Role of 3D Printed Orthotic Products for making Atma Nirbhar Bharat

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ABSTRACT
Drop foot is a neuromuscular disorder that deteriorates patients' walking ability by preventing them from raising their feet during the swing. This issue causes two main problems during walking which include: unrestrained declining of the forefoot after heel strike which subsequently makes foot slap and dragging of the toes when the pretentious leg starts fluctuation. Orthotic devices are the most universal treatment for drop foot patients, in which a guarded force prevents the foot drop and foot slap during the stance and swing phases of the gait, respectively these devices are proposed to progress patients' gait guide and normalize it. An Ankle Foot Orthoses (AFO) is a mechanical device worn by drop foot patients with paretic ankle dorsiflexor muscles, to support and improve the working of the foot and ankle joint. In the existing designed gait. Solid part of ankle foot orthosis is to be divided into two halves that are the foot and the leg and the two have to be joined by using an appropriate mechanism. First designing is done using design software namely SOLIDWORKS and further analysis is done on ANSYS. Two mechanisms proposed: adjustable and hinged. Mechanisms that have their own glitches. Hence throughout the course of study both mechanisms are analyzed and the mechanisms are analyzed and after overcoming the technical glitches one of two is to be 3D printed also known as additive manufacturing. In short, these goals have defined India's additive manufacturing journey for the foreseeable future. It also aspires to embody the tenets of 'Make in India' and ***'AtmaNirbhar Bharat Abhiyan,'*** *which advocate and promote self-reliance through technological innovation and* ***transformation.***

Keywords: Ankle Foot Orthoses (AFO), Gait Analysis, 3D Printing, Neuromuscular Disorders

I INTRODUCTION

In the final remaining one and a half years, there has hushed up energy the nation over, be it makers, organizations to residents on embracing the 'Made in India' items, all gratitude to the pandemic. At the point when COVID-19 stopped our lives, the worldwide inventory network was gravely hit. India confronted an adequate number of difficulties in the acquirement of unrefined substance from unfamiliar provinces as the store network was disturbed because of the conclusion of worldwide limits. Different nations also were in a similar circumstance. This brought organizations across the horde business (in each country) to a halt. To arise more grounded from the mind-boggling circumstance, the Indian administration stressed the need of an independent India, and concentration towards Atmanirbhar Bharat. This had the ability to have a significant impact on India's outlook towards business capacities where we don't have to rely upon others. Furthermore, by following the courses, it has massive potential which can reverse the situation for us, and lift the GDP development too. Our nation has taken up the second with intensity towards this thought. In numerous enterprises, be it pharma, food, internet business, and different others, the nation has displayed in a limited capacity to focus, the "independent India" approach will be to improve the general public. However, it might come as a shock for some, native assembling which upheld independence of the nation, was pervasive since the sixties and the seventies. Perplexingly, where the pandemic had been the wellspring of an emergency, it went about as an impetus by aiding the country in returning to a lost reason, yet additionally bobbing back with a more helpful and rebuilt suggestion [1].

An Ankle Foot Orthosis (AFO) is a mechanical gadget worn by drop foot patients with paretic lower leg dorsiflexor muscles, to help and work on the working of the foot and lower leg joint. Albeit, the point of AFO is forestalling the forefoot to drop in influence by blocking the lower leg development, it likewise further develops the lower leg capacity to help body weight, gives progression and gets push-off capacity for the time of position period of strolling. A lower leg foot orthosis (AFO) is ordinarily utilized for foot drop brought about by lasting neuropathy. Ordinary assembling of AFO comprises of manual mortar projecting, trim of thermoplastic materials, and cutting them as a type of AFO, which needs sensitive capacity and much effort. Likewise, the entire course of this assembling should be rehashed assuming the AFO is obliterated or a patient's condition is changed. Three-layered (3D) printing method, otherwise called added substance fabricating, has been broadly utilized in helpful fields, and their utilization is rising violently [2]. Three-layered printers can create effectively modifiable articles with next to no fixed mouldings that make the things unmistakable. This 3D printing procedure makes it feasible for doctors and specialists to make just quiet custom fitted item for them. As of late, numerous preliminaries to fabricate AN AFO with 3D printing strategy are finished. An orthosis made with 3D printing strategies enjoys benefits in less sensitive expertise and work to make and simple generation over traditionally made orthosis made by trim the thermoplastic material [3]. Also, on the grounds that the planned 3D displaying file is saved once, assembling of an AFO can be effectively rehashed. Likewise, assuming a programmed PC code program for designing| the planning| the look} of orthosis is created utilizing the pre-customized orthotic existing plan, the development of the orthosis would be effectively accomplished and can be modified by patients for themselves [4].A design of orthosis was prepared followed by analysis of the stress and manufacturing the orthosis using the 3D printing technique. In this study, study of manufacturing process of converting the previous solid design of AFO into two new parts and joining the parts with a mechanism is done [5].

