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VIBRATION-DIAGNOSTIC EXPERIMENTS ON TENNIS-RACKETS

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ABSTRACT

The structural characteristics of tennis-rackets can be determined using vibration-diagnostic methods.

АННОТАЦИЯ

Методом вибрационной диагностики могут быть рассчитаны структурные характеристики тенисных ракеток.

KIVONAT

Vibrációdiagnosztikai módszerekkel számszerüen meghatározhatók a teniszütők szerkezeti jellemzői.

INTRODUCTION

When choosing a tennis racket more and more factors are taken into consideration, e.g. the material and structure of the racket and the strings the size of the handle, the weight of the racket, the position of the center of gravity, etc. The physical characteristics of the player are also of fundamental importance as are the make and the price.

The purpose of the experiments presented here is not the qualification but the objective determination of those characteristics giving rise to the complete dynamic behaviour of rackets.

THE MEASUREMENTS

In line with our objective mentioned above we endeavour to use measurements describing not only the individual parts but the complete structure too and we ignored as far as possible the effect of the changeable parts, viz. the strings.

The experiments were carried out on an exciter table. The swept sine-excitation at constant acceleraton level served to measure the transfer characteristics. At the typical resonance frequencies the measured response compared with the varying level of excitation refers to the damping and load-dependence of the structure. The way the rackets were fixed on exciter table and the direction of excitation are shown in Fig.1. In the first version denoted "A", the center of the fastening belt -5cm in width- is above the optimal stricking point. In version "B", the edge of the belt covers the entire edge of frame and the belt is approximately in the center of gravity of the racket.

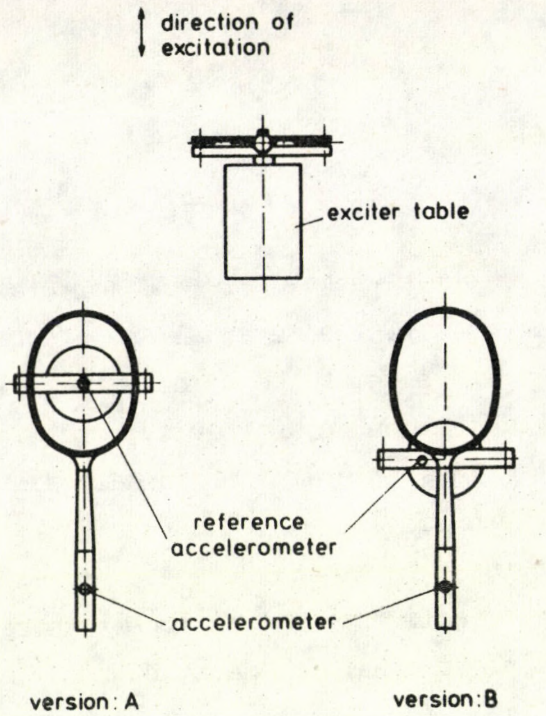

Fig. 1

Fixing of rackets and the direction of excitation

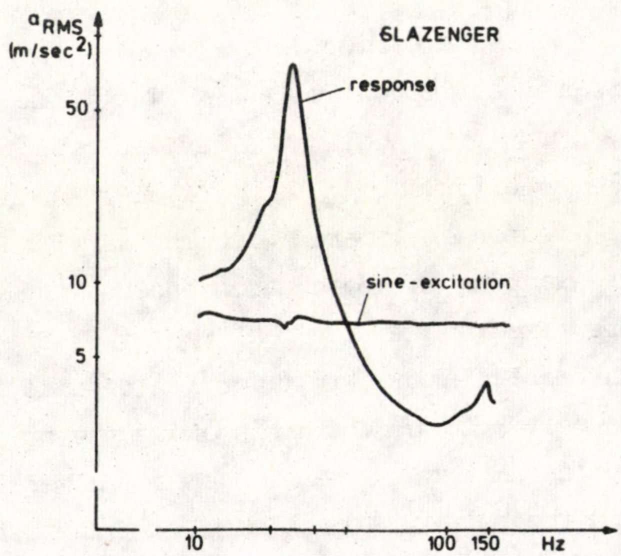

Fig. 2

A typical transfer characteristic curve for "A" type fixing

THE MEASURED TENNIS RACKETS

Eight tennis rackets were examined. Except for two of them the rackets were produced by different firms. Their weights including strings were in the range of 3.7-4.2 N. Detailes of the rackets are given in Table. I.

Firm	Type	Size	Construction
ADIDAS	660	Light-Med 4.3/4	steel
DUNLOP	MAXPLAY-FORT	Med 5	wood
ITALSPORT*	PICCADILLY	Med 5.1/8	wood
SLAZENGER	CHALENGE No1	Med 6	wood
STOMIL	?	Light-Med 5	steel
TRETORN	?	? 4	wood
WILSON	T3000	Light-Med 5	steel
WILSON	T5000	Light 4.5/8	steel

Table I.

