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Research on Lumbar Calibration of 50th Crash Dummy

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Abstract: By doing H-III 50th dummy lumbar calibration tests, this paper research on the lumbar calibration method, and discusses the lumbar hardness. It is valuable to the dummy performance research and vehicle crash test assessment system.

Keywords: Dummy, Lumbar, Chest Calibration, Hardness

Introduction

The vehicle safety is always an important aspect in consideration of the vehicle design，The vehicle crash test is an important method in vehicle safety research. In crash test, different load cells are installed in the dummy, which used for the measurement of the head acceleration, neck bending force, chest displacement and acceleration, femur load, tibia load etc. After analysis of the test data, the vehicle safe of the passenger protection can be acquired. Therefore, dummy is the vital equipment in crash test. Currently, there are various kinds of dummies in crash test and H-III 50th male dummy is most widely used in frontal impact test. With the improvement of the vehicle safety assessment system, the performances of dummy's parts will directly influence the evaluation result in car assessment. Therefore, dummy calibration test is an important method to identify the dummy property. For the H-III 50th dummy, the dummy company has laid down the calibration procedures for head, neck, chest, leg and so on. However, there is no clear requirement for lumbar calibration. Furthermore, there are few studies on lumbar performances. This paper will discuss the relationship between the lumbar hardness and calibration results through the research on H-III 50th male dummy lumbar calibration test procedure.

5 Lumbar hardness of the H-III 50th dummy

2.1 Hardness measurement

Hardness is the resistance capacity of other hard objects pressed into its surface. Magnitude of hardness is the conditional quantitative reaction which indicates the hardness and softness degree of the material. It is a kind of integrated index which is composed of a series of mechanical properties such as resilience; plasticity and toughness while not a simple physical quantity. And it is determined by material property, measurement condition and method.

Measurements of hardness are various and Shore hardness test is mainly used for rubber materials. After inserting the Shore durometer into the tested material, connect the indicator of the dial plate to a pin by mechanical spring, and stab the surface of the tested material, the figures shown on the dial plate is hardness value. The unit of Shore hardness is degree and described by Shore A and Shore D, which showing the different hardness range, Shore A is for 0～90 degree and Shore D is for 90 degree and above.

2.2 Lumbar hardness

The lumbar of the H-III 50th male dummy is shown in Figure 1. The normal hardness of the rubber part is 75 to 85(Shore A)[1]. The hardness of the lumbar will influence on the dummy condition in a certain extent. As a result of the soft lumbar, the upper torso will tend to lean forward and shift easily in the impact[2].

保护试验评价中的重复性和可靠性仍待进一步验证，但 FLEX-PLI 相较 TRL-FLI 来讲，技术上无疑是更加先进的。

目前，除日本外，TRL-FLI 仍是各国法规所采用的行人下腿冲击器，但多年的研究证实，FLEX-PLI 具有更好的生物力学特性，因此，部分国家和地区的 NCAP 率先引入了 FLEX-PLI，并制定了未来将 FLEX-PLI 引入法规的时间表。尽管如此，FLEX-PLI 也存在结构复杂、部件寿命较低等缺点，但相信通过应用过程中发现并解决所存在的问题，FLEX-PLI 会更加完善，并最终被行人保护法规所接受。

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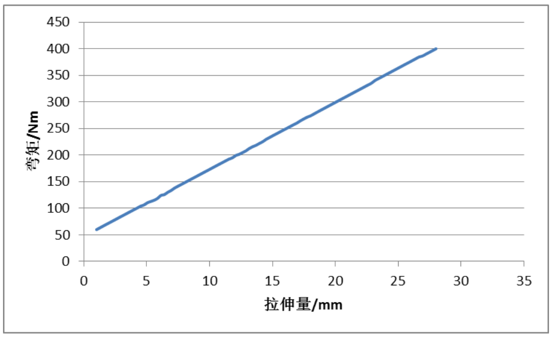


Figure 14. Bending moment-tensile displacement of knee of FLEX-PLI
图 14　FLEX-PLI 膝部拉伸量与弯矩的关系

