

Design and Analysis of Bio-Enhancing Boots

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Abstract - Bio Enhancement Boots are the most futuristic concept for improving human capabilities. Inspired from the fastest non flying bird "Ostrich", which can run to the speed of 45 mph. They can store elastic energy in the Tendons and release of this elastic energy generates 83% more power than in humans. We decided to make similar replica for the Human Beings which will store and release elastic energy similar as 'Ostriches'. The Bio Enhancement Boots could increase the running speed of humans to 40kmph. These also help in running off-road or climbing hills with greater agility.

Bio Enhancing Boots comes with high strength rubber springs which can store high amount of elastic energy and releases it for high speed. Design will be strong, durable and maintenance free. Bio Enhancement Boots will be easy to mount and dismount and can be easily used for short or medium distances. This will reduce the use of fossil fuels, and also make human beings more active.

As per future scope is concerned, this boots can be used in Human Enhancement, Robotic, Army and Futuristic sport applications.

Keywords — Bio Enhancement Boots, Ostrich, elastic energy, strong, durable, future scope.

1. INTRODUCTION

The Bio Enhancement Boots let you run as fast as a car. Spring shoes mimic ostrich's gait to let you travel at up to 25 miles per Hour. Shoes have springs on the back that imitate Achilles tendon of an ostrich. The spring provides the wearer with more down force when running with their wide, springy gait. Ostriches can reach speeds of 40 mph (70 km/hr), covering up to 16 ft (5 meters) in a single stride.

We have been working on the boots for several months and have already provided Dozens of prototypes. Last 15 Days we took our Bio Enhancement Boots to demonstrate its capabilities. In its current form, the device can reach speeds of up to 25 mph (40 km/hr) – or the same speed as a slow-moving car.

Featuring a spring-loaded sole, it helps people recover from sport injuries by taking away the impact of running on their joints.

1.1 Problem Statement:

To design and fabricate an attachment for enhancing the range and abilities of operator for faster running, climbing and jumping with less effort so as to facilitate longer and safer travel between large distances. To also provide a mechanism for amputees for greater mobility and self-reliance.

1.2 Objectives:

1. To enhance the human capability for greater reach and improved performance.
2. To reduce dependence on fossil fuels and promote exercise in fellow humans.
3. To introduce a new mode of transportation between destinations.
4. To take a step in new direction of bio-mechanical engineering to facilitate completion of bio-suits for future adventures.

1.3 Scope:

We see a vision of a prototype, encompassing a full-powered protective suit with onboard readouts of speed, distance, system power outputs, and more. It's our Bionic concept that could be revolutionary for the society in terms of mobility, safety, range and efficiency.

1.4 Methodology:

- Step 1: Basic Design
- Step 2: Materials Selection
- Step 3: Virtual Analysis
- Step 4: Manufacturing
- Step 5: Testing
- Step 6: Validation of Results

2. MATERIAL SURVEY:

Traditional model building materials have always catered for Design of lightweight nature whilst providing acceptable levels of strengths. Bio Enhancement Boots always be susceptible to damage from crashes and maneuvering or cyclic stresses because they can operate at considerable speeds. Hence, the materials to be used

need to have certain specifications which can cater to the conditions on the field such as,

Materials used for Bio Enhancement Boots are:-

1. Fibre Reinforced Plastic:

Fibre-reinforced plastic is a composite material made of a polymer matrix reinforced with fibres. The fibres are usually glass, carbon, aramid, or basalt. Rarely, other fibres such as paper, wood, or asbestos have been used. The polymer is usually an epoxy, vinyl ester, or polyester thermosetting plastic, though phenol formaldehyde resins are still in use.

Reason to choose...

