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CHARACTERIZATION OF DYNAMIC PROPERTIES OF POLYURETHANE FOAMS FOR AUTOMOTIVE SEATS BY VIBRATION TESTS

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ABSTRACT
Dependence of the dynamic stiffness of foam materials for car seats on 1) magnitude and duration of static compressive load and 2) static stiffness is experimentally investigated for several specimens. The static stiffness is obtained from the Indentation Force Deflection (IFD) curves. The dynamic stiffness is obtained at 5 Hz at which dynamics of seats is most influential on the ride comfort. It is observed that dynamic stiffness and its variation with static loading duration in logarithmic scale are proportional to the static stiffness at the given static loading regardless of types and dimensions of the foam. It is shown consequently that, using such proportional characteristics, dynamic stiffness of the foam materials at a given magnitude and duration of static loading can be predicted from the IFD curves.

1 - INTRODUCTION
Human occupants in a vehicle are in direct contact with seats, of which the primary function is to improve ride comfort by isolating passengers from vehicle body vibrations induced by road surface. Hence, tuning works are often done for a better ride by changing the seat dynamics. Major portion of the seats is constructed with flexible polyurethane foams, which means that seat dynamics is controlled mostly by shapes and material properties of the foams.

It is important to note that, for a better design of car seats, dynamic stiffness of the foams depends on two factors; magnitude of static compressive loading [1] and duration of the static loading. The latter is known to be due to inherent creep behavior of the viscoelastic foam materials [1, 2]. In this study, dependence of the dynamic stiffness of foam materials on magnitude/duration of static compressive load and static stiffness is experimentally investigated in a more systematic way for several specimens. Dynamic stiffness and static strain were measured with respect to duration of the static loading for given static loads. The static stiffness was obtained from measurements of Indentation Force Deflection (IFD) curves with respect to compressive static loads. The dynamic stiffness and its variation with static loading duration in logarithmic scale were found to be proportional to the static stiffness regardless of types and dimensions of the foam materials. Using such characteristics, variations of the dynamic stiffness with loading duration were predicted from an IFD curve and compared with the actual measurements for different compressive static loads.

2 - FOAM SPECIMENS AND MEASUREMENTS
Several types of foam specimens were prepared for the static and vibration testing, which are classified into three groups as follows:

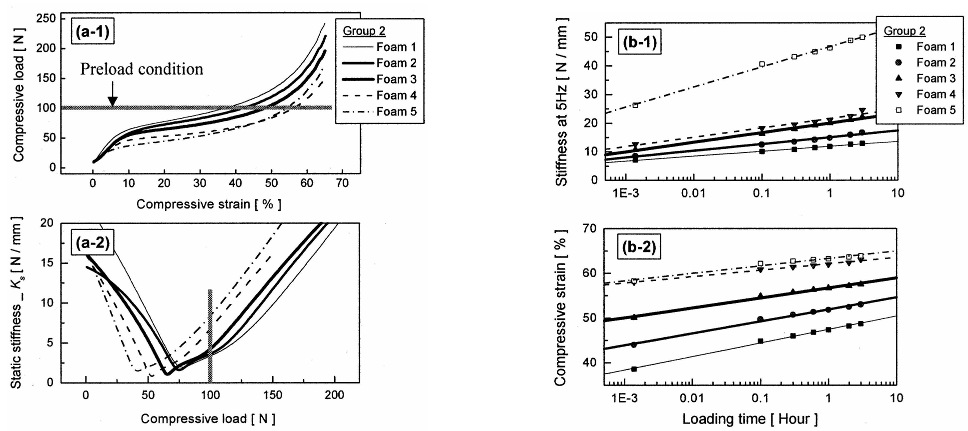
- Group 1. Two kinds of molded foam blocks: 400×400×100 mm^3
- Group 2. Five kinds of foam blocks cut from seat cushions: 100×100×50 mm^3

- Group 3. Five kinds of foam blocks cut from seat backs: $100 \times 100 \times 30$ mm^3

Indentation Force Deflection (IFD) curves of all these foams were measured according to ASTM D-3574 [3]. Static compressive loads for dynamic stiffness measurements were chosen as 400N for group 1 by considering mean weight of human body and 100N and 50N for groups 2 and 3 respectively by considering the loaded area.

