

FOOTWEAR CUSHIONING EVALUATION METHOD BASED ON HUMAN RESPONSES

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INTRODUCTION

It has been said that running shoes has 8 requirement properties, cushioning, stability, flexibility, grip, durability, air-permeability, light weight and fitting. Especially shoe cushioning property is one of the most important factors for runners, because runners are always subjected to ground reaction impact force during contact phases. In this study the new simple evaluation method of this cushioning property based on the human response is proposed. In order to check the validity of the proposed method, the cushioning properties of EVA foams obtained are compared with sensual testing results. Finally the practical designing example of sole cushioning based on the proposed evaluation method method is introduced.

PROPOSED EVALUATION METHOD

The ground reaction force which causes the injury implies components with various frequencies. To clarify the effects of various frequency components upon the human body is very difficult. There is an important fact that the lower frequency component is more uncomfortable for human body. In this evaluation method time series of the accelerations obtained from human drop tests onto a rigid surface and EVA foam are processed by Fast Fourier Transformation. When compared both the results, the reduction in each power spectra corresponds to the shock absorption in the EVA foam. *Cushioning Parameter (CP)* is defined as the following Eqn.1.

$$Cushioning\ Parameter \equiv \sum_{f=5}^{50} d(f) / f^3 \quad Eqn.1$$

Where f and $d(f)$ denote the frequency and the reduction in power spectrum, respectively. $1/f^3$ indicates the weighting function which weightens the reduction in lower spectrum.

EXPERIMENT

A subject with extended knee position is dropped onto various midsole material (EVA) sheets from the height of 50mm. The velocity is similar to the impact velocity on the normal running. The position of the accelerometer attached is 100mm apart from the tibial plateau on the shank. The history of the acceleration output is measured during the contact. The frequency domain curves are obtained by FFT and CP values corresponding to each EVA sheets are calculated. EVA foams used are E40_15, E50_15, E60_15 and E70_30. Here E40_15 denotes the EVA foam with SRIS-C hardness 40 and 15mm thickness.

RESULTS AND DISCUSSIONS

Time series of accelerations for E_40_15, E70_30 and bare foot are shown in Figure 1. The barefoot result has much higher acceleration peak than other results. This indicates that EVA foam insertion can reduce the

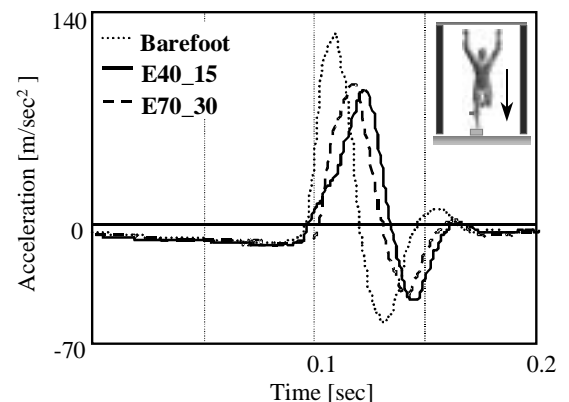


Figure 1 Histories of acceleration obtained from three kinds of human drop tests.

maximum acceleration excited in human lower extremity. The important point to note is that the peak value obtained from E40_15 is similar to that of E70_30. By using the conventional cushioning evaluation method (Cavanagh, 1980), the cushioning property of E40_15 is almost the same as E70_30. However the subject could feel a quite difference in both the test specimens. Judging from the subject's feeling, E40_15 has much better cushioning rather than E70_30.

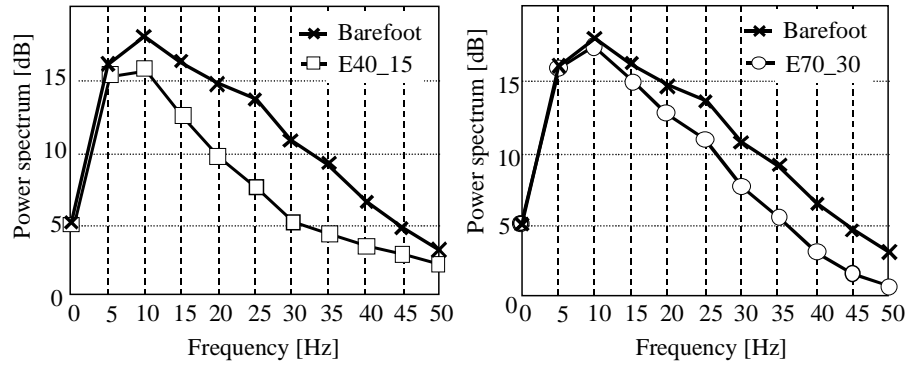
Bode diagrams obtained from Figure1 are shown in Figure 2. By substituting the reduction of power spectra in every frequency for Eqn.1, *CP* values are calculated. Figure 3 shows the comparison of *CP*s with sensory testing results. In the sensory test, cushioning feeling is processed by the paired comparison method. Subjects are 4 males with various heights and weights. Subjects could not look at any EVA foams in this test. This comparison indicates that *CP* value corresponds to the human feeling concerning cushioning property of EVA foam. In other words, EVA sheet with the higher *CP* value can produce the better cushioning.

DESIGNING EXAMPLES

Figure 4 shows the designing example of running shoe sole. For increasing the *CP* value, it was found that the application of shear deformation in shoe sole was effective. In order to produce the shear deformation, sloped groove was designed in the first contact area. This off-axis effect between ground surface and groove slope can produce the higher shear deformation. In case that the off-axis angle θ shown in Figure 4 is 45 degree, *CP* value predicted by the numerical simulation (Nishiwaki, 1999) is maximized. At the same time sloped gel which can produce the higher *CP* values was designed.

REFERENCES

Cavanagh, P.R., *The Running Shoe Book*, Anderson World Inc., pp.46-59. 1986
 Nishiwaki, T., *The evaluation method of cushioning property based on the numerical simulation*, Proceedings of 6th JISSE, pp.775-778.



(a) Bode diagrams obtained from E40_15 (b) Bode diagrams obtained from E70_30

Figure 2 Comparison of Bode diagrams between bare foot and EVA foams.

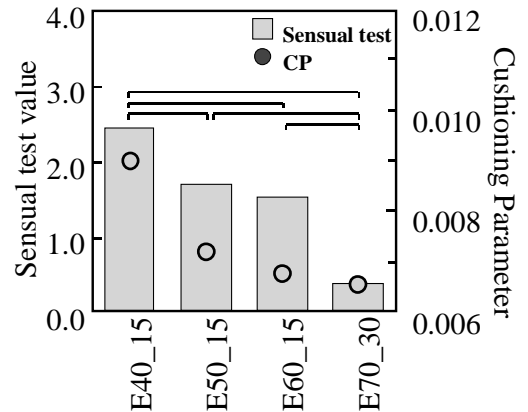


Figure 3 Comparison between *CP* measured and sensual testing results.

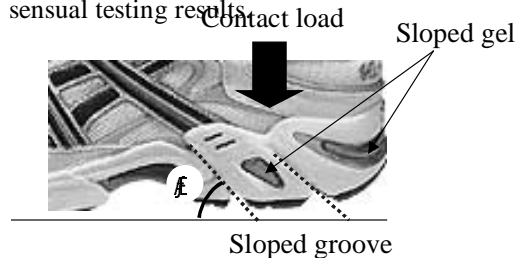


Figure 4 Sole designing example.