© by IAAF
21:4; 57-66 2006

Hammer handle testing

By Denis Wilson, Krishna Shankar, Bob Clark, Pat Nolan, Alan Fien

ABSTRACT

In keeping with the IAAF Technical Committee's more rigorous approach to certification of implements and equipment, testing of every manufacturer's hammer handles is required before an IAAF Product Certificate can be granted. The School of Aerospace and Mechanical Engineering, University of New South Wales, Australian Defence Force Academy in Canberra was engaged to develop a method for determining handle strength and test available handles. One of the aims of the project was to make it possible to quantify the stipulation in IAAF Rule 191.7 that the hammer handle "shall not stretch appreciably while being thrown". This article outlines the test requirements, the design of the test rig and the test procedure. To date some 40 handles from 10 manufacturers have been tested. The overall results are presented and details for representative handles are discussed. The authors conclude with a set of comments to guide the design hammer handles.

AUTHORS

Denis Wilson is a former Chairman of the IAAF Technical Committee Stadia Working Group and is currently a technical adviser to the IAAF Technical Committee.

Krisha Shankar is a Senior Lecturer at the Australian Defence Force Academy (ADFA) with over 18 years experience in Mechanical Testing, Structural Analysis, Fracture and Fatigue.

Bob Clark is a Technical Specialist at ADFA with over 20 years experience in Laser Optics, Non Destructive Inspection and Mechanical Testing.

Pat Nolan has over 20 years previous experience in the automotive, aerospace and gas turbine industries and has been employed at ADFA for the last 11 years conducting Materials Testing, Mechanical Design and Fatigue Testing.

Alan Fien is a Senior Lecturer at ADFA with over 30 years of experience in industry and academia. He is an expert in Mechanical Design, Materials Testing, Rotary Wing Analysis, Fatigue and Fracture Mechanics.

Introduction

In the past hammer handles have been regarded as an integral part of the total hammer assembly that had just to pass some rudimentary dimensional and weight checks before being allowed into competition.

In keeping with the International Association of Athletics Federations Technical Committee's more rigorous approach to certification of implements and equipment, testing of every manufacturer's hammer handles is now required before an IAAF Product Certificate can be granted for a manufacturer's hammer assembly.

Background

During the men's hammer throw final at the 2000 Olympic Games it was discovered that the hammer being used by all the throwers had stretched some 9mm during competition as the brace wires of the hammer handle were pulling out of the grip. The same defect was found in the same model of hammer handle used at the warm-up track.

In the IAAF Handbook 2002-2003 and subsequent editions changes were made in Rule 191.7 to the dimensions of the handle and its specification in an endeavour to improve the reliability of the handles. The current wording in Competition Rules 2006-2007 as compared with the 1985-1986 wording has the following additional specification:

"The handle may have a curved or straight grip with a maximum width inside of 130mm and a maximum length of 110mm. The minimum handle breaking strength shall be 8kN (800kgf). The sides of the handle may be straight or slightly curved where the sides meet the grip so as to provide greater room for the thrower's hands.

Note: *The strength of a handle shall be determined in accordance with the procedures given in the proposed IAAF Calibration Handbook to be published later."*

The School of Aerospace, Civil and Mechanical Engineering, University of New South Wales, Australian Defence Force Academy, Canberra, Australia was engaged in 2004 by the IAAF to develop a method for determining handle breaking strength and test manufacturers' hammer handles.

The maximum centripetal force generated in a 7.26kg hammer's wire when the hammer is travelling at 32 metres per second (the assumed maximum speed that can be generated by a thrower) is 3.72kN. Incidentally, a 3mm diameter spring steel hammer wire will stretch 2.6mm when subjected to a force of 3.72kN.

Initial tests indicated that the 8kN minimum handle breaking strength could be achieved without increasing the weight of the handle unduly with a minimum factor of safety of approximately 2.15.

Test requirements

The IAAF handle test requirements include the following:

- Hammer handles are to have a load applied in a universal-testing machine at a uniform rate with the extension recorded until destruction.
- The gripping of the handle should simulate in simple terms the grip by a thrower.
- A load extension curve is to be produced for each handle tested, the ultimate strength recorded, and the point and type of failure recorded.