Figure 15. Static load test of TRL-LFI
图 15　TRL-LFI 的静力加载测试

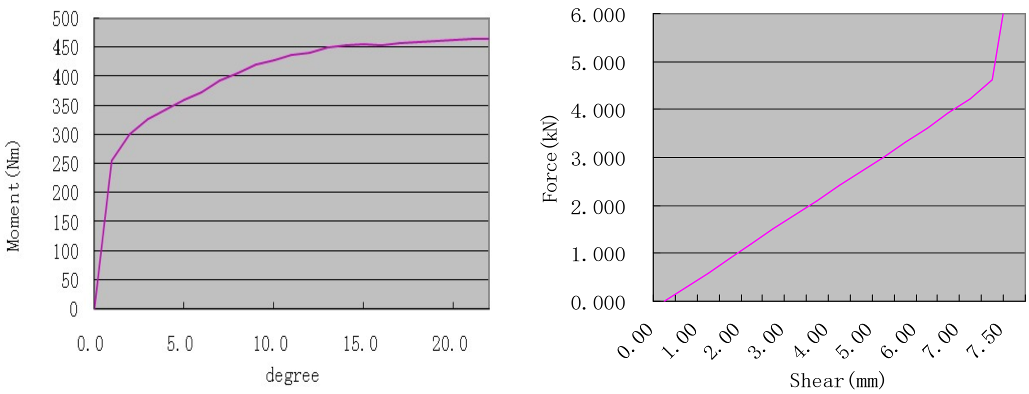


Figure 16. Load-bending angle & load-sheering displacement of knee of TRL-LFI
图 16　TRL-LFI 膝部弯角、膝部剪切位移与载荷的关系

5 总结与展望

综合本文以上论述可知，在结构上，FLEX-PLI 较 TRL-FLI，增加了对大腿、小腿骨胳的模拟，增加了对前、后、内侧及外侧韧带的模拟，评价指标更加具有针对性、更加全面，更为接近人体腿部构造；同时，在生物力学性能方面，FLEX-PLI 更加接近人体的生物力学特性，具有更高的生物仿真度。尽管将 FLEX-PLI 应用于行人

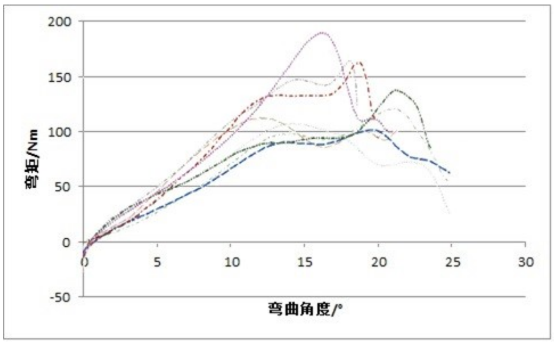
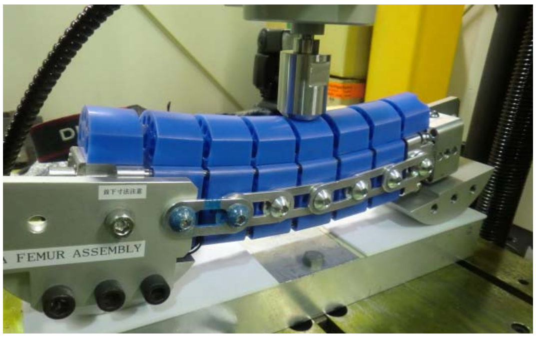


Figure 11. Bending angle-bending moment of knee

图 11 膝关节弯曲角度与膝关节弯矩关系

为了进行力学特性对比，对 FLEX-PLI 的大腿、小腿和膝部进行静力加载测试，图 12 所示为大腿和膝部的静力加载试验，通过记录试验中腿部模块受到的载荷、弯矩、变形及其相互关系，即可获得其力学特性。图 13、图 14 所示为 FLEX-PLI 大腿、小腿和膝部弯曲载荷与变形之间的关系，对比其受力变形特性与腿部的生物力学特性可以看出，FLEX-PLI 具有较高的生物仿真度。

图 15 所示为 TRL-LFI 的静力加载测试，对腿部施加弯矩，对膝部附近施加剪切力，得到 TRL-LFI 的膝部弯角、膝部剪切位移与载荷之间的关系，如图 16 所示。可以看出，TRL-LFI 膝部弯角对载荷的响应整体上与膝部的生物力学特性接近，但有所差别。