3 - IFD CURVES AND DYNAMIC CHARACTERISTICS OF FOAMS

Fig. 1(a-1) shows IFD curve measurements for group 2 and Fig. 1(a-2) shows the static stiffness derived therefrom as functions of compressive static loads. Fig. 1(b-1) shows variations of the dynamic stiffness at 5 Hz with respect to the duration of loading in logarithmic scale for a chosen static loading and Fig. 1(b-2) shows compressive creep behavior. It can be clearly seen that, greater the static stiffness, greater the dynamic stiffness itself as well as its rate of increase with respect to time. It can also be seen that both dynamic stiffness and static strain can be well fitted by linear functions of the loading duration in logarithmic scale.



(a): IFD curve (1) and static stiffness (2).

(b): Dynamic stiffness (1) and creep behavior (2).

Figure 1: Static and dynamic properties of various foam materials.

4 - RELATION OF DYNAMIC STIFFNESS TO STATIC STIFFNESS AND DURATION OF STATIC LOADING

The dynamic stiffness measured at 5Hz is highly proportional to the static stiffness as shown in Fig. 2 regardless of the types of the foam used in this study. Furthermore, the rate of increase in the dynamic stiffness with respect to the logarithmic duration of the static loading is also found to be proportional to the static stiffness and the proportionality is independent of the types and dimensions of the foam as presented in Fig. 3. From these two figures, it was thought that the dynamic stiffness as well as its variation with the loading duration could be estimated from the measurements of static stiffness. Then, dynamic stiffness and its variation with duration of the static loading was predicted using the IFD curves for other specimens at given static loads and compared with the actual measurements.

Fig. 4 shows some results, where it can be seen that predictions of the dynamic stiffness and its variation with the loading duration are very accurate.

5 - CONCLUSIONS

Dynamic stiffness and its variation with loading duration are predominantly governed by the static stiffness that can be obtained from the IFD curve. In this viewpoint, requirement of dynamic testing of the foam materials for the seat design and analysis can be fairly reduced by exploiting the IFD curve measurements.

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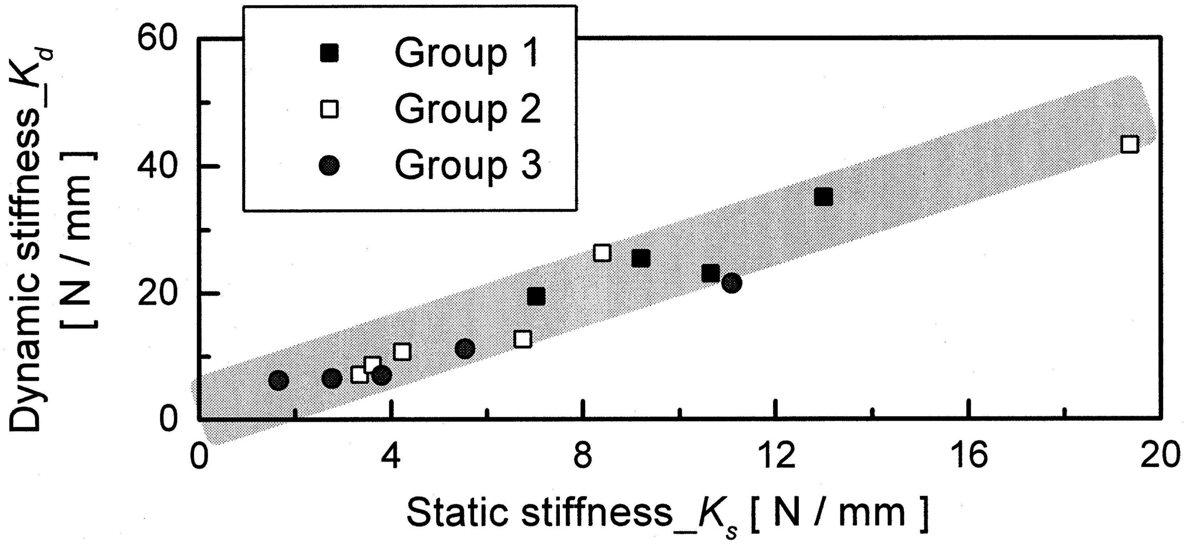

Figure 2: Modulus of dynamic stiffness linearly dependent on magnitude of static stiffness.