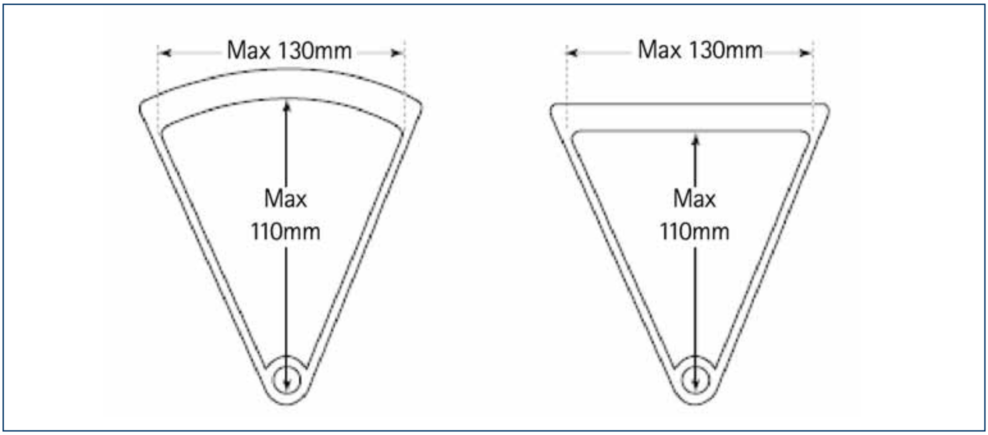

Figure 1: Examples of hammer handles from the IAAF Competition Rules 2006-2007

- The physical details of the handle are to be recorded including handle make & model, length and width of the handle, the weight and the material composition of the handle if known.

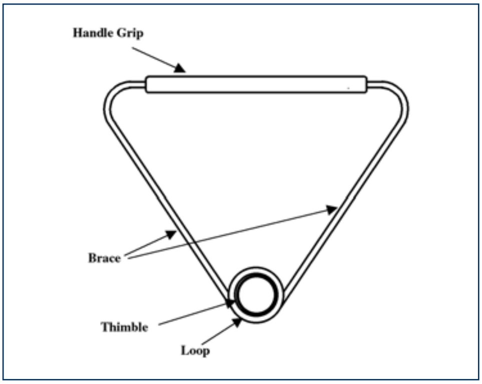

Figure 2: Generic hammer handle showing nomenclature used

Test rig design

The test rig was designed to load the hammer handles in uniaxial tension on a hydraulic universal testing machine (250kN capacity Instron in SACME). The test rig consisted of two parts: an upper component on which the handle grip is mounted and a lower mount to which the loop of the handle is attached. The component parts of the mounts are shown in Figure 3.

A loading pin is inserted through the thimble or the loop in the brace at the apex of the hammer handle and mounted in a yoke that fits in the Instron lower grip.

The centrifugal pull from the handle wire is transmitted through the two side braces as lateral forces at the two ends (or the brace joints) of the handle grip. In the real situation these lateral forces on the handle grip are reacted by a distributed load provided by the fingers and the palm of the thrower. The actual distribution of the load on the handle grip may not be uniform but is likely to vary from person to person depending on individual variations in gripping. However, it appears reasonable that the two outer fingers are likely to provide greater support than the inner two fingers in a natural grip with the four fingers spread symmetrically along the handle grip. This situation is simulated in the loading rig by employing two rollers to provide simple support symmetrically at quarter points along the span of the 130mm wide handle grip. Note that the same test rig can be employed for testing hammers with straight handles as well as curved handles. The positioning of a hammer grip over the rollers is shown in Figure 4.

The loading of the handle grip is shown schematically in Figure 5 along with the bending moment distribution along the span

Figure 3: Components of a modified test fixture

Figure 4: Handle in the modified test fixture (Note: the thick ridge along the base of the grip)

of the hammer grip. It may be noted that the bending moment due to the lateral load is then uniformly distributed across the central half of the span and has a value of PL/8, where L is the length of the handle grip (nominally 130mm). This situation is less severe but more realistic than the bending moment distribution provided by a point load at the centre, and at the same time easier to simulate than a uniformly distributed support along the mid-span of the beam.

Test procedure

The hammer handles were mounted on the upper and lower mounts (as described above), which were inserted into the jaws of the Instron Hydraulic Test machine. The test data consisting of the applied tensile load and the axial displacement (elongation of the hammer handle) were recorded digitally via a data acquisition board into a PC for processing. All specimens were initially loaded up to about 4kN (approximately the working load, i.e. the maximum load expected to be exerted on the hammer handle when used in competitions) at a slow loading rate of 1mm/min, and the load and displacement data collected at a sampling rate of about 4 samples/sec. The specimens were then unloaded and inspected for any permanent deformations. An intermediate load step of up to 8kN was employed if the handle was capable of withstanding this load. Finally the specimen was loaded until failure occurred. For the final tests (loading up to failure) a typical displacement rate of 5mm/min and sampling rate of 20Hz (20 samples/sec) were employed. The failure mode of the hammer handle was observed and recorded photographically.