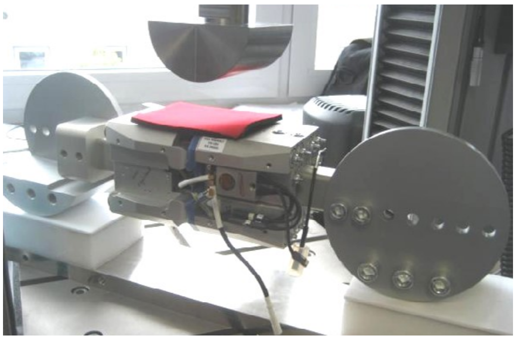
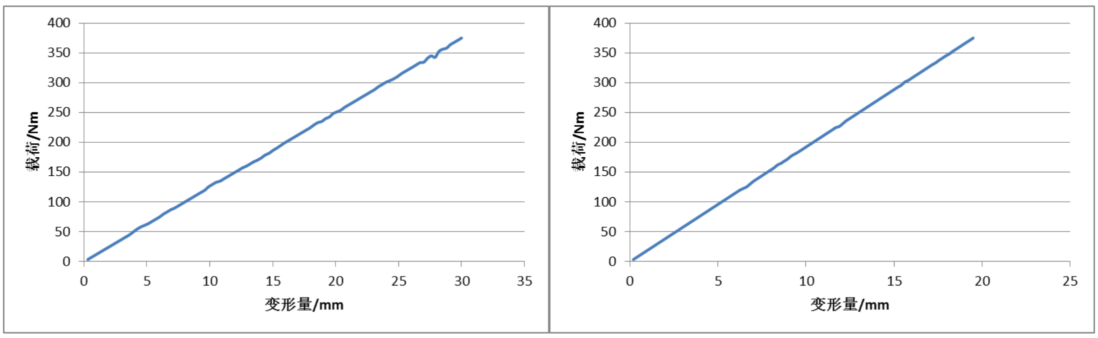


Figure 12. Static load test of femur and knee of FLEX-PLI

图 12　FLEX-PLI 大腿、膝部静力加载测试



大腿　　**小腿**

Figure 13. Bending Moment-displacement of femur and tibia of FLEX-PLI

图 13　FLEX-PLI 大腿、小腿弯矩与变形的关系

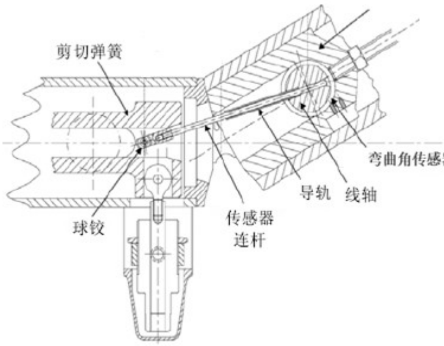


Figure 6.Knee structure of TRL-LFI

图 6　TRL-LFI 膝部结构

4 FLEX-PLI 与 TRL-LFI 性能对比

尸体试验是获取人体的生物力学特性的有效手段，对大腿、小腿、膝关节等新鲜尸体施加一定的载荷，直至骨骼折断或膝关节韧带断裂，通过传感器记录试验过程中的力矩、变形量、弯曲角度、剪切位移等数值即可确定大腿、小腿和膝部的生物力学响应。Kerrigan et al 等研究者通过对试验得到的结果如图 7~图 11 所示。