An Ankle Foot Orthosis (AFO) is a mechanical contraption used by drop foot patients with paretic lower leg dorsiflexor muscles, to help and work on the working of the foot and lower leg joint [6]. Regardless of the way that, the mark of AFO to hinder the forefoot to drop in impact by restricted the lower leg advancement, it also further develops the lower leg ability to assist with bodying weight, gives movement and confirms push-off limit with respect to the hour of position time of walking [7]. A lower leg foot orthosis (AFO) is consistently used for foot drop achieved by suffering neuropathy. Customary collecting of AFO involves manual mortar tossing, adornment of thermoplastic materials, and cutting them as a kind of Ankle Foot Orthoses (AFO), which needs delicate limit and much effort [8,9]. Additionally, the whole strategy of this collecting should be repeated in the event that the lower leg foot orthoses (AFO) is demolished or a patient's condition is changed [10,11,12]. Three-layered (3D) printing framework, in any case called added substance creating, has been by and large used in healing fields, and their use is rising fiercely [13,14]. Three-layered printers can make actually modifiable articles with no decent mouldings that make the things specific. This 3D printing method makes it practical for specialists and experts to make basically calm custom fitted thing for them by 3D checking the math of the foot of the patient [15,16]. 3D separating isn't simply used in helpful fields anyway contemplates have shown its applications and inclinations in various endeavors. As of late, various fundamentals to deliver a lower leg foot orthoses (AFO) with 3D printing technique are done [17,18]. An orthosis made with 3D printing frameworks has central focuses in less delicate inclination and effort to create and straightforward increase over expectedly made orthosis made by trim the thermoplastic material. Likewise, in light of the fact that the organized 3D showing record is saved once, gathering of an AFO can be really repeated [19,20].

Finite Element Analysis (FE assessment) is used to anticipate pressure spread plan at the surface and in the tissue to allow appraisal in a fitting method of the effect and its response under different circumstances [21]. Taking into account a previous report, various models of foot and AFO have been developed whose reason are doubts like clear math of development properties and direct breaking point conditions without the withering effect of scouring [22]. The delayed consequences of this assessment might impact the restricted part examination considering the way that a veritable situation of non-linearity might approach. Various examinations have been done using weight sensors however since of the difficulties and nonattendance of better strategy for the investigation, the stack trade framework and the strain assessment inside the AFO isn't particularly tended to. To beat this requirement Finite Element Analysis has been swung to for showing [23,24]. The FE examination has been an aide to tests to expect load dispersals and stress assessment. An arrangement of orthosis was prepared followed by assessment of the strain and gathering the orthosis using the 3D printing system. In this examination, examination of gathering method of changing over the past solid arrangement of Ankle Foot Orthoses (AFO) into two new parts and joining the parts with a framework is done.

II METHODOLGY

Three-dimensional mesh geometry directly from patient's limb was taken using the 3D laser scanner. Consequently, 3D printable orthotic design is created from simple input model by means of SOLIDWORKS software. A customized design is produced by breaking the solid piece in two different parts. To make these parts work they were joined with a joining mechanism and eventually the two mechanisms were analyzed on ANSYS and the best mechanism is to be 3D printed.

The Fig 1 explains the approach followed during the study and the analysis of the Ankle Foot Orthosis (AFO). This methodology is the basic methodology to follow and study the problem given and to reach out to a proper solution.