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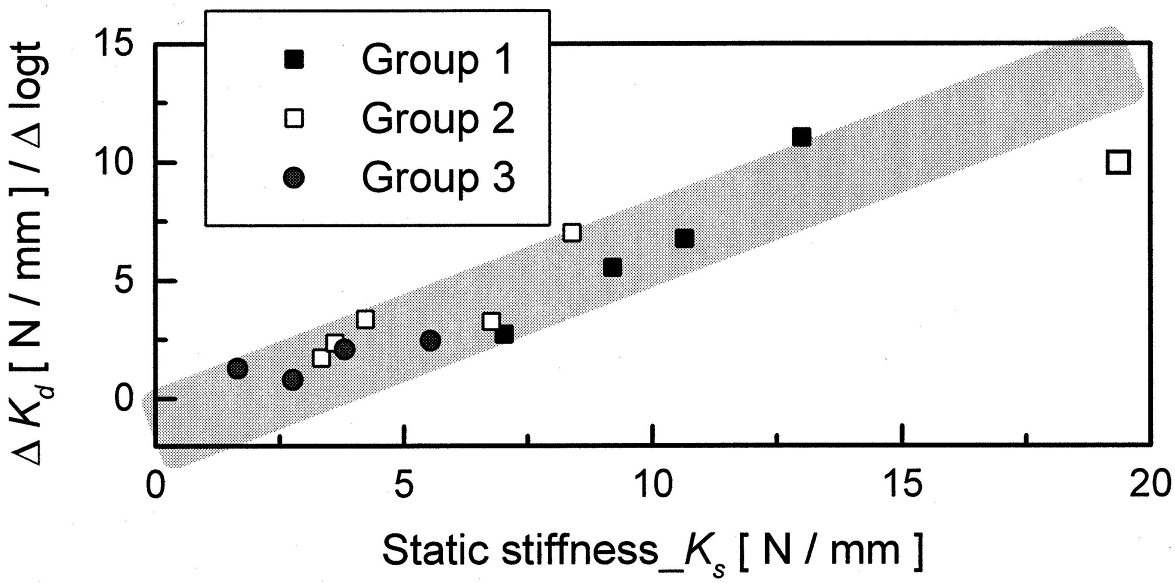

Figure 3: Rate of increase of dynamic stiffness with respect to loading time of logarithmic scale.

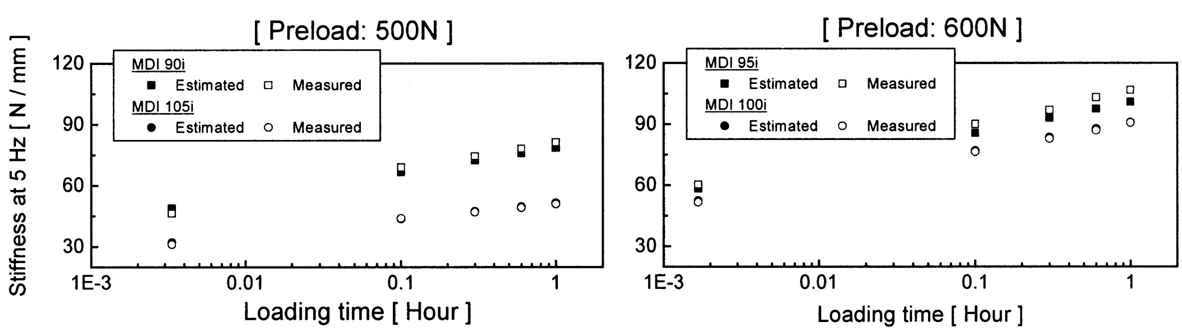

Figure 4: Predicted dynamic stiffness from static stiffness.