FRP allows the alignment of the glass fibres of thermoplastics to suit specific design programs. Specifying the orientation of reinforcing fibres can increase the strength and resistance to deformation of the polymer. Glass reinforced polymers are strongest and most resistive to deforming forces when the polymers fibres are parallel to the force being exerted, and are weakest when the fibres are perpendicular. Thus this ability is at once both an advantage or a limitation depending on the context of use. Weak spots of perpendicular fibres can be used for natural hinges and connections, but can also lead to material failure when production processes fail to properly orient the fibres parallel to expected forces. When forces are exerted perpendicular to the orientation of fibres the strength and elasticity of the polymer is less than the matrix alone. In cast resin components made of glass reinforced polymers such as UP and EP, the orientation of fibres can be oriented in two-dimensional and three-dimensional weaves. This means that when forces are possibly perpendicular to one orientation, they are parallel to another orientation; this eliminates the potential for weak spots in the polymer.[3.1]

2. Aircraft Grade Aluminum (Al-6082T6):

6082T6 aluminium alloy is an alloy in the wrought aluminium-magnesium-silicon family (6000 or 6xxx series). It is one of the more popular alloys in its series (alongside alloys 6005, 6061, and 6063), although it is not strongly featured in ASTM (North American) standards. It is typically formed by extrusion and rolling, but as a wrought alloy it is not used in casting. It can also be forged and clad, but that is not common practice with this alloy. It cannot be work hardened, but is commonly heat treated to produce tempers with a higher strength but lower ductility.

Chemical Composition:

The alloy composition of 6082t6 aluminium is:
 Aluminium: 95.2 to 98.3%
 Chromium: 0.25% max
 Copper: 0.1% max

Iron: 0.5% max
 Magnesium: 0.6 to 1.2%
 Manganese: 0.4% to 1.0%
 Silicon: 0.7 to 1.3%
 Titanium: 0.1% max
 Zinc: 0.2% max
 Residuals: 0.15% max

Mechanical Properties:

Table 1 Mechanical Properties of Aluminum 6082T6

Density	2.71 g/cm ³
Young's Modulus	71 GPa
Ultimate Tensile Strength	140 to 330 MPa
Yield Strength	90 to 280 MPa
Thermal Expansion (α)	23.1 $\mu\text{m/m-K}$

3. Extension Spring:

A spring is an elastic object used to store mechanical energy. Springs are usually made out of spring steel. There are a large number of spring designs; in everyday usage the term often refers to coil springs.



Fig. 1. Tension Spring

A coil spring may also be used as a torsion spring: in this case the spring as a whole is subjected to torsion about its helical axis. The material of the spring is thereby subjected to a bending moment, either reducing or increasing the helical radius. In this mode, it is the Young's Modulus of the material that determines the spring characteristics.

Metal coil springs are made by winding a wire around a shaped former - a cylinder is used to form cylindrical coil springs

4. Mild Steel:

Mild steel (steel containing a small percentage of carbon, strong and tough but not readily tempered), also known as plain-carbon steel and Low carbon steel. It is now the most common form of steel because its price is relatively low while it provides material properties that are acceptable for many applications. Mild steel contains approximately 0.05–0.25% carbon making it malleable and ductile. Mild steel has a relatively low tensile strength, but it is cheap and easy to form; surface hardness can be increased through carburizing.

It is often used when large quantities of steel are needed, for example as structural steel. The density of mild steel is approximately 7.85 g/cm³ (7850 kg/m³ or 0.284 lb/in³) and the Young's modulus is 200 GPa (29,000,000 psi).[1.3]

We got the information about the Bio Enhancement Boots from above sites. We have studied research methodology, methods and techniques by Kothari C.R. new age international limited publishers, second edition ,CH3 page no.37-39, methods of data collection CH6 page no. 117-150.

The research phase formed a vital role that was pivotal in progressive in the project into the design phase. Understanding the fundamentals of Bio Enhancement Boots as well as key aspects of components that were specified as being relevant meant that conceptual designs could be sketched and the components of interest could be sourced. After the information from the research phase had been considered it was decided that simplest components and design aspects would be incorporated into the Bio Enhancement Boots to conformed to the project title were the emphasis was on a 'BIO-ENHANCING BOOTS'.

