SAFETY CONSIDERATIONS FOR GYMNASTICS LANDING MATS — Properties, Construction, Standards and Use

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INTRODUCTION

The dismount is a critical phase of any routine, especially in the high bar and vault. Poor landing may result in injury and / or point deduction (e.g. up to 0.2 points for a hop after landing according to the FIG code de pointage). Previous research indicates that the landing can be separated into a 'high impact' phase and a so called 'balance-phase'.

The landing phase should ensure controlled, stable and safe conditions. In well executed landings the largest part of the energy is absorbed by negative dynamic work of the extensor chain of the lower extremities. However, the human body is not well suited to cope with the high impact forces occumng within 50 to 60 ms after touch-down. Hence a synergistic system is needed with the gymnast as active part and the landing mat as a passive component to reduce the initial peak force without negative effects on the remaining landing phase.

Soft mats do not solve the problem. They are constucted for body landings or non-controlled situations. As soon as the gymnast, performs a controlled landing, the soft mat is excessively compressed due to its point elastic bahaviour. This causes fixation of the feet and potentially serious injuries such as torsional fractures. Landing mats should have homogeneous, surface elastic behaviour. Despite the fact that all mats used in major competitions have to be tested and approved by the FIG, complaints do not cease, injuries are reported and additional mats on top are used and tolerated. The single and accumulated loads imposed on the gymnast increase because of higher and more complicated dismounts. Hence, continous research effort is needed to improve the equipment as well as the norms and standards.

METHODS

The FIG norms are basically obtained by sliding a 20 kg mass down a rod. The height is adjusted to offset frictional losses and ensure a velocity of 3.96 m/s prior to impact. This is equivalent to a drop from 0.8 m. We chose to use different masses (10 and 20 kg and heights of 1.6 and 0.8 m) and a free falling impactor. Data from a PCB accelerometer was read into the APAS analog module with a sampling rate of 10 kHz. The averaged data from ten measurements for each of nine points on the mat was analyzed. Deformation of the mat - i.e. penetration of the mass was computed through double integration of the acceleration data and plotted vs. force. Furthermore the energy vs. force, the penetration vs. energy and the penetration vs. velocity plots were produced to help visualize the behaviour of the mat. The graphs presented in this paper were obtained by dropping the masses with identical energy in order to demonstrate the visco-elastic properties of the mat.

RESULTS AND DISCUSSION

The sides,corners and, in the case of adjacent mats, gaps, deserve special attention. If those areas are not reinforced with higher density foam, the ankle is proned to getting injured. The commonly used glueing of harder blocks at the edges causes delamination and non-continous surface behaviour if the mats are placed adjacently. We had the best results with wedge shaped inserts around each mat to avoid these problems.

The FIG uses standards and procedures developed by Schweizer (1985). These were adopted by other standardizing committees. A 20 kg mass instrumented with an accelerometer slides down a 0.8 m rod. The acceleration vs. time data is then used to compute the maximum decelerating force, the indention of the mat and the rebound height. We see validity related problems with this approach: Can a mat be adequately characterized by this procedure? And is it legitimate to conclude from one specific experimental setup (i.e. mass and height dropped=constant) to the total scope of the mat? Table 1 summarizes the maximum values for the respective parameters as defined by the current FIG norms,

TABLE 1: FIG norms for 12.15, and 20 cm thick mats

Thickness of the mat	12 cm	15 cm	20 cm
Penetration (mm)	< 105	< 105	< 110
Rebound (mm)	< 150 (< 100)	< 100	< 120 (< 90)
Maximum Force (N)	< 4500 (< 4000)	< 4000 (< 3500)	< 3650 (< 3000)

The latest draft (March 1994) for norm changes is indicated in bracquets. Neither procedure nor parameters but only selected standards were changed. The penetration is limited to a maximum value to avoid foot fixation. This makes sense only when there is no force distributing layer near the top of the mat. It is evident that a longer path for deceleration can be used to lessen the impact on the body. However the norms allow 87.5%, 62.5% and 55% compression of the 12, 15 and 20 cm mats respectively. We are not surprised to find that good 15 cm mats fulfill the 20 cm norms. In our opinion the norms should not limit the penetration, provided that the mat does not bottom out and the feet remain unfixed. Comparison of the two experimental conditions where the mat and the energy of the impactor were constant but the masses (10 and 20 kg) and heights (1.6 and 0.8 m) were varied clearly show the visco-elastic properties of the mat. Figure 1 shows the velocity - penetration graph for the two conditions. The 10 kg mass dropped from 1.6m touches the mat with a velocity of 5.6 m/s, compresses it by 96 mm and looses contact with the mat 37 mm below its surface with a rebound velocity of 2.7 m/s. The 20 kg mass dropped from 0.8 m to have identical energy at contact has a touch-down velocity of 3.96 m/s, a maximum deformation of 104 mm and a rebound velocity of 1.7 m/s 45 mm below the mat's top.

The deformation vs. Force graph (Figure 2) shows that the mat reacts stiffer when loaded with the small mass at higher velocity. This can easily be seen from the slope of the curve up to the maximum of force.

