HAMMER CAGE SAFETY NETTING

Introduction

The netting used in hammer safety cages is the single most important safety component of the cage but unfortunately to date there has not been a very scientific approach to its specification for athletics.

In the 2000-2001 Handbook, as an interim measure, the minimum breaking strength of the cord used in the netting was increased to300kg from 165kg. However, the actual strength of netting in practice is determined by a number of other factors apart from cord strength.

Design Factors

The kinetic energy of a hammer striking the netting at 32 m/s = $0.5mv^2 = 0.5 \times 7.26 \times 32 \times 32$ = 3,717 Nm = 3.717 kJ.

The netting absorbs this kinetic energy by a combination of the work done in moving the mass of the netting and strain energy absorbed by stretching of the netting.

If the netting was completely unrestrained the distance travelled by the netting would depend on mass. A 10 square metre section of 5mm diameter polypropylene netting would weigh approximately 4kg. The work done to move the netting 1 metre would be $4 \times 9.8 \times 1 = 39.2$ Nm which is insignificant compared with the hammer's kinetic energy and therefore can be neglected.

The closeness of the point of hammer contact with the cage netting with respect to the nearest points of support is very important. Most damage to cage netting is tearing near to a support or crushing of the netting against the metal supporting structure. It is claimed that physically the maximum angle of hammer release to the horizontal is 52°. At the rear of a stand alone hammer cage the horizontal distance is no further than 3m and the maximum height of the point of contact with a an early released hammer would be approximately 3.8m. Similarly it is possible to calculate the following approximate heights:

• Edge of IAAF 2004-2005 gate	9.6m
• Edge of Wilson proposed alternative (gate 3.2m wide)	6.7m
• Gate pivot point 4.2m from centre of circle	6.1m

The calculation of static strain energy let alone dynamic strain energy in netting subject to a moving load would be exceedingly complex therefore laboratory testing is used to classify the strength of netting.

Laboratory Testing

European Standard EN 1263-1997 uses both static and dynamic testing of industrial safety nets. In the dynamic test a 100kg steel ball 500mm diameter is dropped 7m onto the centre horizontally supported 5m x 7m netting so that the kinetic energy to be absorbed by the netting is approximately 7kJ. We see from above that this compares favourably with the kinetic energy of the hammer that is 3.7kJ but does not take into account the additional stress that the netting would endure if the hammer hits the netting close to a point of support nor the effect of ageing on the netting strength.

The dynamic test simulates the 7 metre fall of a 100 kg body before being caught by netting and checks strength of the netting and its attachment to the supporting structure.

The static testing of netting applies a gradually increasing upward pull via a 500mm diameter ball on the centre of a 3m x 3m square of netting. The static energy absorption must exceed the minimum breaking energy defined in EN 1263-1 by a 1.5 factor of safety and an additional factor to account for decrease in strength due to ageing (1.2 might be appropriate for polypropylene netting). The static test is used to determine the type of netting that is appropriate for the industrial safety use.

One would expect that if the static test was undertaken using a 110mm sphere then the energy absorbing capacity would be slightly less than that obtained with a 500mm sphere.

The other difference with hammer throwing to a falling body is that the angle at which a hammer usually hits the netting at maximum energy is approximately 45 degrees to the plane of the netting.

The most damage is done to netting that is attached directly to a metal frame particularly the cage gates as there is minimal possibility of the netting acting effectively as an energy absorber. It is not appropriate to design the entire cage netting for such a situation. The manufacturers in those circumstances usually apply foam padding to the metal structure and double up the netting over the gate.

To minimise the cost of hammer cage netting it is logical to use where possible the existing industrial netting test facilities with changes as appropriate. Therefore I would suggest that the static test pulling sphere should be 110mm diameter applied at the centre of 3m x 3m netting

The dynamic test might be conducted by dropping a mass onto the netting 9m x 7m which is attached to the supporting frame on all four sides such that the plane of the netting is at 45 degrees to the horizontal. The test mass to be dropped vertically at distance 1.5m (2.12m along the plane of the netting) from the lower short side with new netting. (see attached sketch).

The selection of the size of the test mass is critical as is the appropriate test kinetic energy. It would appear that in the EN 1263-1 dynamic test no allowance is made for a factor of safety or a factor for future ageing of the netting. If this was adopted for our testing then the required dynamic energy absorption is 3.717kJ. A 110mm diameter sphere of 7.8 specific gravity steel weighs 5.436kg and would have to be dropped 69.8m to develop 3.717kJ kinetic energy. This is unrealistic and even a more realistic drop height of say 10m would mean that the diameter of the test sphere would be considerably greater than the size of the hammer head with consequent test error.

Another possibility is to use denser materials such as:

Lead	SG 11.34 (too soft)
Tungsten	SG 19.22
Depleted Uranium	SG 18.7 (environmental concerns)

A combination of materials might also be practicable.

If the test sphere is made of tungsten then the diameter of the sphere required for various testing heights to develop 3.717kJ kinetic energy is shown below.

Height m	Sphere Dia. mm
28.33	110
17.15	130
10.00	156
7.00	175

Another alternative is to drop a cylinder with a half sphere head 110mm diameter onto the netting. The lengths of the steel and tungsten cylinders to be dropped 7m are 694mm and 260mm respectively. The concern is that the cylinder may flop over on hitting the angled netting. This would be more likely with the longer steel cylinder.

It may also be possible to fire a hammer head as a cannon ball at the suspended hammer cage netting but this may be more technically challenging as it would be necessary to carefully determine the explosive charge to give a 32 m/s velocity.

Conclusions

It should be possible to adopt the testing principles used in EN 1263-1 to test hammer cage netting but using different sized masses in both the static and dynamic tests. The natural and artificial ageing tests used in En 1263-1 might be adopted for hammer cage netting.

It is not possible to allow in the test for poorly designed support structures that let the hammer hit the support as well as the netting. This is an issue for the manufacturer and the IAAF if it provides a product certificate for such a cage.

Information provided by one manufacturer would seem to indicate that 5mm dia polypropylene with 45mm mesh would meet the above test requirement.

Recommendations

A testing laboratory that already undertakes testing of industrial netting, e.g. Zentrum fur Sicherheitstechnik at Erkraft, to be asked to comment on the practicability of a dynamic strength test as outlined above using a tungsten sphere dropped from 10m, or a shaped tungsten or steel cylinder from a height of 7m.

Subject to the testing laboratory advice, full scale static and dynamic testing should be undertaken on netting selected using the EN 1263-1 design techniques and the adopted hammer cage netting test.

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