3. CAD DRAFTING:

1. Fiber Reinforcement Plastic Moulds:

The simplest molding process, hand lay-up is used in low-volume production of large products, e.g., wind turbine components, concrete forms and radomes. A pigmented gel coat is sprayed onto the mold for a high-quality surface. When the gel coat has cured, glass reinforcing mat and/or woven roving is placed in the mold, and the catalyzed resin is poured, brushed or sprayed on. Manual rolling then removes entrapped air, compacts the composite, and thoroughly wets the reinforcement with the resin. Additional layers of mat or woven roving and resin are added for thickness. A catalyst or accelerator initiates curing in the resin systems, which hardens the composite without external heat.

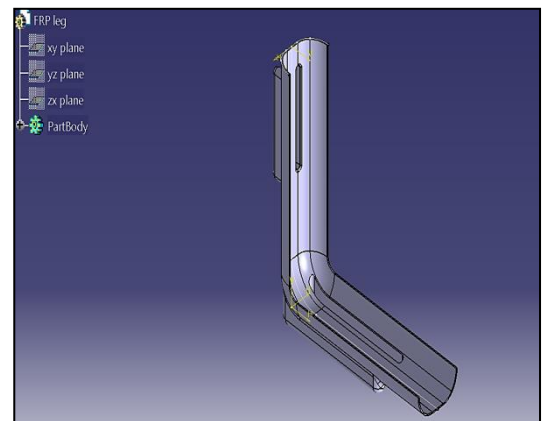


Fig. 2. FRP molds

The simplest molding process, hand lay-up is used in low-volume production of large products, e.g., wind turbine components, concrete forms and radomes. A pigmented gel coat is sprayed onto the mold for a high-quality surface. When the gel coat has cured, glass reinforcing mat and/or woven roving is placed in the mold, and the catalyzed resin is poured, brushed or sprayed on. Manual rolling then removes entrapped air, compacts the composite, and thoroughly wets the reinforcement with the resin. Additional layers of mat or woven roving and resin are added for thickness. A catalyst or accelerator initiates curing in the resin systems, which hardens the composite without external heat.

Similar to hand lay-up, spray-up offers greater shape complexity and faster production. Spray-up utilizes a low-cost open mold, room temperature curing resin, and is ideal for producing large parts such as tub/shower units and vent hoods in low to moderate quantities. Chopped fiber reinforcement and catalyzed resin are deposited in the mold from a chopper/spray gun.

As with lay-up, manual rolling removes entrapped air and wets the fiber reinforcement. Woven roving is often added in specific areas for thickness or greater strength. Pigmented gel coats can be used to produce a smooth, colorful surface.

2. Strut Member:

It is a bar of Aircraft Grade Aluminum with dimensions to reduce weight of bar, without affecting its strength, circular shape slots are drilled. This member is placed in between the springs and tyre rubber foot. Strut is pivoted to the Sole base clamping plates using bush and pin arrangement. There is another pivoting at the bottom for clamping the rubber foot base. Since Strut member carries the whole weight of human body, to analyse its strength, FEA analysis is performed for confirming its dimensions.