CONCLUSIONS

Landing mats should absorb the initial peak force. This requires optimally large deformations. To avoid foot fixation, a force distributing layer near the top of the mat is needed to ensure the necessary surface elasticity. The procedures for standardization and the absolute norms should be reconsidered. The viscoelastic behaviour of the foam causes the necessity to test a range of energies with varied test conditions (masses and heights dropped).

More realistic electro - mechanical systems, possibly in conjunction with biomechanical models and standardized evaluation by gymnasts are needed to keep improving the safety of the equipment.

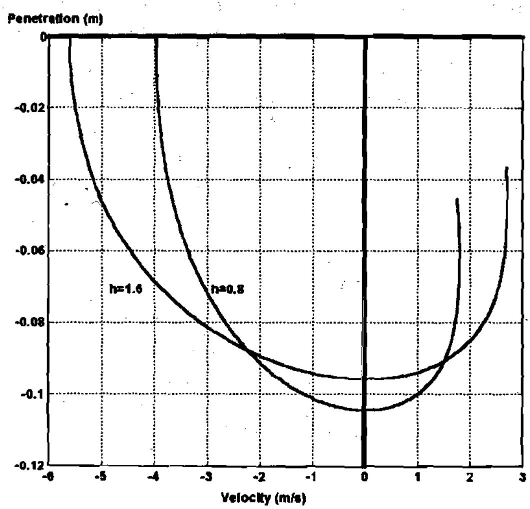

FIGURE 1: Penetration vs. Velocity

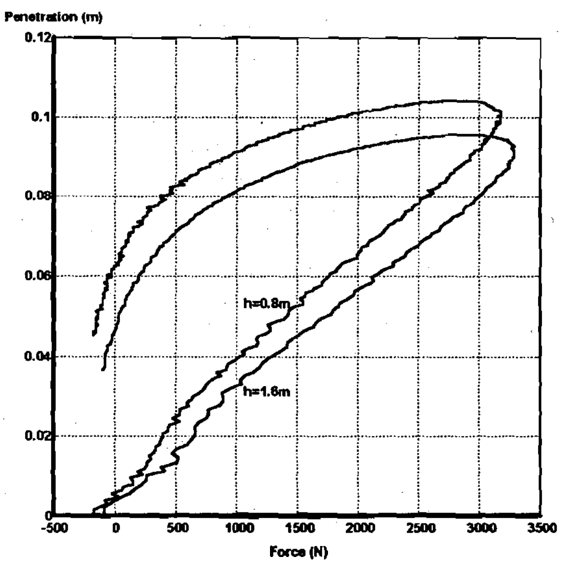

FIGURE 2: Penetration vs. Force

The energy vs. force curves (Figure 3) show the higher peak force for the test condition with the small mass. The penetration vs. energy graph (Figure 4) helps to visualize the absorbed and returned energy. The presented results lead to the conclusion that the drop test with a single condition (20 kg and 0.8 m) does not adequately describe the mat's behaviour.

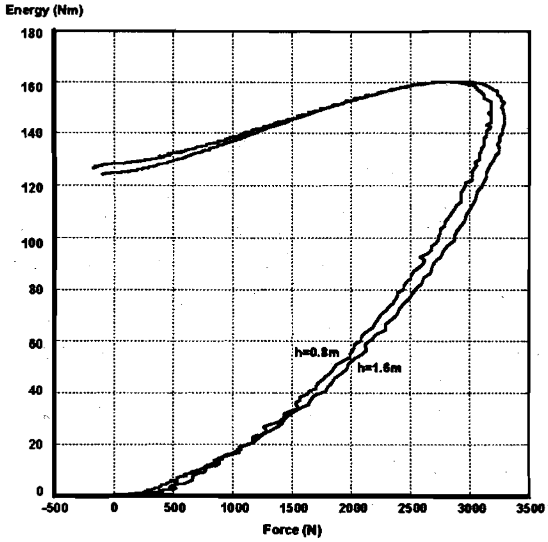

FIGURE 3: Energy vs. Force

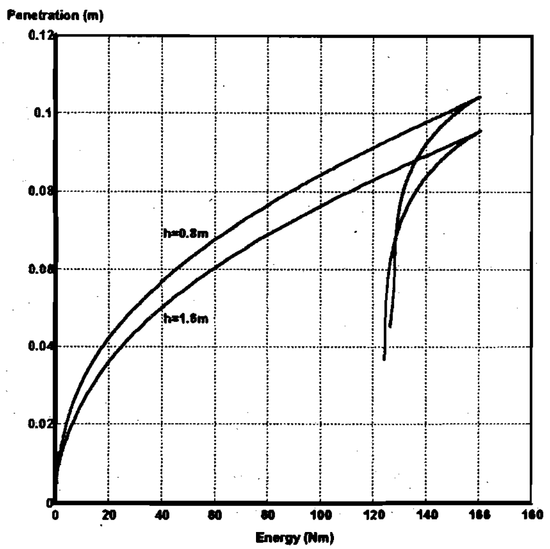

FIGURE 4: Penetration vs. Energy

When looking at these graphs one must keep in mind their partial redundancy. All curves are computed from the basic acceleration - time data but they nevertheless serve well to highlight different facets of the results.