Mechanically Assisted Natural Kinematics (MANK) System

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Abstract: Joint stress and pain coupled with the exhaustion that many associate with running is a major deterrent to the mode of transportation among people in all categories of society. Many shoes today have one way or another to soften the impact of running and even claim to return some efficiency in the process, but the added weight or lack of focused intention in these designs prove many of the systems to be a gimmick.

Ultimately, my design will harness and redirect existing forces in human locomotion that are typically dissipated during impact absorption through the joints, as well as assist the user in practicing efficient and proper running gait. This system would be tunable and ideal for athletes, military, the casual runner, the elderly, or every day walkers.

Kinematics of Running:

With every footfall, the force of nearly three times your body weight is transmitted throughout your lower limb. My design will capture these forces throughout several phases of the running process. Running form, or running gait, can be broken down into two basic phases: stance phase and swing phase. My design research is focused on promoting unity between both these phases to utilize maximum efficiency of the mechanics involved. The Stance phase occurs when the foot is in contact with the ground and is often characterized by the ground reaction forces involved along with the components of heel strike, mid-stance, and toe-off. Recognizing, isolating, and analyzing the individual characteristics of each of these phases will allow the MANK system to optimize locomotion (Swelin-Worobec).

Demographic:

Being a 21-year-old athlete of 16 years who suffers from knee pain and is constantly trying to improve his performance, I am part of the demographic that would benefit from the MANK system. While my knee pain may have come prematurely for my age, many young athletes will experience similar issues later in life as a result of their activity today. The MANK system would decrease their likelihood and/or severity of future joint pain. Relief of stress and increase of efficiency will also promote activity in those who already have joint pain, as well as help those in professions where they must be active (Swelin-Worobec). The military would benefit from incorporating aspects of the design in their soldiers regular apparel. The system would be tunable to increase running efficiency and decrease joint damage while having to run with heavy equipment. With functionality and durability in mind during design, the individual components of the MANK system would utilize the benefits of carbon fiber composites that are stronger and lighter than steel, as well as other lightweight and durable material such as pro-resilin, the most efficient elastomer known (CSIRO, What Is Carbon Fiber?).

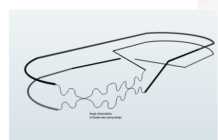
The Design:

The design will be based on fundamental mechanical properties. The affects of several augmentation concepts and systems based on the phases of human locomotion will be modeled and analyzed through the use of computer aided modeling, as well as prototype development and testing that will turn the raw conceptual force data into mechanical actualization. Some of these augmentation concepts include ground reaction force redirecting and exploitation, assisted ankle rotation, artificial external elastic ligaments, and swing assistance. Once derived from computer modeling, the ideal system will be implemented and tested with the translation of modeled forces being made through equivalent mechanical systems. The use of the most affective materials will be in mind. As aforementioned, these materials would include carbon fiber composites that are known to be stronger and lighter than steel with greater resilience, pro-resilin that is the most efficient elastomer known, and possibly nanogenerators based on piezoelectric nanostructures. The end design would be based on what is found to be the most efficient mode of force and energy transfer. This may include custom wave spring design, as well as other efficient mechanical systems that would utilize available materials.

Summary Of The Project:

My project originated with the intent of improving walking, jogging, and sprinting efficiency. The hypothesis was that the proper and specific design of a composite spring to be utilized between the foot and the ground would exploit the ground reaction forces that are typically either absorbed by the body and joints or by shoe padding with little return of energy. This was to be done with the use of various derivatives of the wave spring concept in a single spring design that would span the entire ground-foot interface with deliberate design at each contact point. The use of a carbon fiber, and possibly fiberglass, epoxy composite was found to be the ideal spring material based on several desirable features among the composite including the large tensile strength and structural integrity of carbon fiber and the compressive resilience of epoxy resin.

Expanding on my original ideas after doing kinesiology and biomechanics research, I began researching the motion of other animals while jumping. This lead to my discovering of pro-resilin, which is a vital part of how many insects perform leaps of relatively tremendous height and distance. In thinking of how to tie this type of system into my original design, I realized that I was going about solving my problem in too small minded a way and began expanding my research to the human locamotive system as a whole rather than focusing on the stance phase.



Mechanical Properties of Carbon Fibre Composite Materials, Fibre / Epoxy resin (120°C Cure)

	Units	Std CF Fabric	HMCF Fabric
Young's Modulus 0°	GPa	70	85
Young's Modulus 90°	GPa	70	85
In-plane Shear Modulus	GPa	5	5
Major Poisson's Ratio		0.10	0.10
Ult. Tensile Strength 0°	MPa	600	350
Ult. Comp. Strength 0°	MPa	570	150
Ult. Tensile Strength 90°	MPa	600	350
Ult. Comp. Strength 90°	MPa	570	150
Ult. In-plane Shear Stren.	MPa	90	35
Ult. Tensile Strain 0°	%	0.85	0.40
Ult. Comp. Strain 0°	%	0.80	0.15
Ult. Tensile Strain 90°	%	0.85	0.40
Ult. Comp. Strain 90°	%	0.80	0.15
Ult. In-plane shear strain	%	1.80	0.70

Results:

In my research, I found that while the concept of using a specific and deliberate composite spring design to help utilize the wasted forces involved in human locomotion is a sound one, it is not the most efficient system to achieve the desired results. Incorporating this concept in a larger system, however, allows for greater total efficiency of the device-human system as a whole. At this point it is unclear whether using the originally proposed system in its original fruition will be best for the system as a whole. Focusing simply on the ground-foot interface for both harnessing and redirecting the forces was too closed minded for a system as complex as that of human locomotion. The effects of the pendulum-like driven oscillation of the swing phase were discovered to be too profound to leave out of the equation.

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