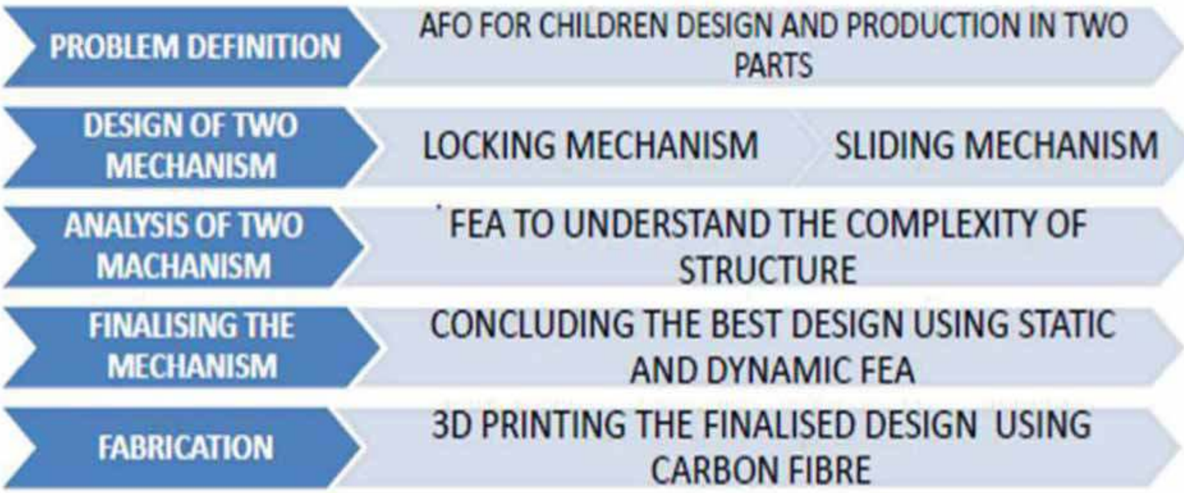

Fig. 1: Methodology carried out during the study

(a) Problem Definition - First the design of the mechanism for AFO which are of two types sliding type and locking type Adjustable and hinged mechanisms of is prepared that have their own glitches. Hence throughout the course of this study both mechanisms were studied thoroughly and then it was decided which will be best after analysing the various designs under design software like CAD and analysing the application of forces on it in ANSYS.

(b) Design of the new mechanism - The solid model previously given (Fig.2) had problems, Less flexibility, more rigidity, Less stress/strain endurance capacity and difficulty in motion. To overcome all these problems, we break this model into two parts namely leg and foot and use some linking mechanism for joining and simultaneously overcome the above problems. Hence suggestion was made of two mechanisms: Adjustable and hinged. After studying the two mechanisms in detail a design for the two mechanisms which were as follows was finalised which was to be later studied for finite element analysis (Fig.3).