Test results

To date some 40 handles from 10 manufacturers have been tested. In addition ADFA designed its own prototype handle. To help in the design of the test apparatus and also for comparison with new designs, the IAAF provided two pre-used handle specimens of unknown manufacture.

The results of the tests conducted on a range handles are listed alongside each other for comparison in Table 1. For conciseness

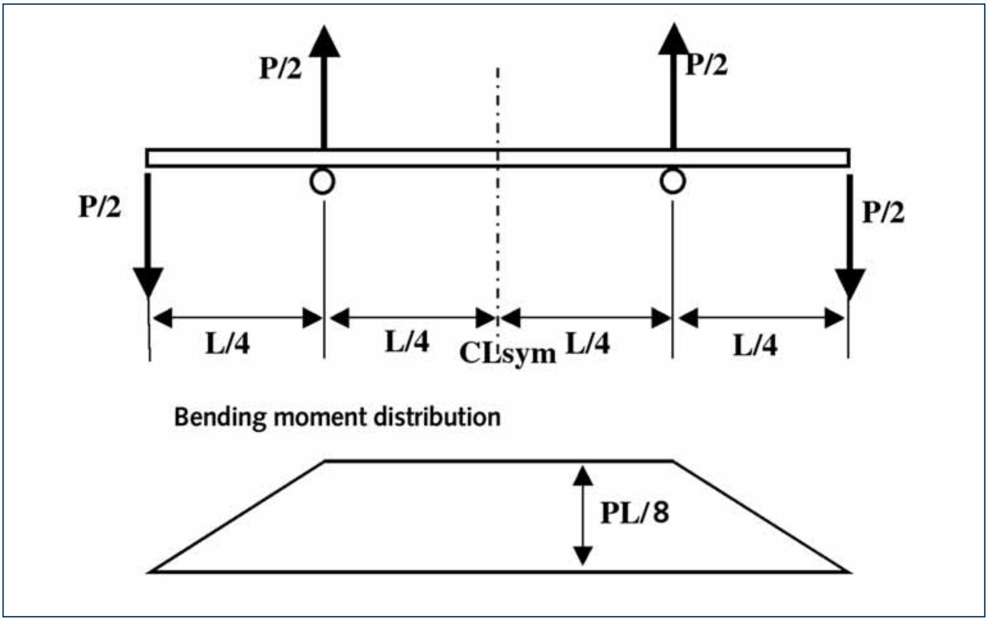

Figure 5: Schematic of loading of handle grip and bending moment distribution

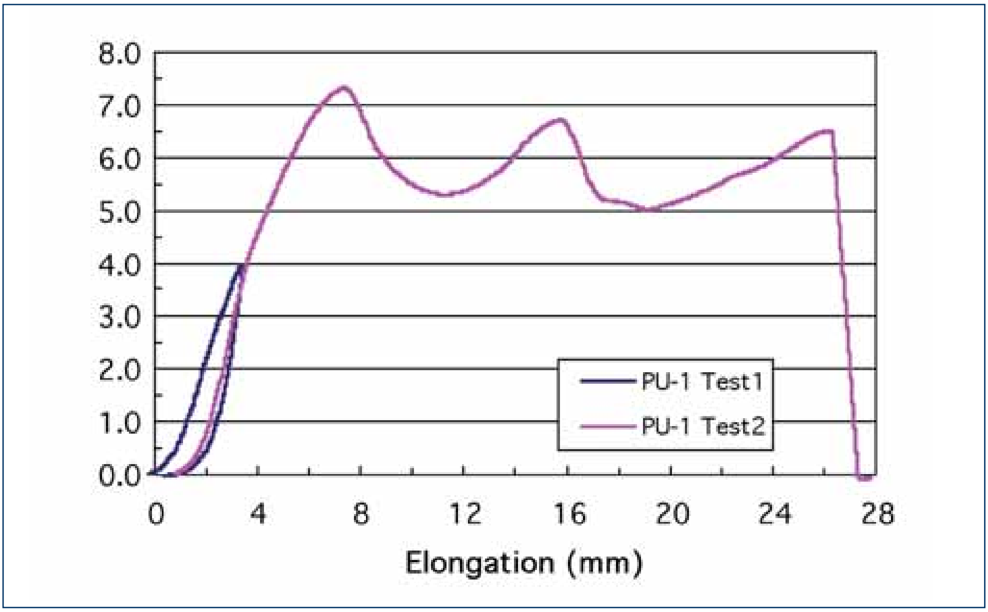

Figure 6: Load displacement plot for pre-used hammer handle PU-1 (All tests)

only the weakest handle of each manufacture is listed. The parameters listed include: the permanent deformation measured after unloading from the first test load of about 4kN, the maximum load carried by the handle, and the failure mode. Specific details observed in tests conducted on some handles are described below.

