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Dual-Ankle Springs (D.A.S.) Foot-Ankle System

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INTRODUCTION

The Dual-Ankle Springs (D.A.S.) foot-ankle system† is a new development in multi-axial, stored energy prosthetic feet. A spring is defined as a device, as a coil of wire, that returns to its original form after being forced out of shape. Different types of spring designs have been introduced in artificial feet with varied capabilities of stored energy. These designs differ in shape and their material makeup according to the functions needed. The anatomical foot is multi-axial in function and, therefore, the shape of the spring system in the artificial foot should also be multi-axial in function. One such spring is the helical spring which also has energy storage capabilities. A leaf spring design is also capable of energy storage, but is limited in its multi-axial function, particularly in medial lateral movements. An attempt to provide a multi-axial foot-ankle system with the capabilities of absorbing, storing, and returning the energy generated in walking, has led to the development of the Dual-Ankle Spring foot-ankle system.

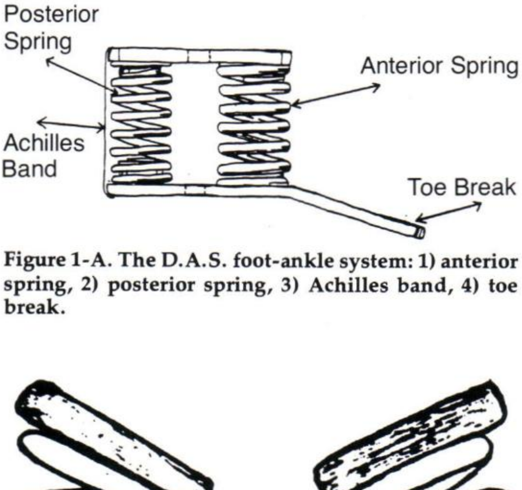
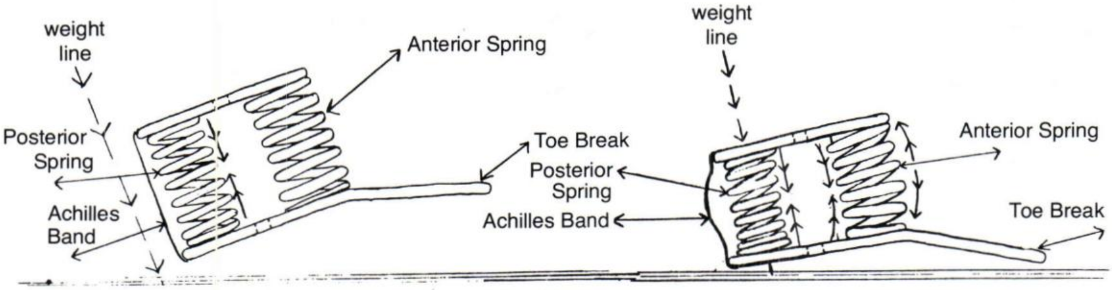


Figure 1-A. The D.A.S. foot-ankle system: 1) anterior spring, 2) posterior spring, 3) Achilles band, 4) toe break.

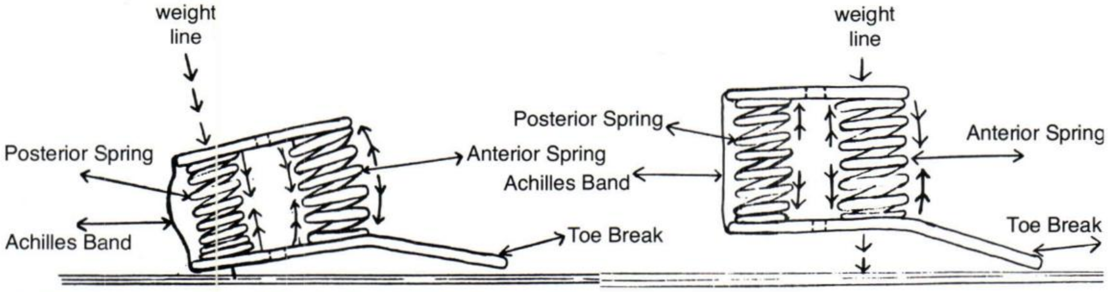
Figures 1-B and 1-C. A posterior view of the left foot, inversion (left) and eversion (right).

Material makeup of the spring is also important. Just as there are different types of carbon-composite materials, there are different alloy type spring steels. A chrome-vanadium alloy spring steel is used in the D.A.S. foot-ankle system and offers increased elasticity and tensile strength over the regular steel spring which is more brittle.