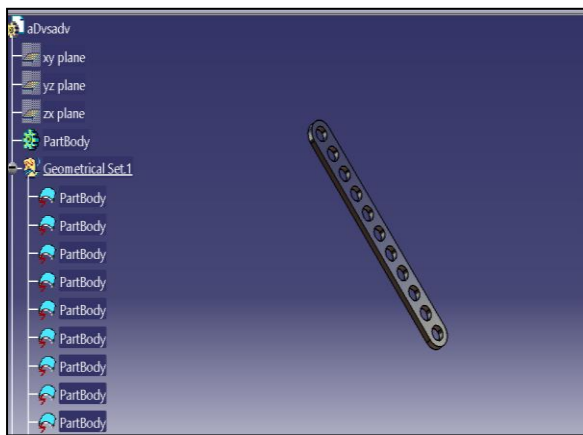


Fig. Strut Member

Strut members are machined through Laser Cutting technique. It is a technology that uses a laser to cut materials, and is typically used for industrial manufacturing applications, but is also starting to be used by schools, small businesses, and hobbyists. Laser cutting works by directing the output of a high-power laser most commonly through optics. The laser optics and CNC (computer numerical control) are used to direct the material or the laser beam generated. A typical commercial laser for cutting materials would involve a motion control system to follow a CNC or G-code of the pattern to be cut onto the material. The focused laser beam is directed at the material, which then either melts, burns, vaporizes away, or is blown away by a jet of gas, leaving an edge with a high-quality surface finish. Industrial laser cutters are used to cut flat-sheet material as well as structural and piping materials.[1.4]

3. Bushing:

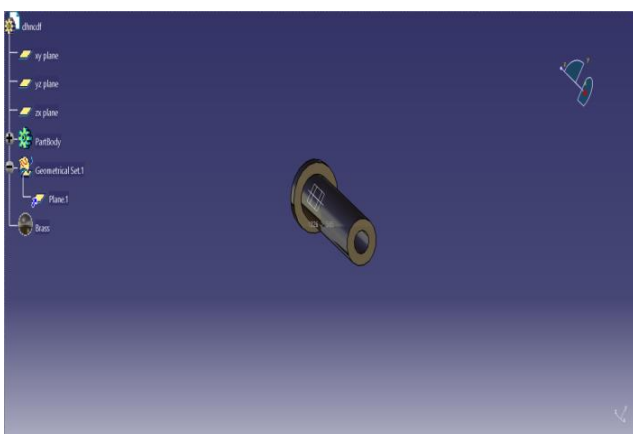


Fig. 1 Bushing

A bushing, also known as a bush, is an independent plain bearing that is inserted into a housing to provide a bearing surface for rotary applications; this is the most common form of a plain bearing. Common designs include solid (sleeve and flanged), split,

and clenched bushings. A sleeve, split, or clenched bushing is only a "sleeve" of material with an inner diameter (ID), outer diameter (OD), and length. The difference between the three types is that a solid sleeved bushing is solid all the way around, a split bushing has a cut along its length, and a clenched bearing is similar to a split bushing but with a clench (or clinch) across the cut. A flanged bushing is a sleeve bushing with a flange at one end extending radially outward from the OD. The flange is used to positively locate the bushing when it is installed or to provide a thrust bearing surface.

Sleeve bearings of inch dimensions are almost exclusively dimensioned using the SAE numbering system. The numbering system uses the format -XXYY-ZZ, where XX is the ID in sixteenths of an inch, YY is the OD in sixteenths of an inch, and ZZ is the length in eighths of an inch.[10] Metric sizes also exist.

A linear bushing is not usually pressed into housing, but rather secured with a radial feature. Two such examples include two retaining rings, or a ring that is molded onto the OD of the bushing that matches with a groove in the housing. This is usually a more durable way to retain the bushing, because the forces acting on the bushing could press it out.

Plain bearings must be made from a material that is durable, low friction, low wear to the bearing and shaft, resistant to elevated temperatures, and corrosion resistant. Often the bearing is made up of at least two constituents, where one is soft and the other is hard. The hard constituent supports the load while the soft constituent supports the hard constituent. In general, the harder the surfaces in contact the lower the coefficient of friction and the greater the pressure required for the two to seize.