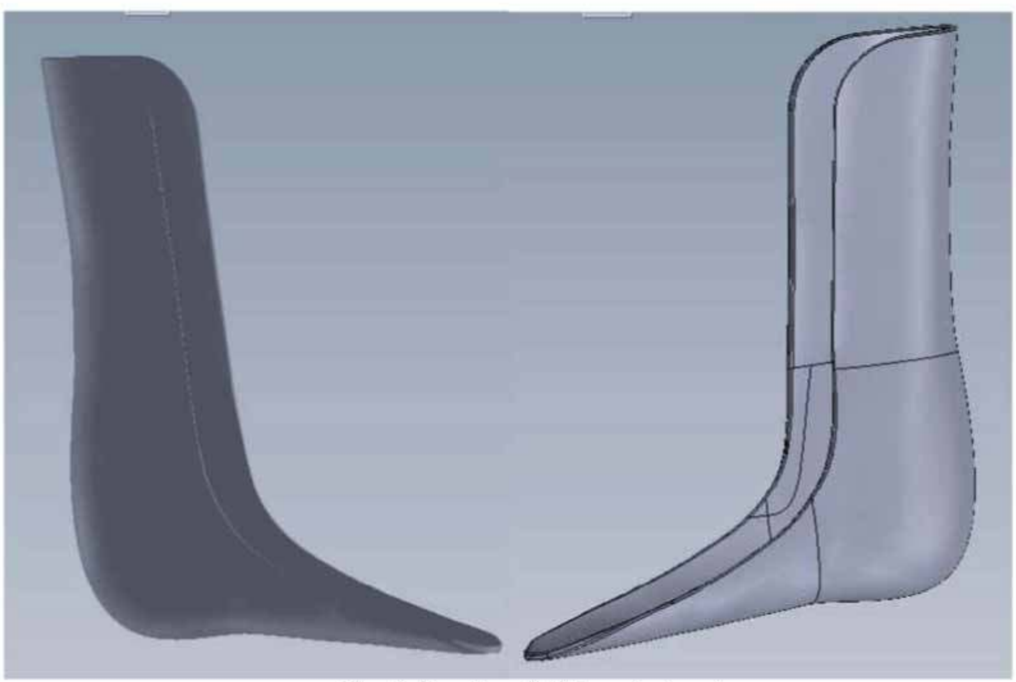

Fig. 2: Previous Solid part given to us

Fig. 3: The mechanism proposed to be 3D printed

Moreover, while stress analysis of the designs we found out that the benefits of our proposed design came out to be: More flexible and higher stress endurance, less deformation under weight of child. Material used gives better results in all tested fields against polypropylene hence has high impact strength. The material now used has better surface finish and better design durability.

(c) Finite Element Analysis of the two mechanisms

The finite element analysis is carried out on ANSYS. Considering weight of a four years old child between 15 to 20kgs and gravitational acceleration to be $9.8ms^{-2}$ force applied on ankle foot orthosis is calculated for different weights. The force is considered on the leg of the orthosis while keeping the foot stationary. The material used in analysis is carbon fibre. Properties of carbon fibre used are (Table 1) :

Table 1
The Standardized Values taken during the study for analysis

Young's Modulus (Pa)	Poisson's Ratio	Bulk Modulus (Pa)	Shear Modulus (Pa)	Density
7.e+010	0.1	2.9167e+010	3.1818e+010	1600 kg m^-3

These inputs put together gave the final mesh structure of the proposed designs. (Fig.4, Fig. 5) There are 8387 elements with 19896 nodes in the hinged mechanism and 7963 elements and 17709 nodes in the adjustable mechanism on which the component of forces applied are integrated on the software to give the final deformation values for the two proposed designs with respect to time in the range of weights considered as shown.