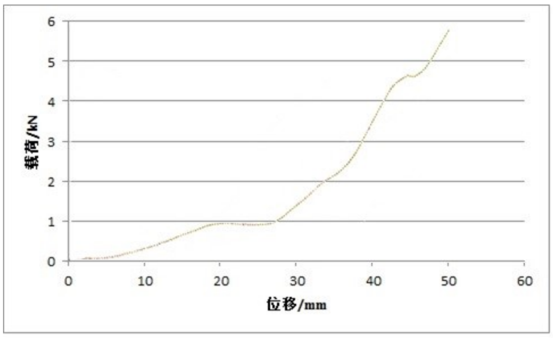


Figure 7.Bending moment-displacement of femur

图 7　大腿中部弯矩与位移关系

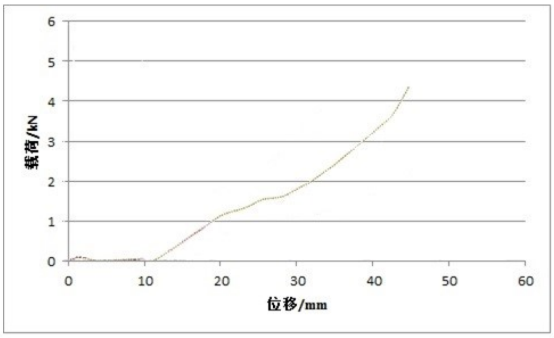


Figure 8.Bending moment-displacement of tibia

图 8　小腿中部弯矩与位移关系

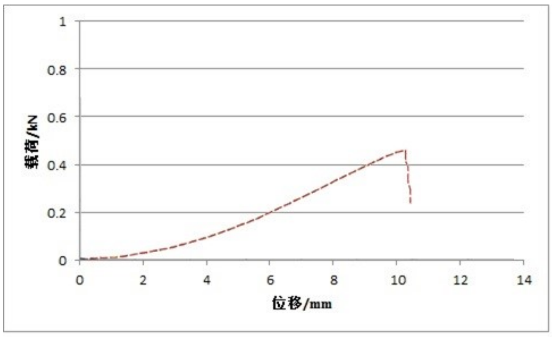


Figure 9. Tensile force-displacement of MCL

图 9　膝部 MCL 准静态拉伸力与位移关系

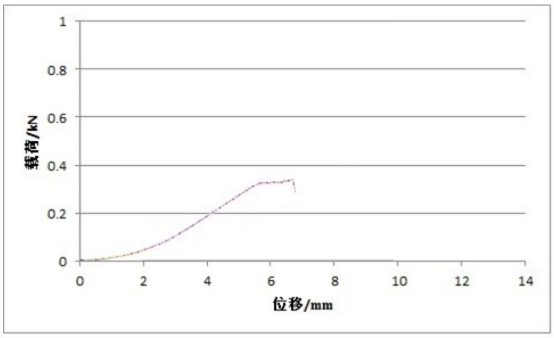


Figure 10. Tensile force-displacement of LCL

图 10　膝部 LCL 准静态拉伸力与位移关系

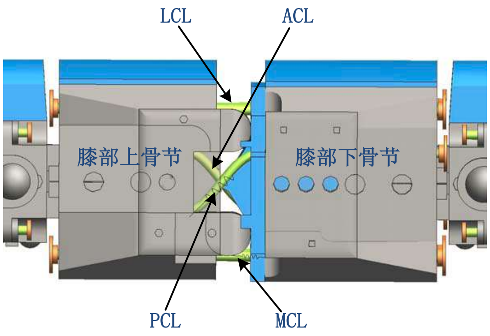


Figure 4. Simulant knee structure of FLEX-PLI
图 4　FLEX-PLI 的模拟膝部结

图 5 所示为 TRL-LFI 的结构。该冲击器上安装了三个传感器，一个加速度传感器和两个角位移传感器，分别用于测量胫骨加速度、膝关节弯曲角及膝关节剪切位移。其中，角位移传感器采集到数据后，经过一定的换算关系得到弯曲角度和剪切位移信息。

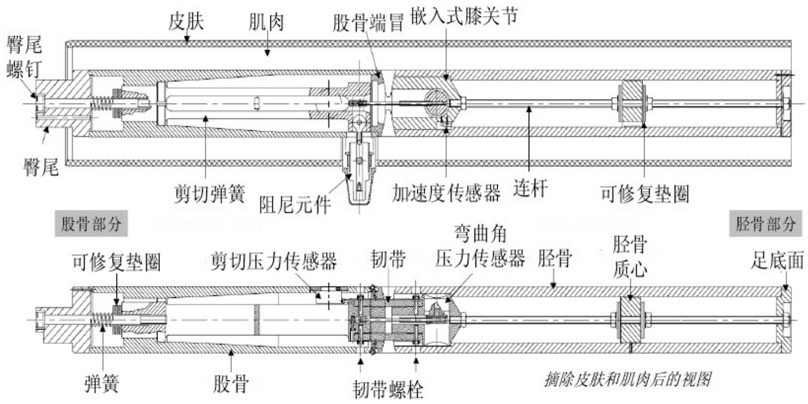


Figure 5. Structure of TRL-LFI
图 5　TRL-LFI 结构图

TRL-LFI 采用了刚性金属管模拟胫骨和股骨，骨骼内部拥有调节腿部质心的机械结构，由于金属管的强度较高，很难有效地模拟人体腿部的变形，因此，TRL-LFI 不能模拟腿骨各个部位的骨折，仅能通过安装在下腿的加速度传感器评价腿部骨折的风险。

图 6 所示为 TRL-LFI 的膝部结构，它是一个可塑形变形的关节，股骨与胫骨之间通过一对金属韧带片相连，该韧带片经过精细的计算与设计以确保与人体膝部韧带的生物力学性能相近。但是，由于发生塑性变形后，膝部金属韧带片的特性有较大改变，其试验的重复性并不理想。同时，TRL-LFI 简化的设计结构与人体膝关节的实际构造有较大差别，因而，其无法模拟膝关节各条韧带的受损情况。

综合以上论述可知，设计方式的不同决定了 FLEX-PLI 在结构上比 TRL-LFI 更接近人体腿部构造，因此，能够针对人体腿部的特定部位放置测量单元，只要腿部模型的力学特性设计能够与人体生物力学性能吻合，其必然能获得更为客观的评价结果。