4. Spring Mounting:

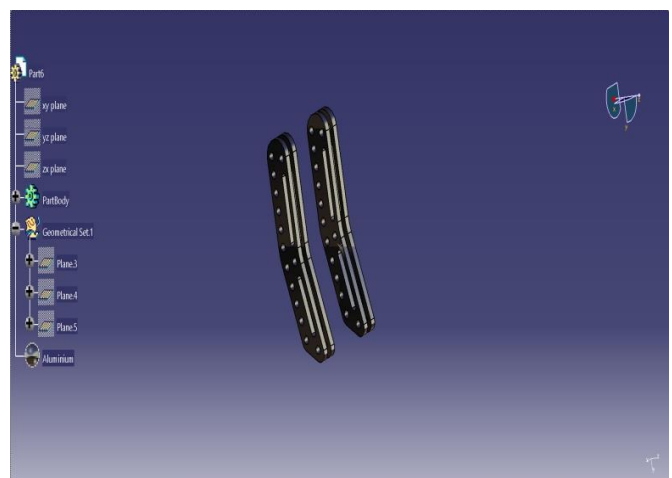


Fig. Spring Mountings

Spring clamps are mounted at the top of FRP moulds by using nut and bolt arrangement. They are made by Mild Steel plates of 3mm thickness. Spring mounts are machined by using Laser cutting technique.

5. Tyre Rubber Base:

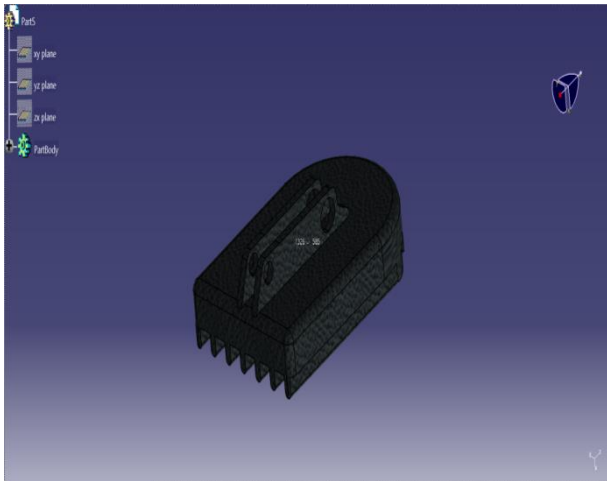


Fig. Tyre Rubber Base

6. Final Assembly:

Assembled View:

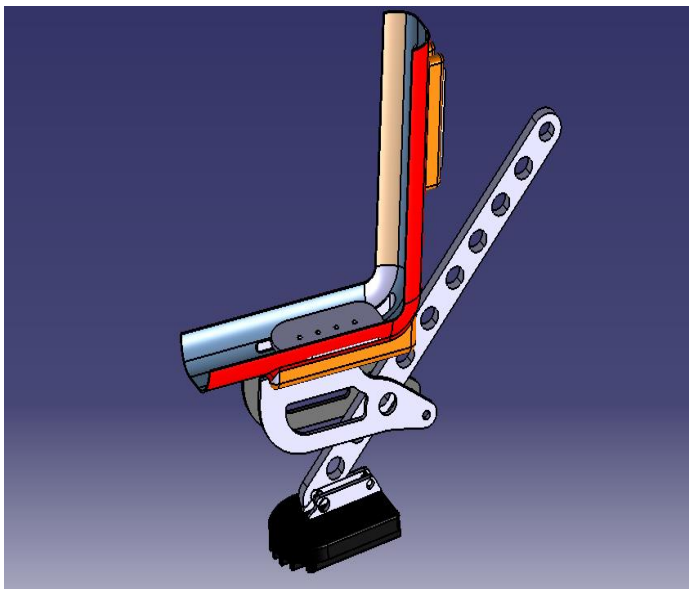


Fig. 2 Final Assembly fig.1

Exploded View:

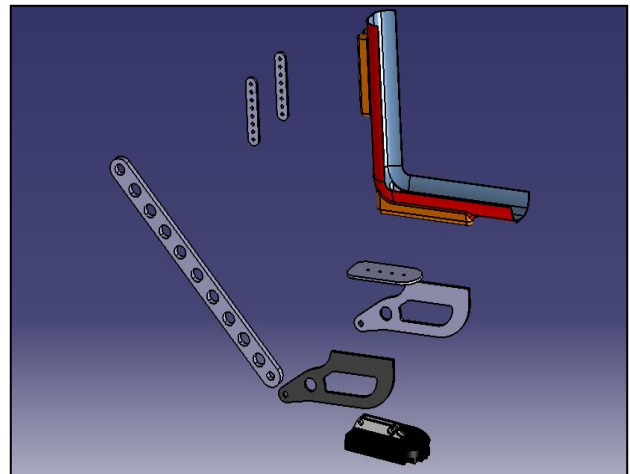


Fig. 3 Final Assembly fig.2.