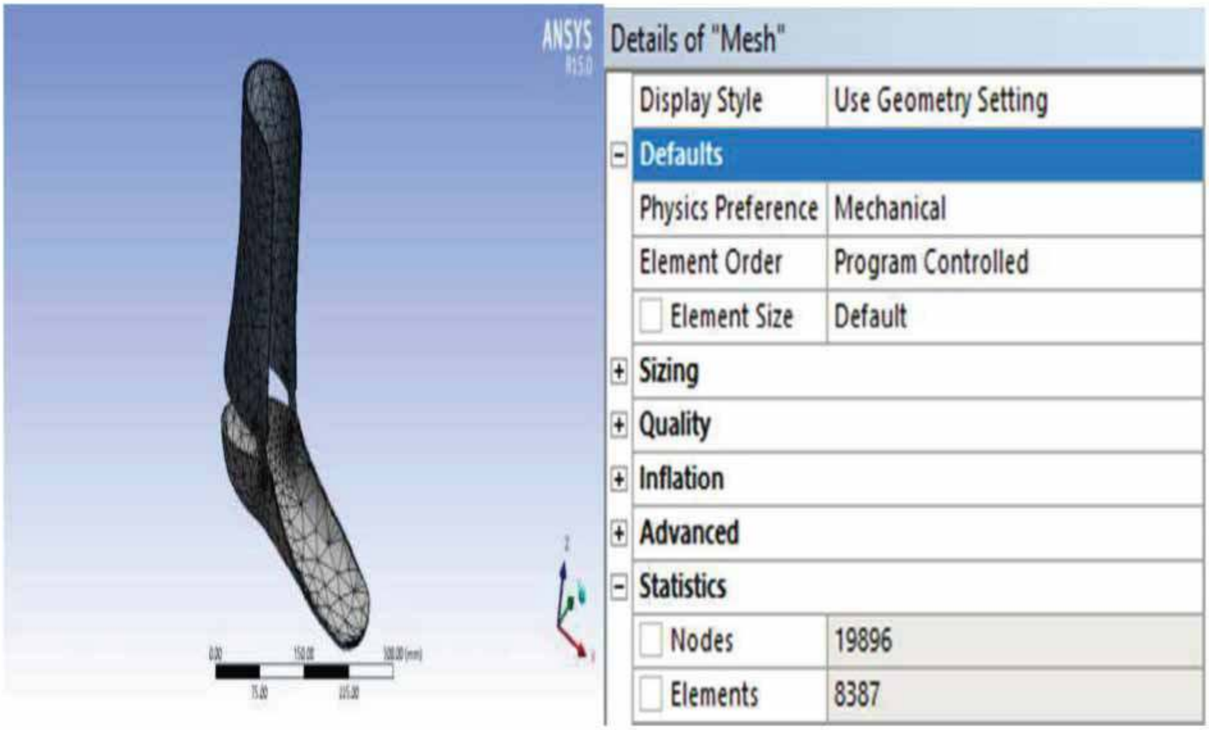

Fig. 4 Details of mesh of Hinged Mechanism

Table 2
Deformation analysis of hinged mechanism

CARBON FIBRE TESTING ON DIFFERENT WEIGHT (HINGED)						
TIME	**15 Kg**	**16 Kg**	**17 Kg**	**18 Kg**	**19 Kg**	**20 Kg**
0.1	0	0	0	0	0	0
0.2	0.244	0.258	0.276	0.290	0.306	0.321
0.3	0.485	0.515	0.552	0.582	0.614	0.647
0.4	0.728	0.774	0.863	0.874	0.922	0.971
0.5	0.971	1.036	1.103	1.165	1.232	1.295
0.6	1.214	1.295	1.375	1.457	1.538	1.620
0.7	1.456	1.553	1.654	1.723	1.844	1.942
0.8	1.703	1.814	1.926	2.041	2.154	2.267
0.9	1.943	2.076	2.203	2.332	2.462	2.592
1	2.1876	2.336	2.478	2.624	2.770	2.916

