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# THE BIOMECHANICAL BEHAVIOUR OF THE INTERVERTEBRAL DISC.

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## Introduction

The spine is built up of alternate rigid and flexilble elements, respectively the vertebral bodies and the intervertebral connections.
The vertebral bodies do not play an active role when describing the biomechanical behaviour of the spine. The mobility is only determined by the deformable connections such as the intervertebral disc, the intervertebral ligaments and the muscles.
In general, spinal aberrations are located in these flexible parts, and especially in the intervertebral disc.
Wear and tear as a result of overload - so mechanical magnitudes are concerned - are often said to be the cause of these aberrations.
Yet, besides the experiments which were frequently carried out on autopsy specimen, such as bending, torsional, tensile and pressure tests, relatively little fundamental researches have been made into the biomechanical behaviour of the disc.
For this reason, at the Eindhoven University of Technology a few years ago researches were started in which by means of the formation of mathematical models and verification experiments on material models, is tried to gain some fundamental insight into the working of the human motion segment vertebra-disc-vertebra.

## The mathematical model

In order to study the biomechanical behaviour of the human intervertebral disc in case of movement in one direction, viz. where forward-backward bending is concerned, a two-dimensional model will serve the purpose.

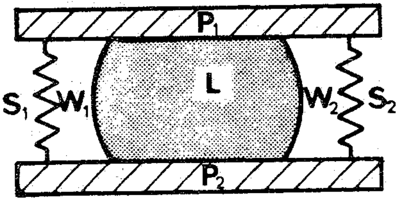


fig. 1. The model of the intervertebral disc.

The model consists of two rigid undeformable plates P1 and P2, between which an incompressible medium L with volume V is to be found. On its sides this medium is shut up between two elastic infinitely supple sides W1 and W2 with spring constants C3 and C4. Further, the plates are connected by two springs S1 and S2 with spring constants C1 and C2 which only when being stretched,are exerting forces in the longitudinal direction of the spring. The plates, the medium with sides and the springs, respectively, represent the vertebral bodies, the nucleus pulposus and the ligamental connections among which the annulus fibrosus.
If this model is loaded with a normal force N which is perpendicular to the plane of symmetry and a bending moment M, both plates will turn through an angle $\gamma$ (fig. 2).

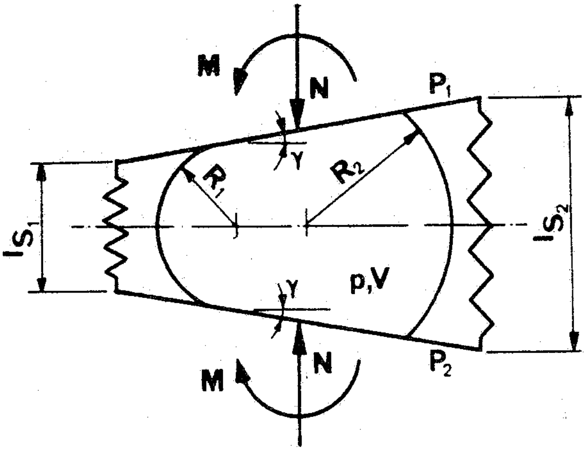


fig. 2. Position of the model after load-application.

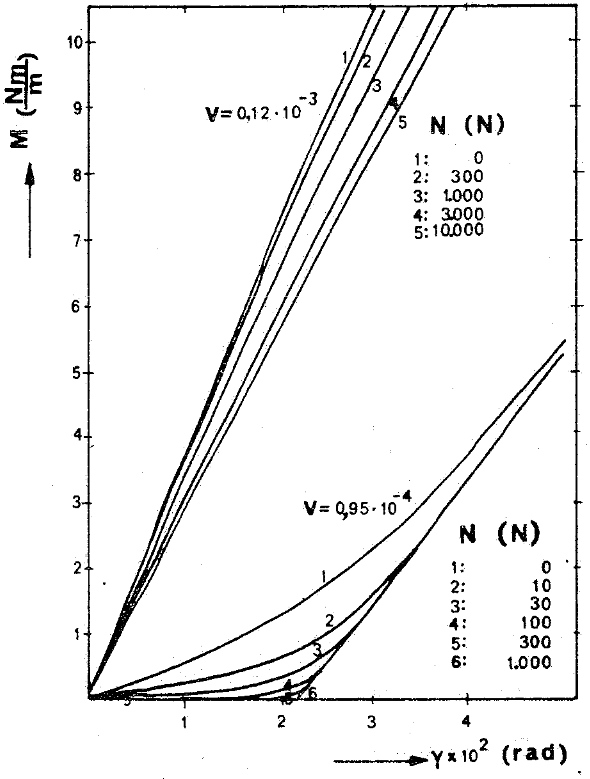


fig. 3. Moment as a function of the angle with the parameters volume and Normal force.

From the mechanical equilibriums of the plates P1 and P2, a number of mathematical relations can be concluded which are mentioning the correlation between M, γ and p.

Fig. 3 shows such a relation, representing the one between the moment M and the angle distortion γ for mathematical models including C1=C2=0 and varying volumes of the medium and for various normal forces N.