4. ANALYSIS:

1. Strut Member:

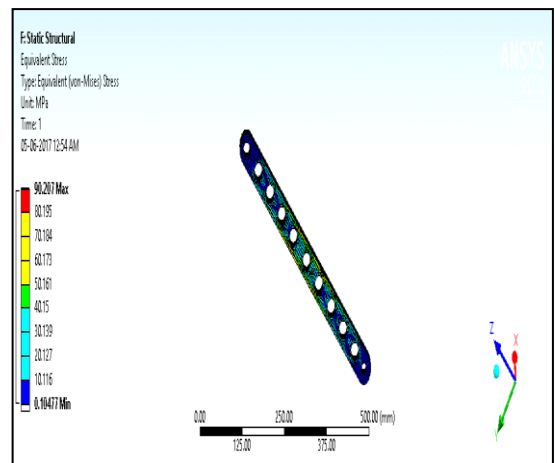


Fig. Stress analysis of Strut

2. Pivoting Assembly Plate:

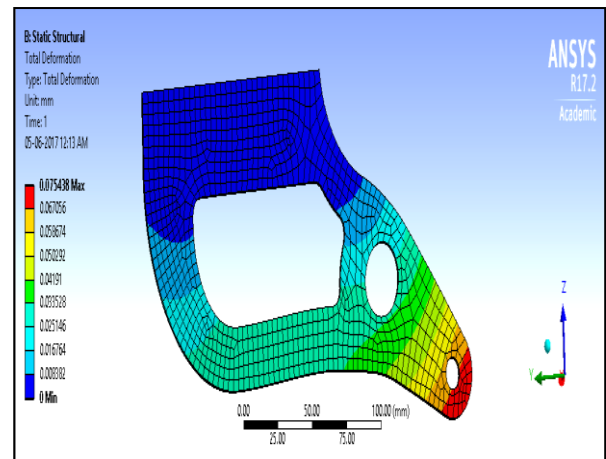


Fig. Total deformation in Pivot plate

5. CALCULATIONS:

Spring Calculations:

For springs, maximum load acting is assumed to be the average weight i.e., 100 kg and as per the requirement of functionality taking total deflection of 80mm.

$$\text{Load} = 100\text{kg} = 9810\text{N} \cong 10000\text{N}.$$

Spring Stiffness:

Number of springs = 4

Factor of Safety = 1.2

$$\text{Load carried by each spring} = \frac{10000 \times 1.2}{4} = 3000\text{N}$$

$$\text{Stiffness} = \frac{\text{Load Carried by each spring}}{\text{total deflection of spring}} =$$

$$\frac{300}{80} = 3.75 \cong 4\text{N/mm}$$

For above stiffness, selecting a standard spring with following specifications,

D= Coil diameter of springs = 14mm

d= Wire diameter of springs = 2mm.

Shear Stress:

As we know, Shear stress induced in the coil wire of spring is given by,

$$\tau = \left(\frac{8WD}{\pi d^3} \right) * \left(\frac{4c-1}{4c-4} \right) + \left(\frac{4W}{\pi d^2} \right)$$

$$\therefore \tau = \left(\frac{8 * 300 * 14}{\pi * (2)^3} \right) * \left(\frac{4 * 15 - 1}{4 * 15 - 4} \right) + \left(\frac{4 * 300}{\pi * (2)^2} \right)$$

$$= 26.567 \text{ N/mm}^2 \leq 45 \text{ N/mm}^2$$

Since the induced stress of 26.567 MPa is within the permissible limits of spring material i.e., 45 MPa. Hence, the selected spring is safe for designing application.