Table 1: Comparison of Tested Hammer Handles

Manufacturer Grip Shape	Weight (g)	Side Brace	Grip	Grip Width between braces (mm)	Permanent Deformation after 4.0kN (mm)	Tota
Preused straight PU 1	56.7	Steel wire	Aluminium Rectangular cast	110	0.9	
Preused curved PU 2	56.8	Steel wire	Aluminium Rectangular cast	110	1.8	
ADFA Prototype	55	Al Alloy Sheet	Aluminium Alloy Sheet	110	0.14	
A Straight	112	Steel wire	Steel Tube	126	2.6	
B Curved	85	Steel wire	Aluminium Rectangular cast	120	0.62	
B Straight	86.6	Steel wire	Aluminium Rectangular cast	120	0.37	
C Straight	84.9	Steel wire	Aluminium Rectangular cast	128	0.7	
D Straight	85.3	Steel wire	Aluminium Rectangular cast	126	0.48	
E Straight	65.1 + plastic grip cover	Al alloy Sheet	Al alloy Sheet	120	0.07	
F Straight	93.9	Steel wire	Aluminium Rectangular cast	127	0.46	
F Curved	89.8	Steel wire	Aluminium Rectangular cast	126	0.36	
G Straight	134.2	Steel rect. wire	Aluminium Rectangular cast	122	0.13	
H Straight	83.9	Steel wire	Aluminium Rectangular cast	130	1.45	
I Straight	82.9	Steel wire	Aluminium Rectangular cast	116.2	5.6	
J Straight	84.8	Steel wire	Aluminium Rectangular cast	126	0.47	
K Straight	156.8	Cast Al.	Cast Aluminium	114	0.12	
L Straight	77.3	Cast Al.	Cast Aluminium	110	0.25	

Failure mode types:
1 Brace wire pulled out from the grip
2 Grip bending and weld failure
3 Fracture of brace wire inside the grip
4 Fracture of brace leg
5 Grip bending failure

l Deformation at 4.0kN (mm)	Max. Load (kN)	Failure Type	Comment
3.5	7.3	1	Pre-2000 handle
3.8	5.6	1	Pre-2000 handle
0.8	18.5	4	Sharp edges/ susceptible to damage
5	7.8	2	Heavy/low load/ high deformation
3.4	12.8	5	Heavy
3.3	18.3	3	Heavy
2.8	9.3	5	Heavy
2.6	8.7	1	Heavy/strength Low
0.97	19.36	4	Sharp edges/ susceptible to damage
1.36	12.9	4	Heavy
1.81	10.65	4	Heavy
1.37	13.2	5	Too heavy
4.87	13.8	1	Heavy/total deformation too high
8.58	11.4	4	Heavy/total deformation too high
2.11	11.8	1	Heavy
0.55	11	4	Too heavy
1.9	13.5	4	This is the benchmark

Test result details for some representative handles

The load versus axial displacement (elongation of the handle) of the initial tests (up to the working load of about 4kN) as well as the subsequent tests performed on the pre-used hammer handles PU-1 and PU-2 of pre-2000 design unknown manufacture are plotted respectively in Figures 6 and 7. In both cases the handles were initially loaded up to about 4kN and then unloaded to observe changes in the length of the handles. The permanent deformations measured after the initial tests on PU-1 and PU-2 were 0.9mm and 1.8mm, respectively. The handle with the straight grip, PU-1, failed at a load of about 7.3kN while the handle with the curved grip, PU-2, failed at a load of about 5.6kN. The latter lower failure load is probably due to the fact that there are additional bending moments generated in the curved grip from the side compressive forces from the side braces.