The measured tennis rackets

Apart from PICCADILLY which was made in 1939, none of the rackets was older then 3 years.

RESULTS

The transfer characteristics of rackets with "A" type fixing show more similarities. A typical transfer characteristical curve is shown in Fig.2. In each case the RMS level of sine-excitation was 7 m/sec^2. The first resonance frequencies are between 23 Hz and 31 Hz; excessive damping can be found in the 80-100 Hz range and other frequencies appear in the 150-200 Hz range. The resonance frequencies of the latter range cannot be compared because of the effect of the covering layer of the handle. Measurements have shown that this effect can be ignored under 150 Hz.

*produced by a Hungarian firm

The load-dependence of the damping factor was investigated at the first resonance frequency. It was found that the amplification /the ratio of response and excitation/ does not depend on the level of excitation. Thus, the measured frames do not have progressive characteristics. Stroboscopic observations on the "A" type fixing showed that only the buckling strain of the frame is notable in the lowest frequency range. For example the buckling srain of the shaft can be ignored. The amplifications at the first resonance frequencies and at the damping points are shown in Fig.3.

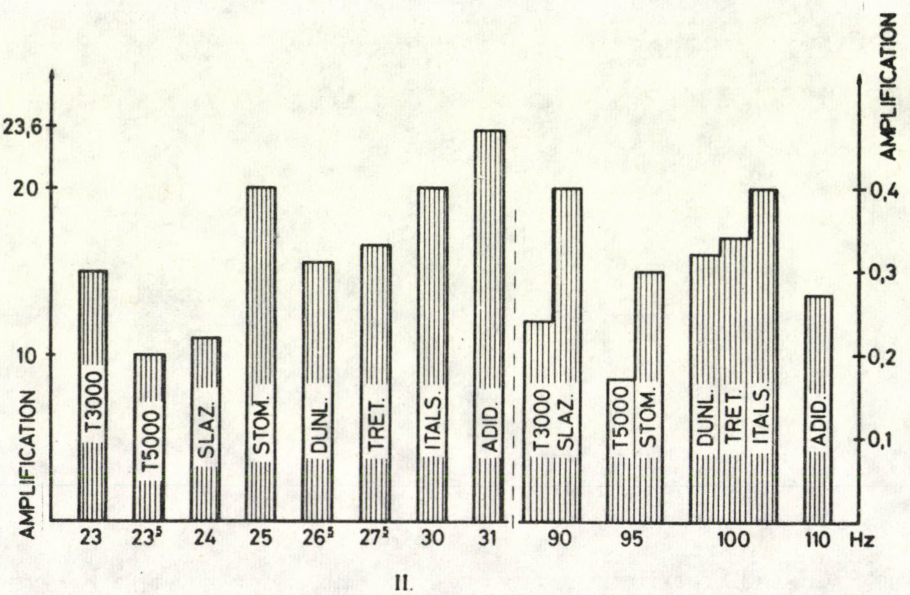

Fig. 3
Amplifications for typical frequencies

The transfer characteristics of rackets of "B" type fixing have two adjacent resonance frequencies. A typical transfer charasteristic curve is shown in Fig. 4. The RMS level of sine-excitation was also 7 m/sec^2.

At the two resonance frequencies the amplifications depends on the level of excitation, and the rackets have very different characteristics. The response excitation curves are shown in Fig. 5. The numerical values near the curves in the figure indicate the resonance frequencies where the measurements were carried out. The curves in Fig. 5 refer to the behaviour of shafts.