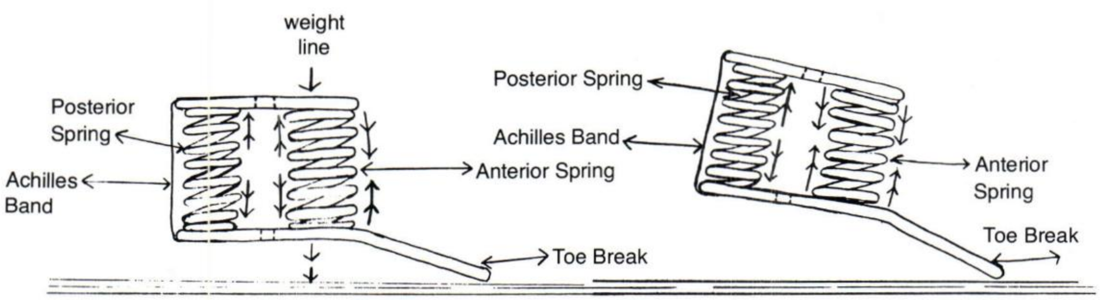
†Patent pending.



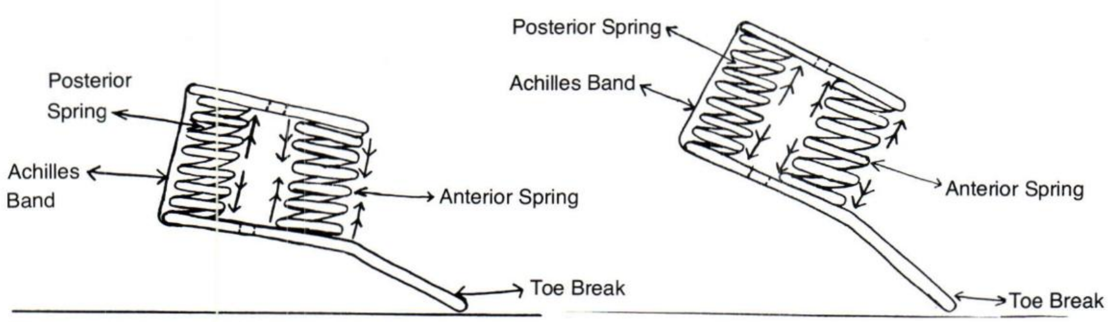
Figures 2-A (left) and 2-B (right). Heel strike and foot flat.



Figures 3-A (left) and 3-B (right). Foot flat and mid-stance.



Figures 4-A (left) and 4-B (right). Mid-stance and heel-off.



Figures 5-A (left) and 5-B (right). Heel off and toe off.

