林用双下肢无源负重外骨骼设计及实验研究

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摘　要:【目的】为解决林业消防人员长时间负重灭火身体负荷大劳动强度高的问题，开展林用双下肢无源负重外骨骼设计实验及其关键技术研究。【方法】提出了一种林用双下肢无源负重外骨骼，建立了攀爬情景下人体运动步态模型，完成外骨骼机械结构设计并利用有限元仿真软件开展了整体静态结构校核，结合人体攀爬步态开展基于 Opensim 的攀爬过程中人体下肢肌肉动力学特性研究，构建了外骨骼人机交互力信息、人体代谢信息、下肢运动信息实时采集系统并通过样机穿戴实验验证外骨骼减负助力性能。【结果】前期研究及穿戴实验结果表明，穿戴者穿戴外骨骼负重相对正常负重行走在平均心率和耗氧量方面分别减少了 5%和 7.62%，穿戴外骨骼负重足压相对未穿戴外骨骼降低了 7.25%。【结论】林用外骨骼机器人可有效减轻穿戴者负重感，节省人体能量支出，为解决林业消防人员森林防灭火工作中长时间、长距离背负灭火器械身体负荷大劳动强度高的问题提供了技术基础。

关键词: 森林防火；外骨骼；负重外骨骼；攀爬步态；人机交互力

Design and experimental study of a double lower limb passive weight-bearing exoskeleton for forest use

Abstract:【Objective】In order to solve the problem of high labor intensity of forestry firefighters who have to bear heavy load for a long time to extinguish fires, we carry out experiments on the design of double lower limb passive load-bearing exoskeletons for forestry and research on their key technologies.【Method】A double lower limb passive load-bearing exoskeleton for forest use is proposed, a human motion gait model is established under the climbing scenario, the mechanical structure design of the exoskeleton is completed and the finite element simulation software is used to carry out the overall static structural calibration, the research on the muscle dynamics of human lower limbs in the process of climbing is carried out by combining with the gait of the human body, and the human-machine interaction real-time acquisition system of the exoskeleton is constructed and the performance of the exoskeleton in terms of load-bearing is verified by the wearable experiment of the prototype.【Result】Previous studies and experimental results showed that wearers wearing exoskeleton weight-bearing reduced their average heart rate and oxygen consumption by 5% and 7.62%, respectively, relative to normal weight-bearing walking, and that weight-bearing foot pressures were reduced by 7.25% with exoskeleton weight-bearing relative to unworn exoskeleton.【Conclusion】Forestry exoskeleton robots can effectively reduce the wearer's sense of weight, save human energy expenditure, and provide a technical basis for solving the problem of high labor intensity of long time and long distance carrying fire-fighting equipment for forest firefighters in forest fire prevention and suppression work.

Key words: Forest fire protection; exoskeleton; weight-bearing exoskeleton; climbing gait; human-machine interaction forces.