A SIMPLE, CHEAP, AND EFFECTIVE LOWER LIMB PROSTHESIS FOR USE BY LANDMINE VICTIMS IN THE THIRD WORLD

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ABSTRACT: We present a simple, low cost yet effective lower limb prosthesis for use in the third world. Stress analysis indicates that this device would be able to withstand the forces of an average weighted individual involved in actions of walking and kneeling. World-wide, landmine explosions claim the lives and limbs of thousands of victims each year. Of the survivors, many are severely incapacitated, and such victims often find it difficult to lead normal lives and maintain their jobs. This leads to a decrease in the input to the Country's economy and a fall in the standard of living of affected individuals. Although there are many high-tech devices available on the market world-wide, such high-tech lower limb devices are beyond the pocket of most people living in the third world. Such devices also require high levels of sophisticated maintenance. The device that we have presented and tested is low-tech. It is built in sections and any one section may be replaced easily and made relatively cheaply from locally produced materials.

Keywords: Lower limb prosthesis, third world.

INTRODUCTION

World-wide landmine explosions are responsible for thousands of injuries. In Bosnia and Herzegovonia alone, data collected by the International Committee for the Red Cross report statistics of 4,313 people being killed or injured by landmines. The breakdown of these figures is presented in tables 1a and 1b below, and from these table it is apparent that most of the victims are aged 26-35 years, in the period of their lives when they would constitute wealth producers in their country's economy, (ICRC, 2000).

The aim of this research was to develop an artificial limb device for use in the third world. The purpose of the creation of such a device was to make a simple yet effective construction that could be made locally, and at low cost. The device is intended to be worn to enable mobility over a short range, to assist standing and kneeling whilst maintaining balance of the land mine victim.

LITERATURE SURVEY

The landmine is one of the most dangerous weapons ever built (Maresca et al 2001). Broadly speaking landmines maybe divided into two main categories (i) APM (anti personnal mine) and (ii) AVM (anti-vehicle mine). APM's are devices designed to explode when a victim treads on them, or in some cases near to them. They are often laid to protect military installations from enemy approach. AVM's are devices that explode when vehicles drive over them. They are commonly used to limit and prevent the movement of enemy troops, ICBL (2000).

Many land mine victims are children aged 6 to 10 years who commonly work in agricultural fields which are infiltrated with land mines (UNICEF, 2000). Many land mines are high- tech, and are difficult to locate, and the relatively recent designs of such mines are made of polymer and so cannot be detected by metal-detectors.

Table 1a

Year	Number of Victims	Monthly average
1992-95	3146	66
1996	625	52
1997	286	24
1998	149	12
1999	94	8
2000 (until March)	13	-
Total	4313	-

Table 1b

Age (years)	Number of Victims
0-5	10
6-10	42
11-18	192
19-25	155
26-35	227
36-45	195
46-60	191
Over 60	88
Unknown	67
Total	1167

Although there are several artificial limb devices available world-wide, most are made of high-tech materials and are expensive-far beyond the affordable pocket of individuals in the third world. Many are made of high-tech materials such as alloys of titanium, aluminium, carbon fibre, or higher order polymers. The knee joints are made with on-board sensors which collect real-time data to control stance and swing phase movements, (Buchhorn et al 1994). A plethora of sophisticated lower limb prostheses are available to fit any type of amputee (e.g. trans-tibial, trans-femoral; King Faisal Hospital, 2004), however, these are costly and also require the individual to undergo time consuming fittings, and the use of a temporary device to allow for a period of shrinkage of the amputee stump, and training in how to use the device.

Clearly with large distances involved and cost of travel in third world countries, this is not a viable option. It is important therefore that such a device to be used in the third world must be made of local materials, that can be fashioned simply, yet effectively and easily replaced. Breakdown of skin over the amputated stump also has to be considered. This has been extensively investigated by Levy (1980). Our simple device enables packing of the amputated stump for protection against skin breakdown using simple materials. Other relatively advanced lower limb prostheses make use of silicone suction sockets (Fillauer et al, 1989) but these are not without problems, and the stocking involved in coverage of the stump must be ideally free of wrinkles, otherwise pressure points and soreness will arise over the amptated stump itself.