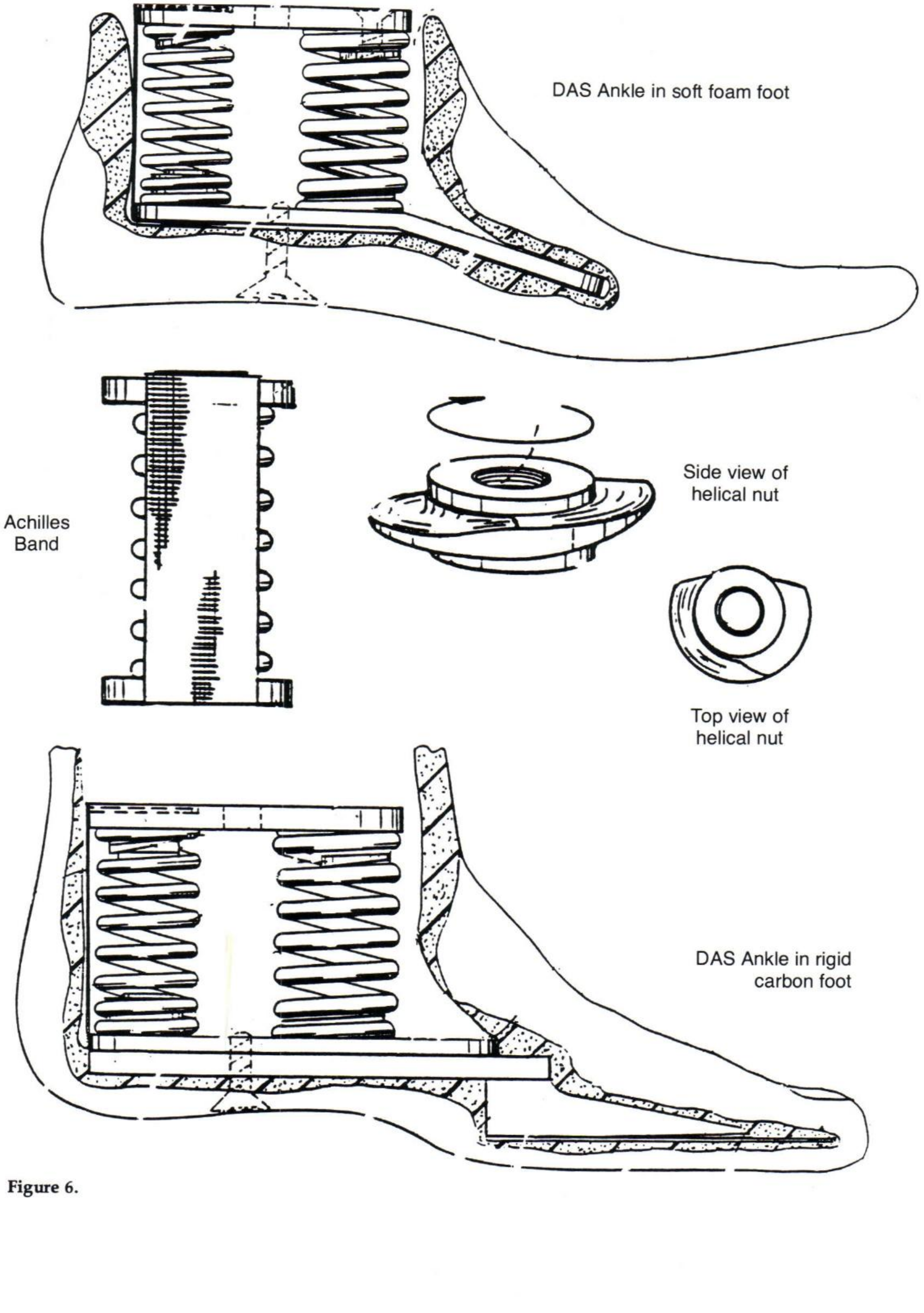

DAS Ankle in soft foam foot
Achilles Band
Side view of helical nut
Top view of helical nut
DAS Ankle in rigid carbon foot

Figure 6.

DESIGN

The D.A.S. foot is basically composed of two flat die helical springs attached proximally to an ankle plate and distally to a plantar plate. These plates are T4 2024 aircraft aluminum with a tensile strength of 68,000 lbs. per square inch.

The method of attachment is by a helical nut[††] (Figure 6). This rigidly attaches these springs to the plates themselves. Unlike welding or tapping, the helical nut method attachment does not change any temper properties of the springs. Substitutions are easily made using different compression strength springs according to the varying needs of the amputee. This may be done at a facility and need not be sent back to the manufacturer for adjustment or exchange.

This system has a posterior positioned flexible member made of Kevlar® covered with buckskin leather extending from the upper ankle plate to the plantar plate which serves as an "Achilles tendon" (Figure 6). This flexible member allows compression of both springs in any direction, but disallows elongation of the posterior spring beyond a certain point. The tensile strength is 8,800 lbs. per square inch.

The flat die helical springs are custom designed individually for each foot and are virtually impossible to deflect with normal usage, due to the memory factor of the alloyed metal (Figure 13). The D.A.S. foot-ankle has no moving components, i.e. cantilevers, ball and socket hinge, hydraulic pistons, valves, universal coupling, or two way hinge, etc., which may lead to malfunction and increase service labor. The D.A.S. foot-ankle system has proven beneficial to below-knee, knee disarticulation and above-knee amputees. This system provides these patients with maximum energy efficiency and stability. The D.A.S. foot-ankle can be used with either endoskeletal or exoskeletal prostheses. If the previous alignment is correct, the D.A.S. foot-ankle may readily be adapted to the amputee's present prosthesis. This system is compatible with many standard artificial knee units, including some hy-

[††] Patent pending.

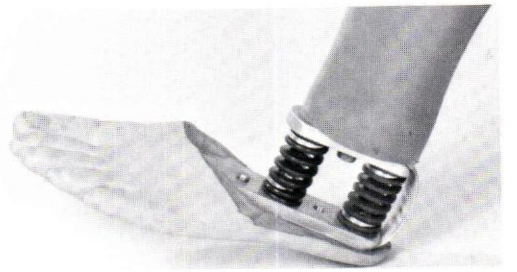


Figure 7-A. Heel Strike.

Figure 7-B. Foot Flat.