Minimum number of turns in coil-(n):

$$\text{Displacement} = \frac{8WD^3 * n}{Gd^4}$$

$$\therefore 80 = \frac{8 * 300 * 14^3 * n}{80 * 10^3 * 2^4}$$

$$n = 15.54 \cong 16 \text{ nos.}$$

Selecting end loops as 'double full loop over center.' Therefore, needs to add 4 extra turns)

Hence, total number of turns (n') = 70 nos.

$$\text{Minimum solid length (Ls)} = d * n = 2 * (70 + 4)$$

$$= 148 \cong 150\text{mm}.$$

Spring Specifications:

1	Coil Diameter	14mm
2	Wire Diameter	2mm
3	Spring Index	7
4	Solid Length	150mm
5	Spring Material	Spring Steel
6	Yield Strength	45 N/mm ²

Feet Pad spring dimensions:

1	Coil Diameter	12mm
2	Wire Diameter	1.5mm
3	Spring Index	8
4	Solid Length	105mm
5	Spring Material	Spring Steel
6	Yield Strength	40 N/mm ²

6. ASSEMBLY AND MANUFACTURING:

This section includes various steps and procedure that we gone through while making the actual model of Bio Enhancement Boots.

The major task in any assembly is to design and manufacture the components in such a way that they can be assembled in the most economical way possibly with respect to time and resources. Hence, this section deals with the various steps needed to be followed to completely assemble the system for proper functional requirement:

After different parts are manufactured and placed together, the first and foremost step is to make slots in the FRP mould which can be used as an opening for sliding the pivot end into it and welding it to the base plate which hold the metal fixed with the FRP Mould.

Now the spring mount is bent into a U shape and placed in slots near the knee of the mould to be fixed with the help of bolts to hold it rigidly in place.

The strut is then placed according to virtual model and the distance obtained between spring eye and its mount is 150mm according to the actual spring ordered.

Now the spring is placed in its respective mounts to get the required motion.

The work starts on the padded member which comes in direct contact with the ground, it consists of a metal spine and rubber padding for vibration absorption and damping.

They are mount on the strut member and a spring of low stiffness in mount between them to give proper orientation to the rubber component.

All these are held together by metal bushings and Bolts of SAE Grade 8.8, which have high load carrying capacity to ensure long life.

The assembly is held in place with the help of Nylon Locknuts which provide positive locking to the threaded members which prevents it from loosening in any case.

Now we drill some rectangular slots in the top and bottom section of the FRP mould so that the leg can be held in place properly with respect to the model with the help of strappings.

After completion of the assembly appropriate steps are taken to make it as comfortable as possible for the used by adding rubber padding and bushes as needed for a more ergonomic feel. The model is also painted to increase the overall aesthetics of the assembly as per the requirement of the end user.

7. VALIDATION OF RESULTS:

Hence, by virtual and theoretical modelling we have successfully designed a component which should increase the speed and agility of human body by 50-60% for a fraction of the energy requirement as before.[1.2]

The results were achieved by ANSYS 17.2 Software by doing static structural analysis to obtain the corresponding deformation, Von-Misses Stress, equivalent strain, FOS, etc.

Various Components were analysed through virtual processes which were the most critical members of the whole system and would surely result in damage in the event of an extreme load. These were the Pivot End and the Strut member which is responsible for handling the complete loads acting on the system. Hence by much iteration we have concluded different materials for these two members, which are aluminium and mild steel.

The Strut was first analyzed with MS as the working material but it soon proved to be strong and heavy for the required application, hence the material selected was changed to Aluminium 6082t6 as it has excellent mechanical properties and wear resistance.

The Pivot End was selected to be of MS as it has a large amount of shear loads acting on it. This would cause it to be more rigid and provide sufficient safety to the user as a whole. This was also validated in practical testing as large forces would not allow any other material to be used in such a place.