Brim shape on the prosthesis has been investigated by Naeff et al (1980) in relation to comfort of the wearer of the prosthesis, and computer aided design techiniques have bee applied to producing the idealsed prosthetic socket (e.g. Krouskop, 1987, Finney, 2000). However, the more complex the device is made, and the more components there are to malfunction, the greater will be the chances of problems arising with the device. The repair of these high-tech devices then requires specialists to facilitate repairs. Although FE nalysis is a powerful computational tool that has been applied to the design of lower limb prostheses, (e.g. Vannah et al 1996), the method does involve some assumptions and approximations being made in the modelling; it is an approximation to the real world, and it is difficult in such modelling to anticipate the extent of e.g. stump shrinkage that will inevitably take place over a period of time.

Friction, slip, tissue response to mechanical loading are also factors that will vary from person to person, and although these factors have been identified by several authors (e.g. Commean et al, 1997; Herman et al, 1999) again it is impossible to predict what would happen in the case of any specific individual wearer of a given prosthesis. It has been reported by individuals that the more sophisticated devices take much longer to put on, (Pearce, 2003) and this time consuming process is clearly undesirable in a third world setting, where earning a living wage is of paramount importance. Given all the problems associated with more advanced lower limb prostheses, and their inhibitory cost, there is clearly a need for the design, construction, and implementation of a simple, effective, low cost, lower limb prosthesis for use in the third world.

Consequently the purpose of this research was to design an build the protoype for a simple affordable device.

THE LIMB DEVICE

The aim of this research was to develop an artificial limb device for use in the third world. The purpose of the creation of such a device was to make a simple yet effective construction that could be made locally, and at low cost. The device is intended to be worn to enable mobility over a short range, to assist standing and kneeling whilst maintaining balance of the land mine victim.

We present such a simple, cheap, effective lower limb prosthesis for use by landmine victims. Although the device is not intended to be for exclusive use in the third world, we anticipate that this will be its major user, and in particular in areas of conflict where landmines are prevalent. Given the major type of user and his/her environment, we have designed and built the prosthesis from low cost materials, (available locally within countries) such that the device is easily repairable, and yet effective.

The prosthesis is made of several parts, each of which can easily be detached and replaced if one or several parts wear out at different rates. The arts essentially constitute:

- Femoral component
- Knee component
- The foot
- The cross-strut

The method of construction and the materials used are described below.

METHOD AND MATERIALS

The prosthesis was designed and built from plastic and wood. The femoral (thigh) component was designed and made from plastic bottles such that the diameter of the plastic could be adjusted to fit the diameter of any thigh. The inside of the plastic thigh component may be packed with comfortable materials to protect the amputated stump. The assembly is fixed in place around the thigh with Velcro. Fixations at the apex of the plastic femoral component enable an attachment to be fastened securely around the waist of the user.

The prosthesis was designed such that it locks in full extension to enable walking (see figure 1 below). However, it has the capacity to enable the user to flex the knee for facilitation of kneeling (e.g. in the fields for agricultural work). In the latter scenario, the device locks into position with a cross-strut (see figure 2 below). The construct thus enables the wearer to stand unassisted by crutches, thereby freeing up the hands for working. The flexion at the knee during bending (and the locking into position) enables the wearer to have balance whilst kneeling, which would otherwise be compromised.

The components may be made out of wood available locally, which will of course vary with geographical location. The component in contact with the ground may also be made of wood, with a rubber attachment fixed to the wood to absorb some of the upward directed ground reaction forces that occur during walking. All the components may be easily and simply replaced. He device is designed so that the relative components can disassemble quickly and easily for repair or replacement.

IMPLEMENTATION

We anticipate that many variations on this design are possible. The prosthetic device shown here has been designed to be very basic in order to keep costs to a minimum. The cost of such a device is dependent only on the cost of the wood available locally, and may be constructed using very simple carpentry tools. It has been purposely designed to be affordable at next to no cost. The calculation of forces were undertaken using a program called "Design Space" at the TGM in Vienna, Austria. This enables 3-D calculations of stress to be undertaken. The calculations were based on assuming a force of about 250 Newtons on each leg. The stress calculations shown in figures 3 to 8 below indicate that the device is capable of withstanding the stresses involved and also show the points of maximum and least stress on the construct.

The next phase will involve testing in the third world, and plans are afoot to establish such a testing programme at field stations in the third world.

Figure 1: The device in full extension

Figure 2: The Device in 90 degrees of flexion

A stress analysis has been undertaken to show the distribution of forces on this device. These are illustrated in figure 3 to 8 below.