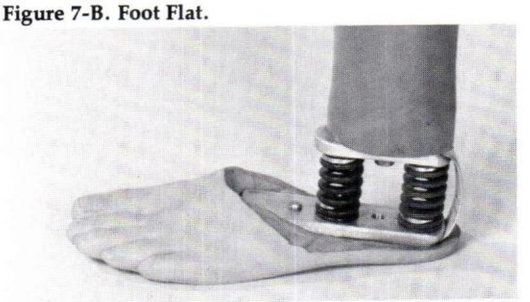


Figure 7-C. Mid-stance.

Figure 7-D. Heel-off.

Figure 7-E. Toe-off

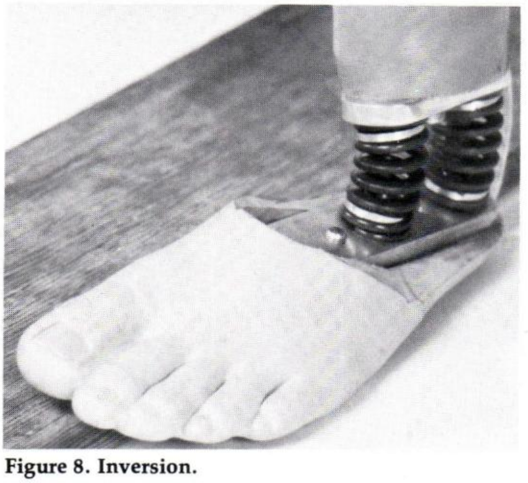


Figure 8. Inversion.

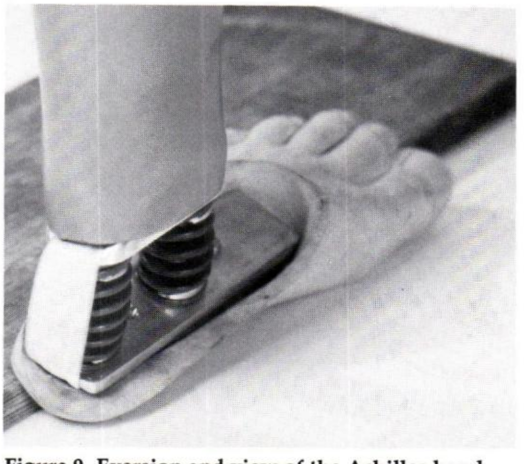


Figure 9. Eversion and view of the Achilles band.

draulic ones. Since its introduction to patient use and field testing 11 months ago, 41 patients have been fitted with the D.A.S. foot. This group is composed of above-knee, knee disarticulation, and below-knee amputees. The D.A.S. foot-ankle system has also been submitted to the Veterans Administration for approval.

FUNCTION

The primary advantages of this system over previously used prosthetic feet are its ability to absorb, store, and return all forces generated in the medial-lateral and anterior-posterior axes. Maximum energy absorption, storage, and return is achieved with the rigid carbon fiber foot that also incorporates a leaf spring system at the toe break section (Figure 6). The smoothest heel-strike to toe-off gait is obtained with the soft foam foot (Figures 6 and 14).

During inversion-eversion (Figures 1-B and 1-C) this system allows anterior spring and posterior spring to work in unison (Figures 1-A, 8, and 9). The main function of all previous multi-axial feet was to conform to irregular walking surfaces. The energy absorbed, stored, and released during inversion-eversion and plantar-dorsi flexion in the D.A.S. foot-ankle is uniformly controlled. This controlled inversion-eversion and plantar-dorsi flexion, with energy absorbed, stored, and returned, negates jerks, abrupt bumps, and inclines which would normally be instantly transmitted from the artificial foot to the residual limb.

The amputee is aided when inversion-eversion, plantar-dorsi flexion occurs because this absorbed, stored, and released