Failure in both cases occurred by gradual straightening of the right angle bends of the braces inserted into the handle grip, with the braces intermittently slipping and getting caught inside the grip tube; this explains the up and down excursions of the load versus displacement plots observed in Figures 6 and 7 respectively. The elongation of the handles at failure was 27.4mm and 18.2mm for handles PU-1 and PU-2 respectively. A photograph of the failed specimens PU-1 is shown in Figure 8. It is to be noted that there is not much deformation of the handle grips, or of the thimble around which the brace wire looped. The handle grip and the brace wire remained intact. The failure in both cases was primarily due to the failure of the joint between the handle grip and the brace ends. Similar failures were noted in a number of new handles of similar design that relied on friction to hold the brace wires in the grip.

The load displacement plots for the ADFA prototype and the manufacturer L very nicely designed handle, and a photograph of the failed ADFA prototype are shown in Figures 9 to 11 respectively.

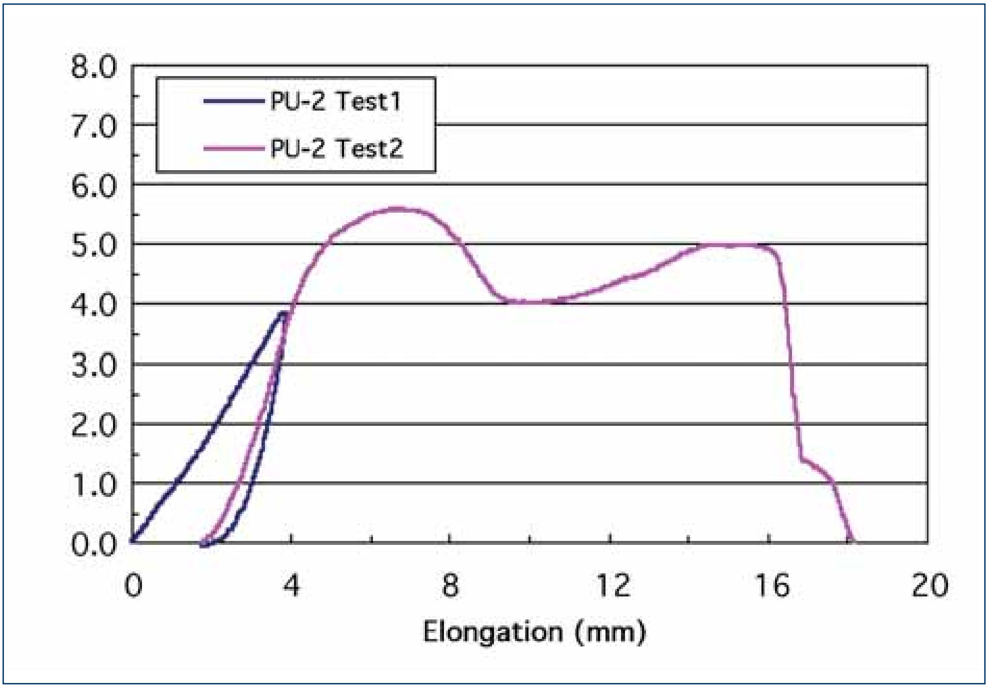

Figure 7: Load displacement plot for pre-used hammer handle PU-2 (All tests)