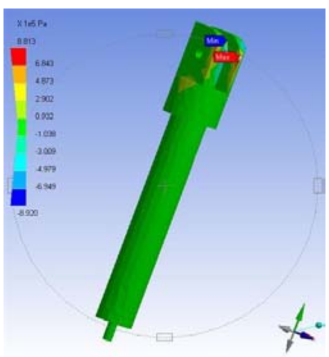

Figure 3: Axial stress – lower knee joint

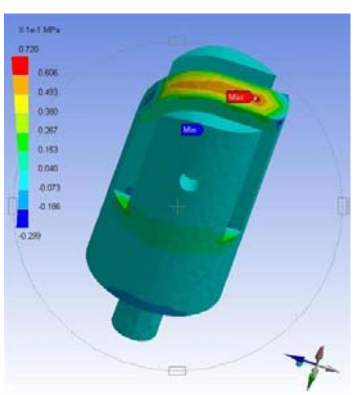

Figure 4: Axial stress – upper knee joint

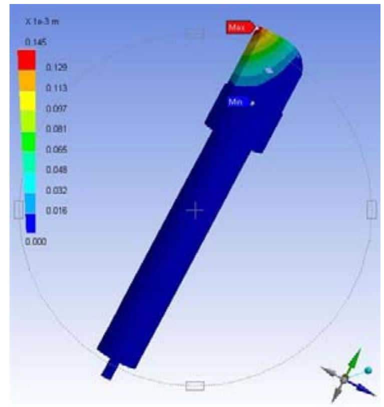

Figure 5: Max. deformation – lower knee joint

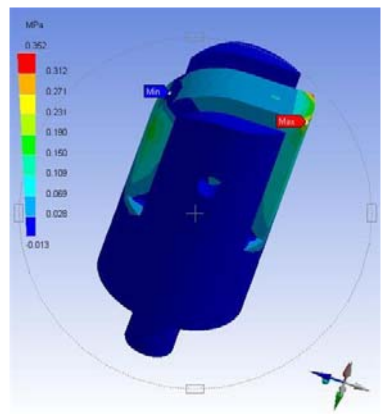

Figure 6: Max. deformation – upper knee joint

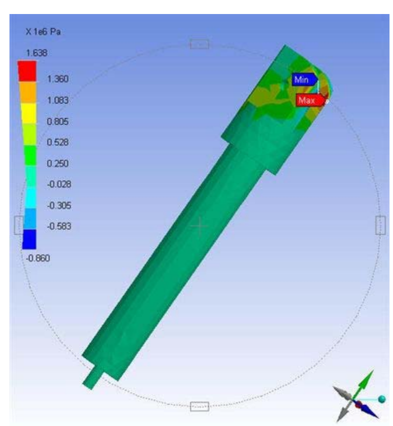

Figure 7: Principal stress – lower knee joint

RESULTS AND DISCUSSIONS

The results from the FE analysis undertaken indicate that the lower limb prosthesis would support an average individual involved in the normal activities of standing, kneeling and walking short distances. Each section of the lower limb prosthesis may be easily constructed from simple materials and replaced as required at relatively low cost. The figures shown above indicate the points of high and low stress, and although the device may lack the sophistication of more advanced devices (e.g. servo mechanisms), it is sufficiently versatile so as to assist the land mine victim in performing every day activities.

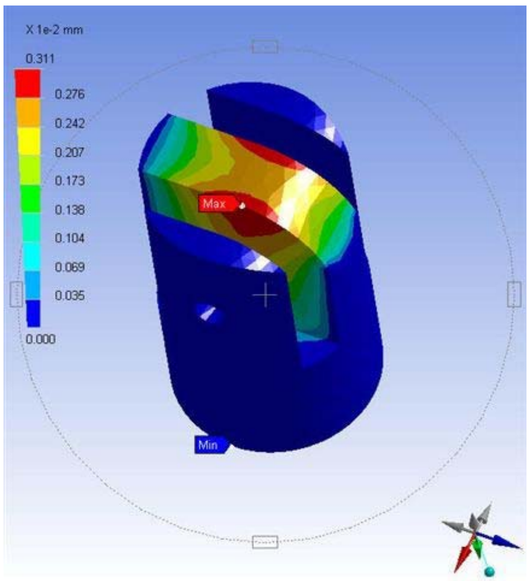

Figure 8: Principal stress - upper knee joint

CONCLUSION

We have designed and built this simple but effective lower limb prosthesis, which is affordable and creatable by individuals anywhere in the world using cheap local materials. Although it may not be as robust or as versatile as many of the more expensive high-tech lower limb prostheses that are available, it may be used to facilitate mobility and above all balance of the human body in the standing and kneeling positions. To this effect, the design is successful. The design of the prosthesis may also be varied to fit the needs of the individual, and that may be undertaken without incurring major engineering costs due to the simplicity of the device itself and its adaptability.

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