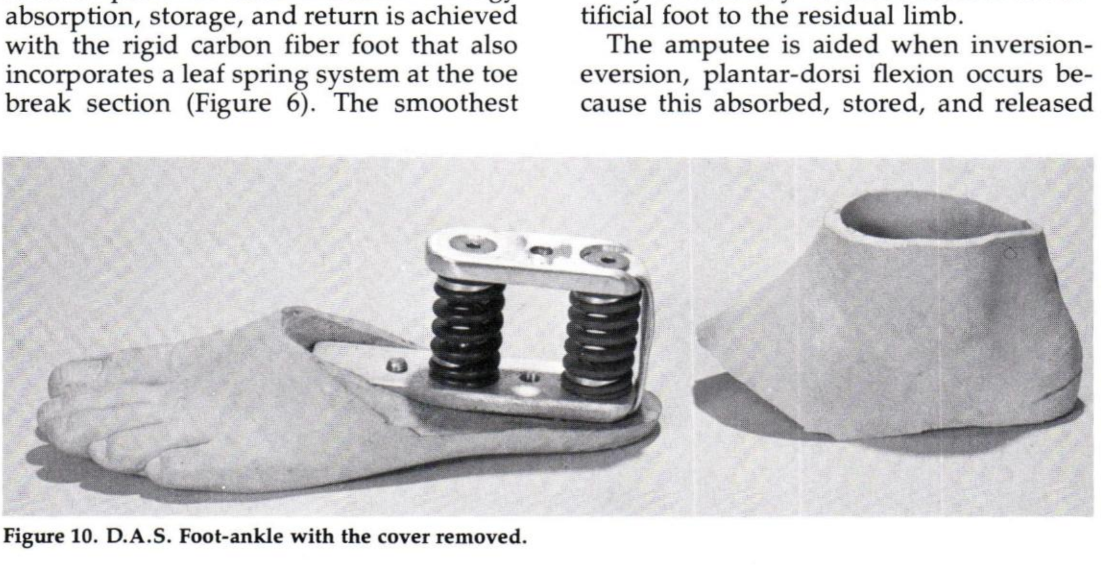


Figure 10. D.A.S. Foot-ankle with the cover removed.

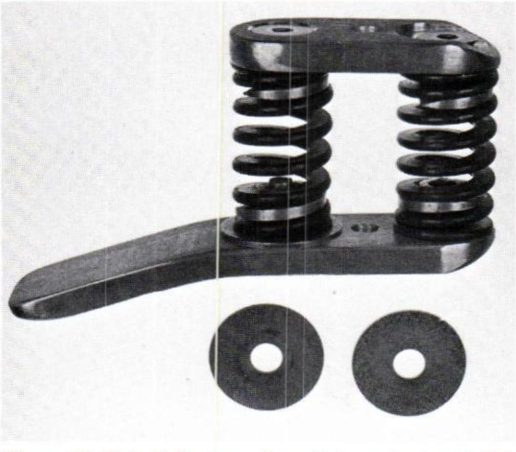


Figure 11. D.A.S. System, for soft foam foot with flat washers for plantar flexion adjustment.

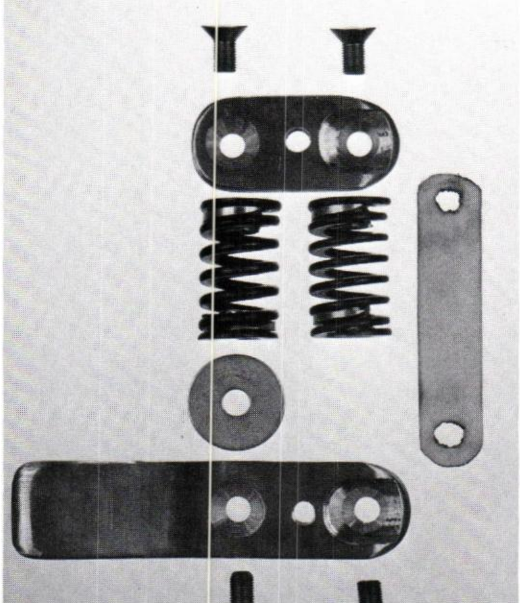


Figure 12. Exploded view of the D.A.S. foot-ankle system.

energy occurs on the prosthetic side (Figures 7, 8, and 9). This allows the amputee to more easily recover his balance with the prosthesis instead of depending solely on the sound limb.

During the dynamic gait cycle of heel-strike to foot-flat (Figures 2-A and 2-B) energy is absorbed and stored while the

Figure 13. Various compression strength springs for the foot with helical nuts and 3/8" flat head screws socket type.

posterior spring is being compressed (Figure 2-A). Simultaneously, the anterior spring is bowing and compression of its posterior aspect with elongation of its anterior aspect may be seen (Figure 2-B).

This absorbed and stored energy is released from foot-flat to midstance as the weight bearing line moves progressively anterior along the foot (Figures 3-A and 3-B). At mid-stance, the Achilles band prevents further elongation of the posterior spring (Figure 3-B).

From mid-stance to heel-off, there is compression of the anterior spring generating the greatest amount of energy absorption and storage (Figures 4-A and 4-B).