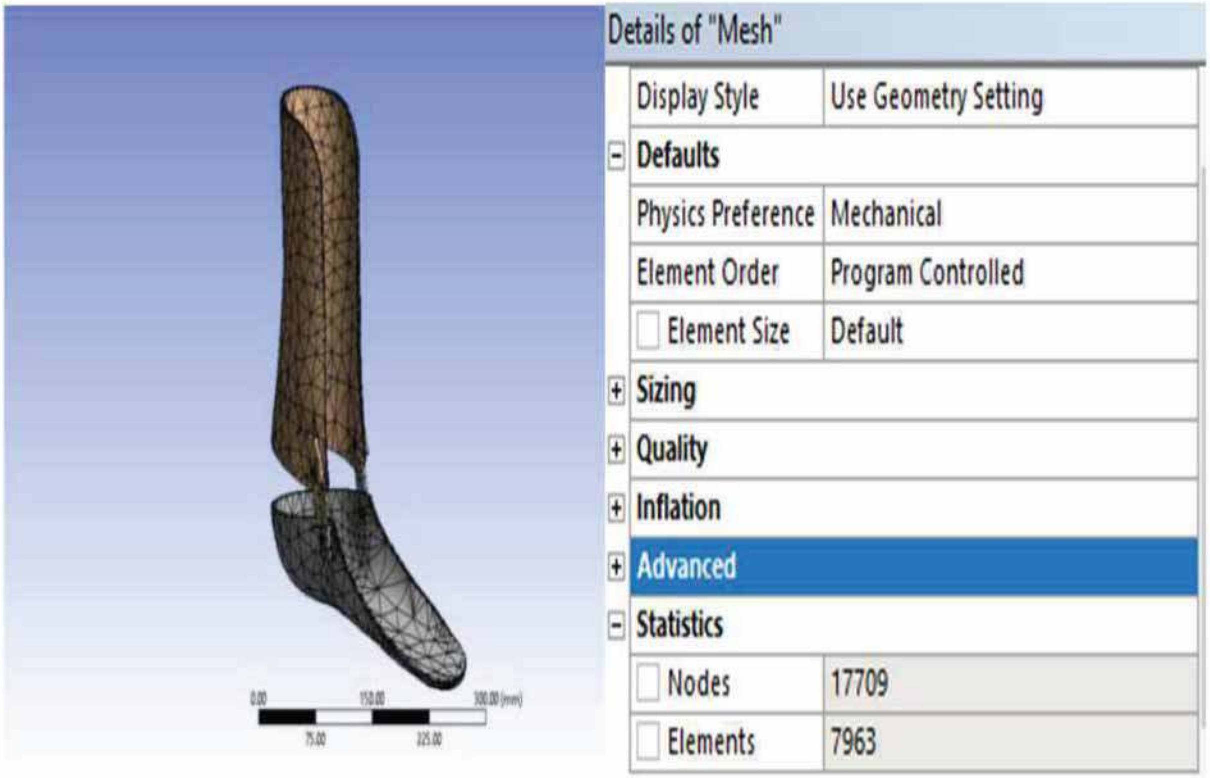

Fig. 5 Details of mesh of Adjustable Mechanism

Table 3
Deformation analysis of adjustable mechanism

CARBON FIBRE TESTING ON DIFFERENT WEIGHT (ADJUSTABLE)						
TIME	**15 Kg**	**16 Kg**	**17 Kg**	**18 Kg**	**19 Kg**	**20 Kg**
0.1	0	0	0	0	0	0
0.2	0.133	0.142	0.16	0.157	0.165	0.177
0.3	0.263	0.284	0.32	0.317	0.337	0.356
0.4	0.364	0.425	0.454	0.474	0.504	0.534
0.5	0.531	0.567	0.602	0.636	0.671	0.713
0.6	0.661	0.708	0.751	0.795	0.843	0.892
0.7	0.792	0.862	0.903	0.954	1	1.071
0.8	0.928	0.993	1.04	1.116	1.174	1.252
0.9	1.062	1.134	1.202	1.273	1.343	1.431
1	1.192	1.273	1.354	1.434	1.512	1.607