Figure 8: Joint failure of hammer handle PU-1

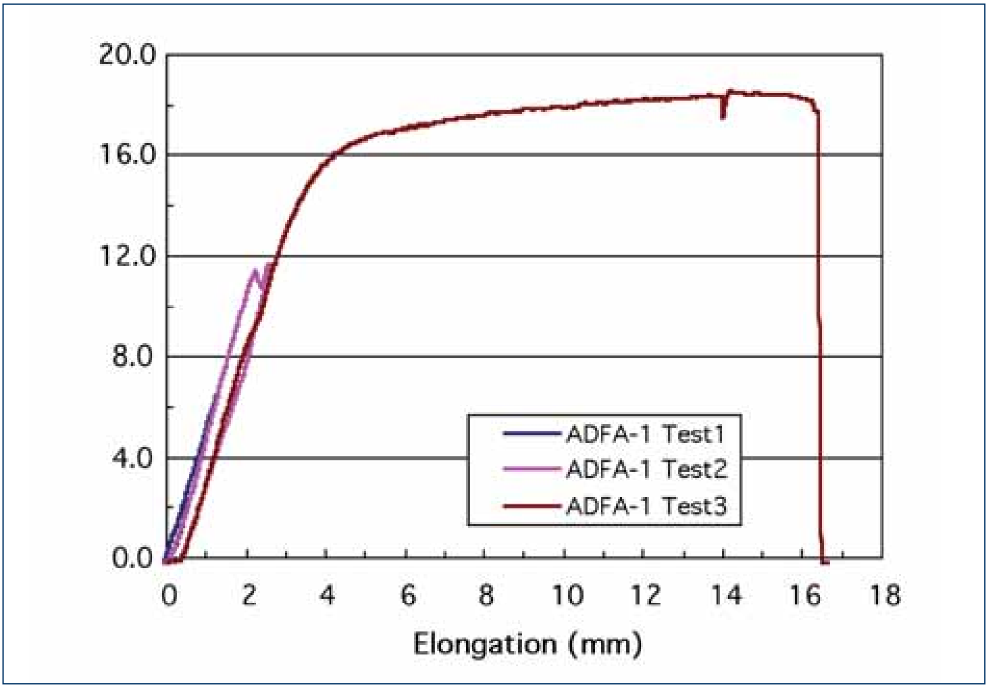

Figure 9: Load displacement plots for hammer handle ADFA-1

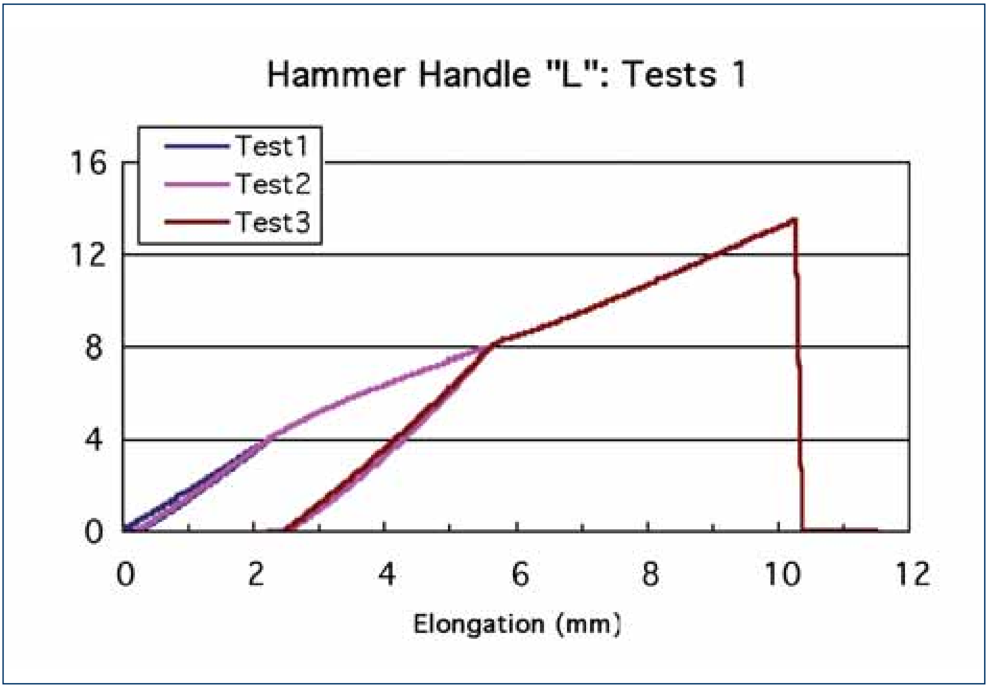

Figure 10: Load displacement plot for manufacturer L hammer handle (three tests)

Figure 11: ADFA-1 Hammer handle after failure

Comments

- Handles that are cut from one piece of material or cast in one piece are lighter for the required minimum strength, less variable in strength and deformation, and have less deformation.
- Handles that rely on friction to keep the side wires in the grip have more variable lower strength and larger deformation characteristics.
- A handle with a curved grip will have a lower strength than a similarly constructed handle of the same dimensions with a straight grip.
- If the width of the grip between the braces is increased the weight of the handle will increase and the maximum load the handle can carry will be reduced.
- At least five handles of a particular type are statistically required to assess properly the handle characteristics.
- Any handle that weighs more than 80g may not be able to be used with existing hammer heads and remain within the maximum weight of 7.285kg for competition of a nominal 7.26kg hammer assembly.
- Heavier handles mean that the hammer head has to be reduced in weight and this would make the hammer less effective.

Conclusion

It is now possible for a realistic upper limit to be stipulated for the total deformation allowed in a hammer handle so as to quantify the stipulation in IAAF rule 191.7: "It shall not stretch appreciably while being thrown".

Please send all correspondence to:
Krishna Shankar
k.shankar@adfa.edu.au
Imre Matrahazi
imre.matrahazi@hq.iaaf.org
Denis Wilson
dwilson@webone.com.au