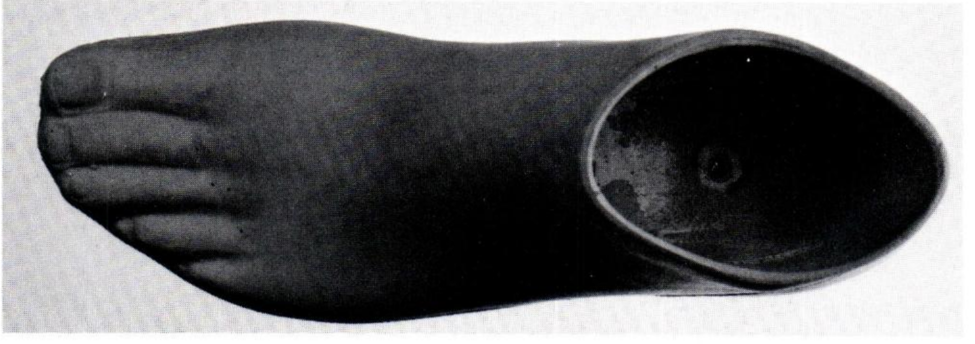
At heal-off to toe-off, this amount of absorbed and stored energy is released from the anterior spring, propelling the amputee forward (Figures 5-A and 5-B).

ALIGNMENT METHOD

When a new prosthesis is being dynamically aligned, a standard S.A.C.H. or similar foot should be used with the adjustable device. This allows the prosthetist the ability to determine a better medial-lateral placement of the foot, as well as the abduction/adduction angle of the socket. Subsequently, the D.A.S. foot-ankle can

Figure 14-A. Soft foam foot: medial view.

Figure 14-B (below). Soft foam foot: top view.



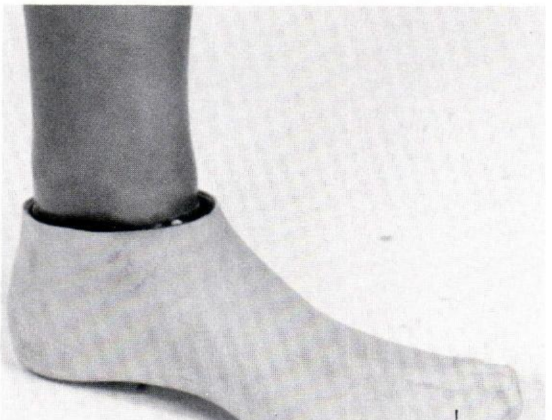


Figure 15. Foot ankle block interface.

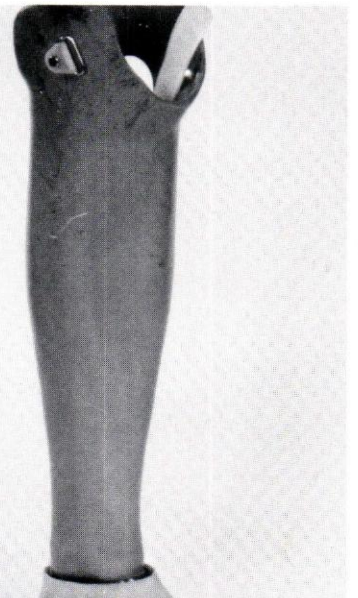


Figure 16. Completed below-knee prosthesis.

be used to determine the correct plantar-dorsi-flexion and anterior-posterior placement of the foot. Plantar flexion may be adjusted on an existing prosthesis by simply adding 1/16" flat washers between the distal end of the anterior spring and the proximal surface of the plantar plate (Figures 11 and 12).

Transferring these alignments from the adjustment device to the finished prosthesis follows standard procedures used in the field today. On exoskeletal prostheses, the ankle block should be shaped to fit inside the soft foam flat ankle section (Figures 15 and 16).

CONCLUSION

Some comparisons can be made between the D.A.S. foot and the standard S.A.C.H. foot. In weight, the S.A.C.H. foot for a size 11 is 1.4 pounds, compared to a 2.2 pound D.A.S. foot. The weight of a prosthetic foot is always of concern to the prosthetist as well as the amputee. Equally important is the degree of function and response of the prosthetic foot. The S.A.C.H. foot is adequate for normal walking conditions on flat surfaces, as is the D.A.S. foot. However, on uneven terrain, the D.A.S. foot excels in its multi-axial capacity to adjust and absorb the impact forces generated during the walking cycle.

The Copes Biomechanical Ankle® is another prosthetic foot which incorporates a singe helical spring and a ball and socket ankle joint. The D.A.S. system has two helical springs which work in unison for maximum energy efficiency throughout the heel-strike to toe-off gait cycle, as well as during inversion/eversion. A major difference between the D.A.S. system and all other helical spring-type feet is the method in which the springs are attached to the plates. Spring steel, once tempered, should not be heated above 750°F. With high heat, as in welding, the spring steel loses memory and weakens, causing early failure either at the weld sight or of the spring itself. This is not a problem for the D.A.S. foot, unlike for the Copes Biomechanical foot.® The helical nut method of attachment bypasses this integral flaw.