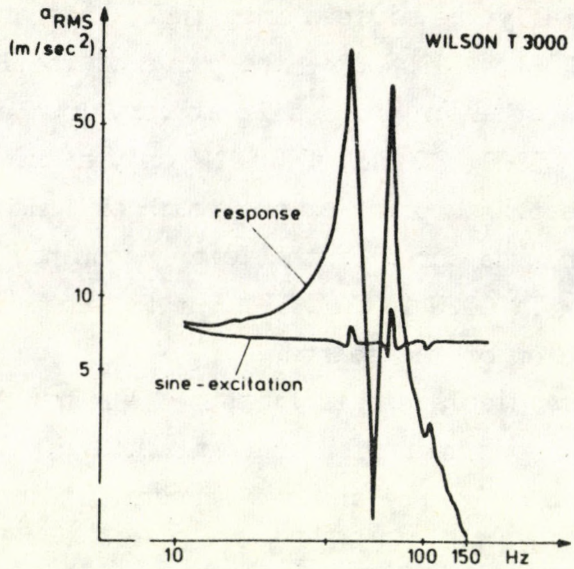

Fig. 4
A typical transfer characteristic curve
for "B" type fixing

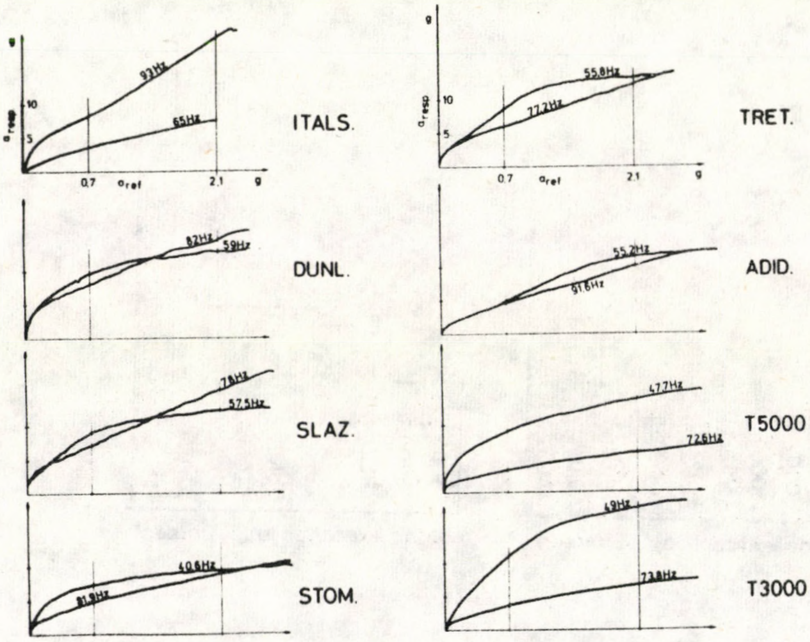

Fig. 5
Response-excitation curves at the
resonance points of rackets

The rackets can, initially, be divided into three categories. In the first /DUNLOP, ITALSPORT, SLAZENGER/, the curve of the lower resonance point is below the other or crosses it at very low level excitation. In the second /ADIDAS, STOMIL, TRETORN/ only at high level excitation does the resonance point of one reach or touch another. Finally in the third the curve of the lower resonance point runs well below the other /W T3000,W T5000/. The curves trace the rigidity and the damping factor of the shafts.

The ratios of relaitive displacements /measured at the "A" and "B" type fixing/ offer a good means for comparison. The relative displacements are between the reference and the measuring point. The values are calculated from the accelerations, for the "B" type fixing at the lower resonance frequency. The values in Fig. 6 approximate the ratios of the rigidities and the damping factors of shafts and frames.

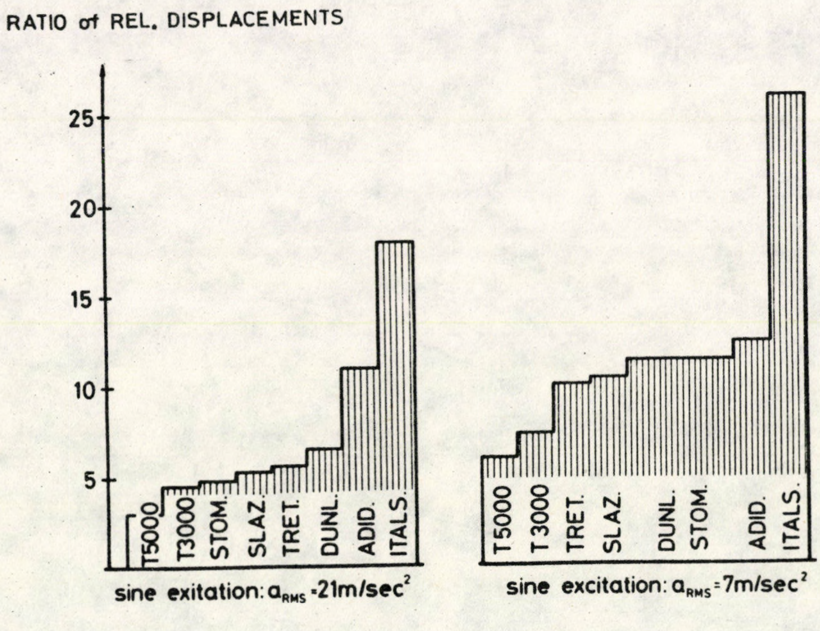

Fig. 6

Ratios of relative displacements

SUMMARY

The structural characteristics of tennis rackets, e.g. the resonance frequencies of frame, the shaft or the complete racket; the elasticity, the rigidity and the damping factor, can all be determined using vibration-diagnostic methods. The experiments were basically related to the rackets only but indirectly refer to the hand-racket relationship and to the vibration burden of the player. The investigations were not concerned with the qualification of rackets since this would involve a detailed analysis of the player-racket interaction.

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