated to certify that the CanSat withstood the whole temperature exposure and can function.

Fig. 15 (a)

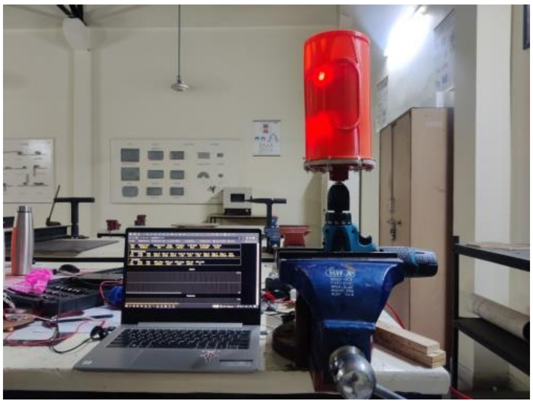

Fig. 15 (b)

Fig. 15. (a) CanSat Structure inside oven at 60 degree Celsius (b) Vibration Test Fixture

J. Vibration Test

This test verifies the structural integrity of each component as well as the battery connections, mounting connections, and mounting integrity. We utilized a drill machine with a rotation speed equivalent to a table sander and a flat head that moved vibrantly as the test fixture. The drill machine repeatedly vibrated the CanSat for a minute. A base plate secures the drill machine upside-down to the bench vise, and CanSat is fixed where the sandpaper is fitted.

We turned on the Cansat and made sure MQTT is configured to collect accelerometer data. We securely clamped the drill machine in the bench vise. We fastened the cansat using a base plate with holes and zip ties. The drill machine

pauses 5 seconds after reaching its maximum speed. The steps should be repeated at least three - four times more. We examined the CanSat for signs of damage, functioning and power loss but all such parameters were still working. We checked if accelerometer data is still being captured. Thus the structure passed the Vibration Test.

K. Drop Test

We built a drop test fixture out of CPVC pipes to test the release mechanism and to make sure it can hold the electronics subsystems in the container structure. One end of the cord was fastened to the horizontal bar of the frame with adequate length for the drop test to occur and open space to prevent CanSat from striking the ground. The other end of the cord was connected to the parachute of the CanSat.

A substantial amount of foam was positioned underneath for the drop test in case the cord fails and falls off. We checked to see if we are receiving telemetry. We raised the satellite using the cord till the attachment point where it was attached to the horizontal frame and the parachute is at the highest height or equal height to the bar. One member from the team sets the Cansat free when said to do so. The Cansat drops and then we check to make sure whether the Cansat lost power or gained any structural damage. We even checked for pieces if they were missing. We checked if the CanSat was still transmitting Telemetry. All such parameters were functional, and there were no structural damage to the attachment points of the CanSat, thus it passed the Drop Test.

Fig. 16 (a)

Fig. 16 (b)

Fig. 16 (c)

Fig. 16. (a) CanSat structure raised to the height of attachment (b) CanSat structure released manually (c) CanSat survives the Drop test

V. CONCLUSION

The integration of bio mimicry principles from the human skeletal system into CanSat chassis design presents a promising avenue for enhancing structural integrity, stability, and payload protection. This research opens the door to innovative solutions in aerospace engineering, demonstrating the potential of nature-inspired design approaches. The above approach was used by Team Agnee in USA Cansat 2022 to develop their Cansat Main structure. The technique helped to develop a lightweight and sturdy chassis. Thus we conclude the mentioned technique and approach would be an acceptable and worthy approach in designing CanSat Light Weight Chassis using Generative Designing. In conclusion, this paper presents a new and effective approach to the design of lightweight CanSat chassis, which combines the advantages of generative design, computer-aided design, and 3D printing technology. We believe that this approach has the potential to revolutionize the design and production of microsatellites, making them more efficient, cost-effective, and reliable.

VI. REFERENCES

[1]. S. Gulgonul, E. Koklukaya, I. Erturk, and A. Y. Tesneli, "Communication Satellite Payload Redundancy Reconfiguration," 2012.

[2]. M. Gokten, A. F. Yagli, L. Kuzu, E. Yanikgonul Veli and Sanli, and S. Gulgonul, "Preliminary Design of TUSAT Satellite Communication Payload," 2012.

[3]. E. Sharifi-Moghadam and A. Ahmadi, "Optimizing Number of Spots and Cluster Size of a High-Throughput Communication Satellite Payload," International Journal Of Satellite Communications and Networking, Vol. 39, No. 6, Pp. 661–685, 2021, Doi: 10.1002/Sat.1414.

[4]. J. Zu, T. Wang, and Y. Wu, "Integrated Design of Platform and Payload for Remote Sensing Satellite," in 5th International Symposium Of Space Optical Instruments and Applications, 2020, vol. 232, pp. 81–89. doi: 10.1007/978-3-030-27300-2_8.

[5]. Y. Yao, “Analysis of Platform and Payload Integrated Design Technology for Optical Remote Sensing Satellites,” in 3rd International Symposium of Space Optical Instruments and Applications, 2017, vol. 192, pp. 9–22. doi: 10.1007/978-3-319-49184-4_2.

[6]. W. S. Hee, SuHee, “Very Small Satellite Program for Expending the Space Technology Base: CanSat Competition,” vol. 40, no. 7, pp. 636–645, 2012.

[7]. M. E. Aydemir, R. C. Dursun, and M. Pehlevan, “Ground Station Design Procedures for Cansat,” In Proceedings of 6th International Conference on Recent Advances in Space Technologies (RAST 2013), 2013, pp. 909–912.

Cite this article as :

Subham Pradhan, Satyam Kumar, Shubham Srivastav, "Canister Satellite Light Weight Chassis Design using Bio Mimicry of Human Skeleton", International Journal of Scientific Research in Science, Engineering and Technology (IJSRSET), Online ISSN : 2394-4099, Print ISSN : 2395-1990, Volume 10 Issue 5, pp. 01-09, September-October 2023. Available at doi : https://doi.org/10.32628/IJSRSET23103217
Journal URL : https://ijsrset.com/IJSRSET23103217