With this new multi-axial stored energy prosthetic foot, the amputee may enjoy all outside activities with minimal concern about ramps, inclines, broken sidewalks, or any other obstacles previously avoided.

ADDENDUM

The following set of illustrations depict prosthetic feet from the late 1800s to the mid-1900s which encompass helical springs. The point of showing these is to demonstrate that the use of helical springs in prosthetic feet is by no means new to the field.

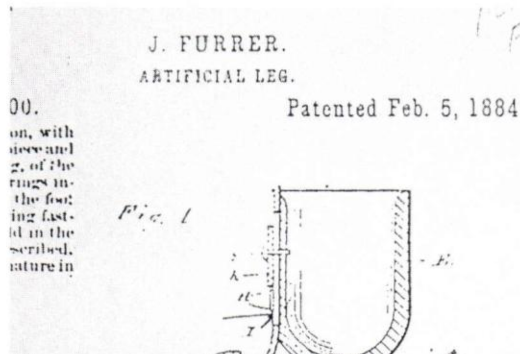


Figure 17. The J. Furrer Artificial leg, patented February, 1984.

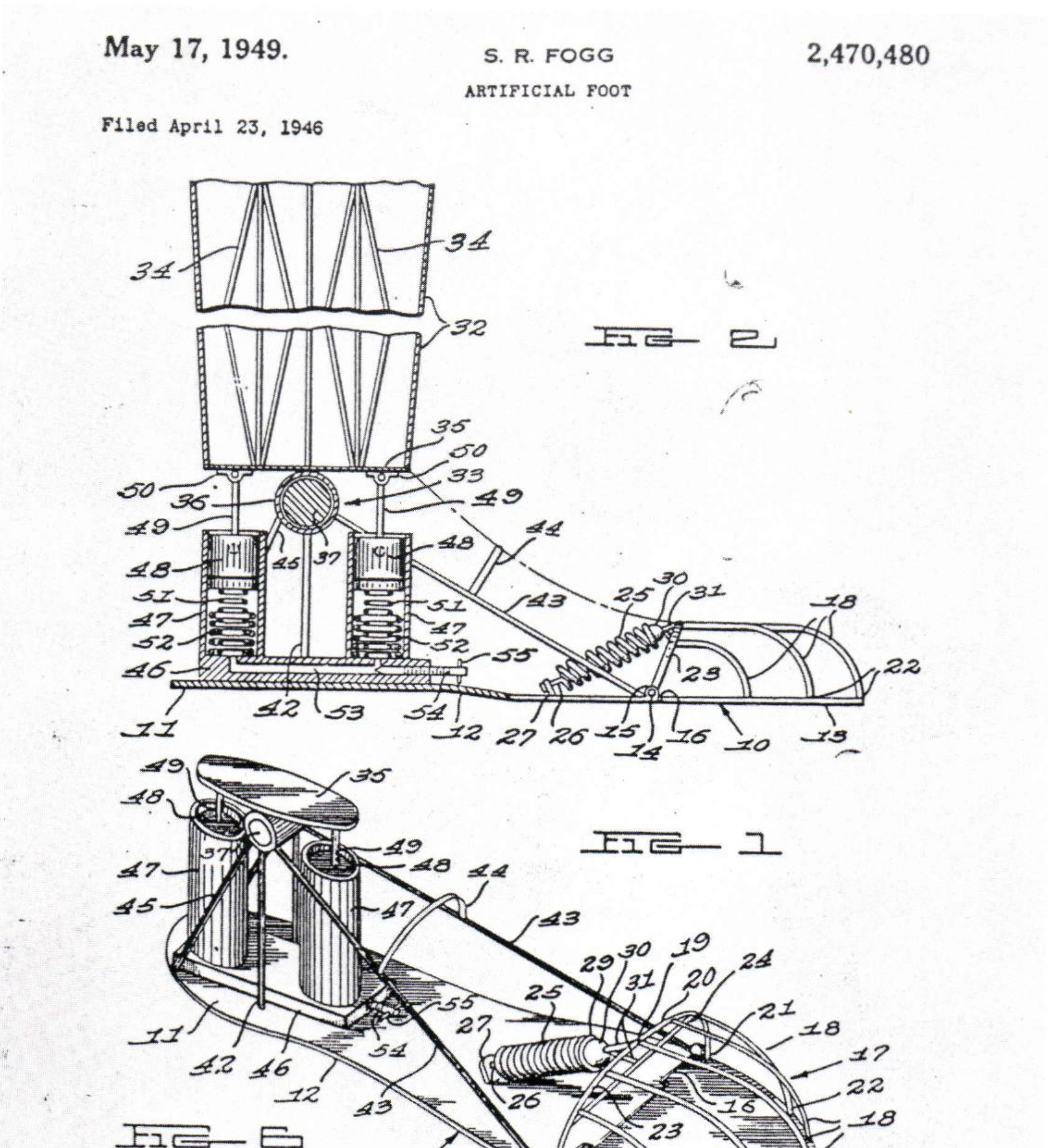


Figure 18. The S.R. Fogg prosthetic foot, patented in May, 1949.