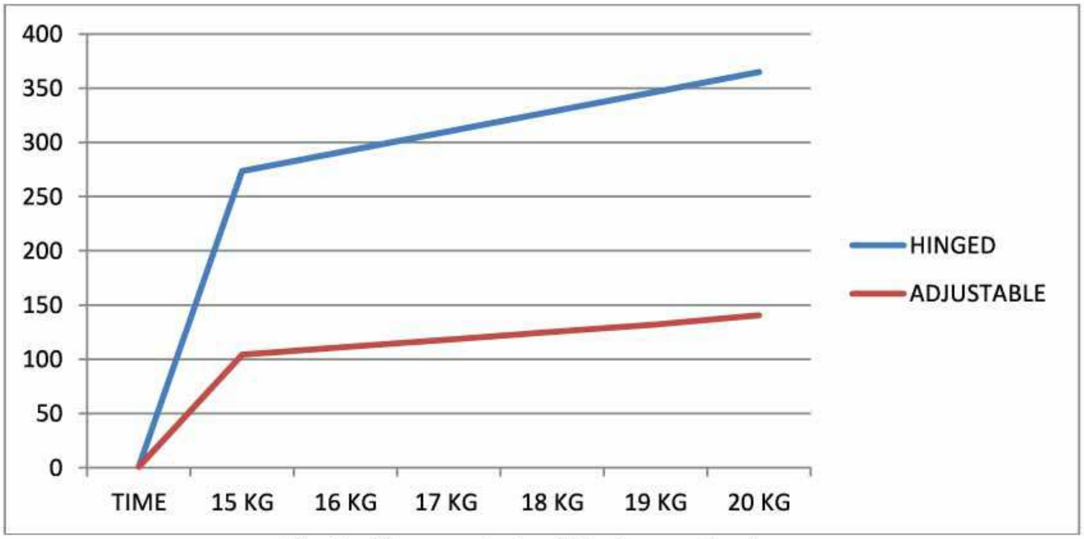

Fig. 6: Stress analysis of the two mechanisms

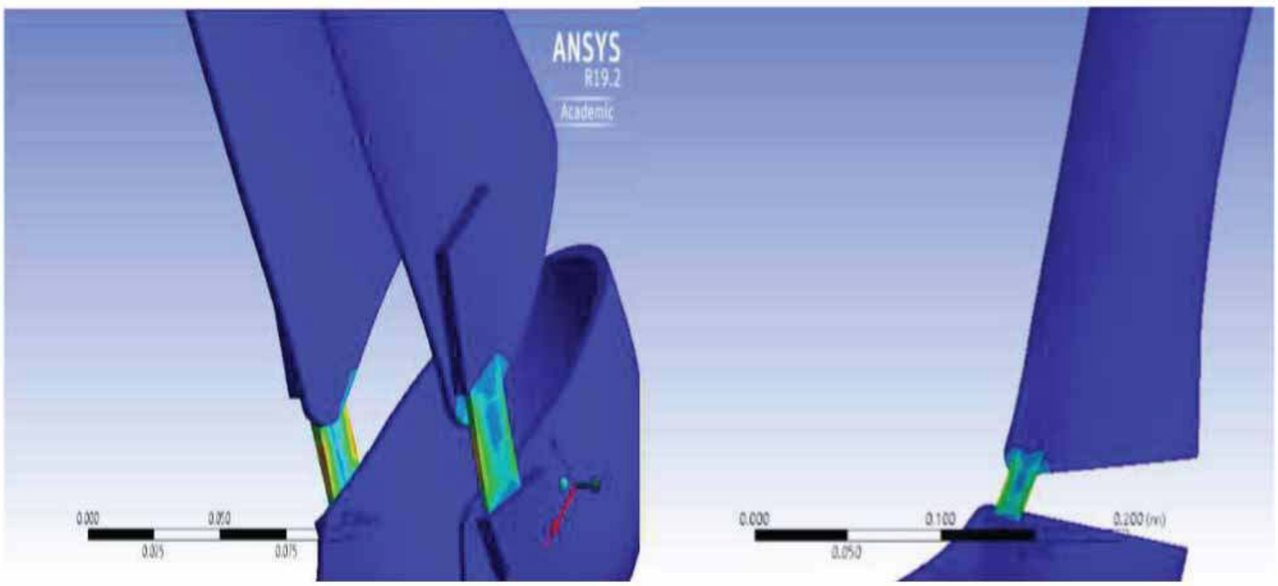

Fig. 7: Area difference of the two joint mechanisms

It was noticed that even though the deformation of adjustable mechanism is less but its stress value is less meaning that it may rupture more easily (Table 2, Table 3). This can be explained by inverse relation of stress and area. Since stress is force per unit area, (Fig. 6) the value of area of the joining mechanism is more than that of hinged and that is why its value comes out to be less. (Fig. 7)

(d) Finalizing the mechanism and fabrication - Our next and the most important step is finalizing the design for fabrication. The design finalized should be a complete homonym of appropriate stress measured, lesser deformation and more flexibility. Next step is making the physical object from the 3-dimensional model typically by laying down many thin layers of carbon fibre from the digital file. Markforged software was used to fix areas which would contain nylon and carbon fibre. The reason behind taking two materials is that mixture of these materials gives a greater strength of model.

III RESULTS

The designed finalized which came out to be the adjustable mechanism gives out the lesser deformation on application of force and bears similar stress because of area under considerations. This adjustable mechanism would be in used for 3D printing using a Markforged 3D printer having Onyx and Carbon Fiber as inks. This material will give out the necessary flexibility and strength needed for fabrication. The Cost analysis comparison between 3D printed and traditional manufacturing techniques as shown in Table 4.

Sr.No	Subjects	Quantity	3D Printed	Traditional Manufacturing
1.	For Kids	01	Rs 300- 350/-	Rs 650-750/-
2.	For Adults	01	Rs 3000/-	Rs 7000/-
3.	Comfort Level	------------	High	Low
4.	Satisfaction Level	------------	High	Low

IV CONCLUSION

This will be trailed by testing on patients for stride investigation in the long run involving it for large scale manufacturing. This assessment work bases on the biomechanical impacts and mechanical properties of changed 3D-printed AFOs and breaks down them to by and large made AFOs. Revamped AFO design using 3D printing appreciates different anticipated benefits, consolidating new material with lightweight movement, to improve biomechanical limit and comfort. Regularly, new applications mean a slow arrangement of progressing around the direct of such contraptions and blending the new arrangement, composite hypothesis and conveyed substance creation. The test results intend to overcome the new AFO structure issues and show the limited parts and stress appraisal. The consequence of the investigation is the better advance example of foot drop patients. Assuming that the energies are channelised in the correct course, innovation is taken on with energetic willingness, and the difficulties defeating us from accomplishing the last objective are actually tended to, then, at that point, our nation can turn into an assembling center. As nations and organizations decide to enhance and recalibrate their stock chains, in this way rebuilding the worldwide assembling request, India is confronted with a generational chance to fortify its incentive and realign its worldwide situating. In this manner, an essential exertion should be attempted to foster native mechanical capacities to completely tap and afterward influence the possible chances of Industry 4.0. An aggregate spotlight on Additive Manufacturing as well, can massively expand India's endeavors to situate itself as the assembling center point of the world.

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