Various analysis were carried out which gave the following results -

Name	Deformation (mm)	Stress (MPa)	Strain (mm/mm)	FOS
Strut	0.41	90.20	0.0045	2.77
Pivot End	0.075	85.02	0.0004	2.94

Table 2. Results Validation

Keeping this in mind we have manufactured the bionic boots to achieve this target to facilitate better transportation between destinations for fellow humans.

After completion of manufacturing, testing began for validation of theoretical results. This phase consisted of rigorous testing of the Boots on a test subject with a control subject without boots.

The control was the normal walking pace of humans which was taken from international standards and actual results we found out from our test subject, by taking an average of these two results we found out the control conditions for comparing the results of our self developed Bionic boots. The path travelled in both experiment is the same so that apt comparison can be made between the two.

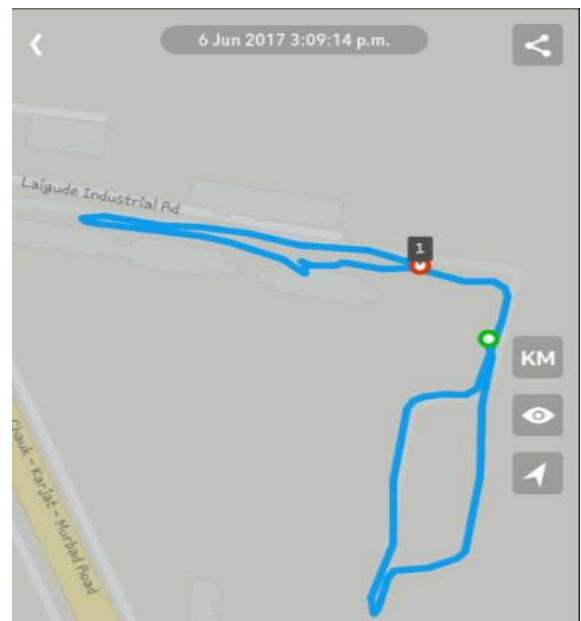


Fig. Human Running path

- [1] Now by testing in both conditions we got the following results to measure the difference in speed between different conditions-

[2] Table 3 Run Test Results

Sr. No.	Without Boots A (minutes)	With Boots B(minutes)	Improvement C=A-B	% Improvement $(C/A) \times 100\%$
Test 1	6.98	4.65	2.33	33.38
Test 2	7.33	4.11	3.22	43.92
Test 3	8.10	4.33	3.77	46.54
Average	7.47	4.36	3.10	41.28

8. FUTURE SCOPE:

There's still a lot to do, future improvements to the Bio enhancement boots to extend the distance and speed. We are planning an onboard electronic feedback control system to help coordinate the power and propulsion to give the most effective timing of power output throughout the running cadence, thus providing maximum efficiency and power expenditure. We also like to explore 3D printing, especially with titanium or carbon fiber – even a 20% weight reduction could give incredible results. Perhaps to include pneumatics like Festo's "fluidic muscle," which enabled the company's Bionic Kangaroo. It uses pneumatic pressure to contract the muscle as air is added. In nature, a kangaroo recovers energy from jumping and stores it for the next leap. In a boot, that could mean greatly increased speed and distance.

In the end, the Bio Enhancement Boots could become a whole interlinked exoskeleton built solely for speed, approaching that of an Ostrich or even a cheetah.

It's a vision of a model encompassing a full-powered protective suit with onboard readouts of speed, distance, system power outputs, and more. It's our Bionic concept that could be revolutionary for the society.

9. CONCLUSIONS

In this sequential way we designed, analyzed and studied a new conceptual model which shows great scope for future. This project educates us about various new software, manufacturing trends, metallurgy and experimental studies. Bio enhancing boots have potential to minimize time, fuel usage and become more practical in terms on mobility. We tested this model and compared with different mobility systems and results are hopeful for future improvements.

Result data is very healthy as compared to normal running, gives almost 50% of improvement in terms of distance and effort for running. Model is quite stable and

rigid for its reliable working span. It is promising for better and comfortable applications like amputees, armed forces and other future needs, by improving materials and manufacturing techniques.

10. ACKNOWLEDGEMENT

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