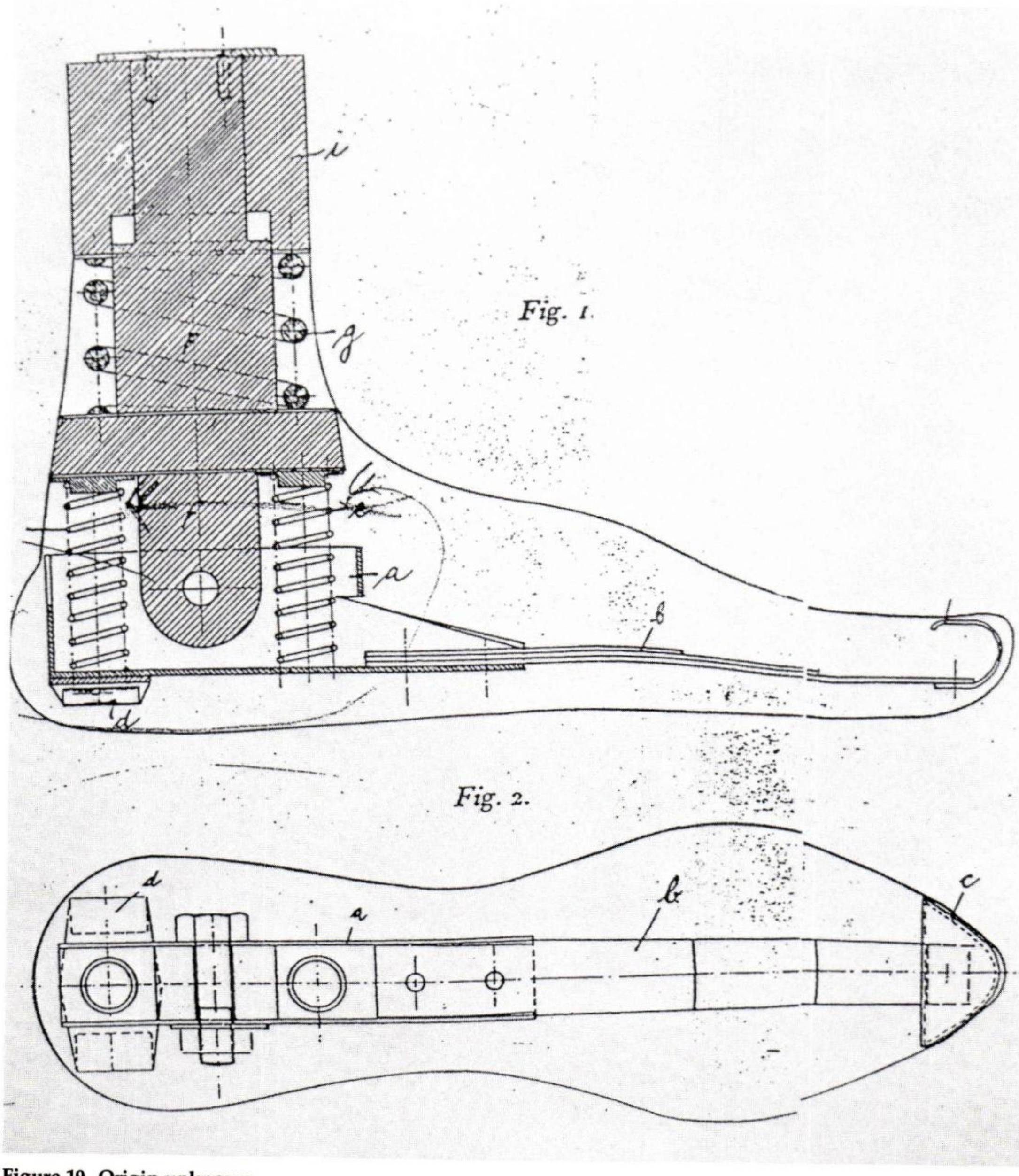


Figure 19. Origin unknown.

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