Verification-experiments

In verification of these theoretically defined curves, experiments have been carried out on a material model. This model consists of two rigid plates of which the measurements perpendicular to the plane in which the movement was described mathematically, are large in respect of the measurements in this plane.

The plates are connected by an undivided diaphragm in which a certain amount of liquid is to be found that possesses a measurable pre-pressure.

The model is fixed in a testing stand(fig. 4) by means of which a pure bending moment can be exerted on the plates.

Registration of moment, angular displacement, and changes in pressure in the model, takes place by means of electronic recorders.

The moment can be varied continuously with the help of a motor.

By means of weights a Normal force can also be provided.

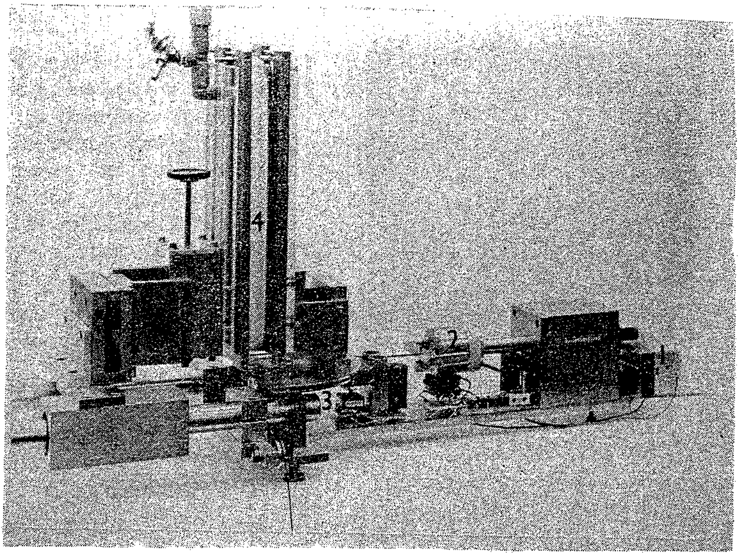
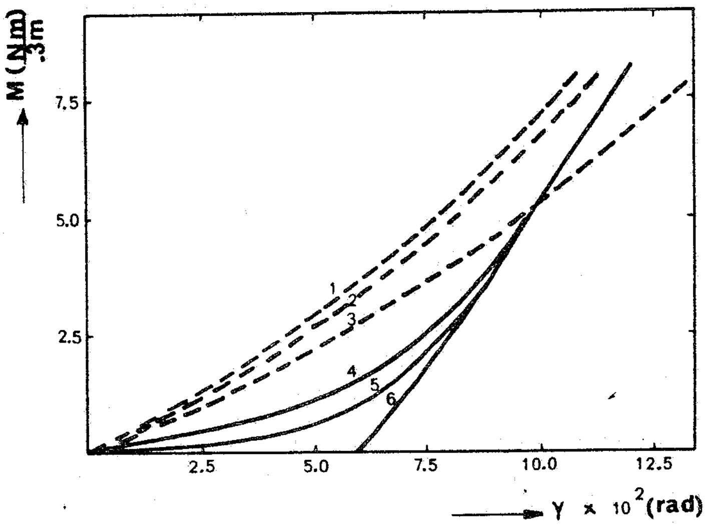


fig. 4. Testing-stand with material model.
1 motor for force provision;
2 dynamometer;
3 anglemeter;
4 material model.



Comparative measuring-results.

– – – material model measuring. ( x 20 ).
—— calculation mathematical model by means of data from material model.
1 - 5 N = 70(N/.3m)
2 - 6 N = 0 (N/.3m)
3 - 4 N =175(N/.3m)

fig. 5.

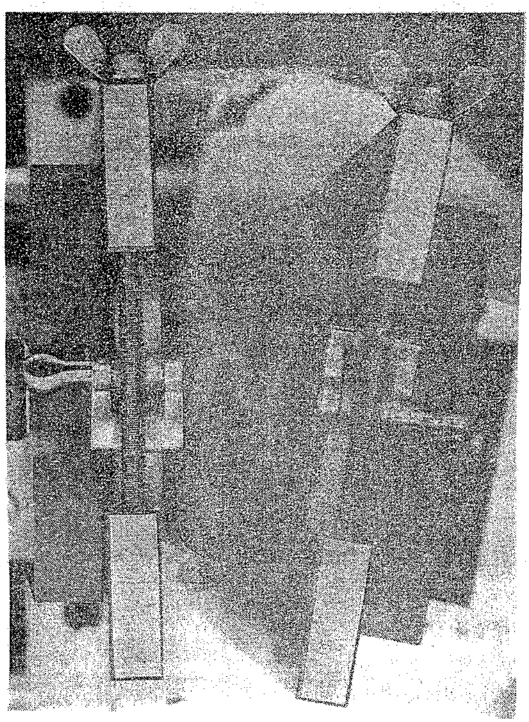


fig. 6.Top view of the material model.

Fig. 5 shows a graph representing the relation between the moment M and the angle-displacement $\gamma$, as on the one hand this was measured on the material model and on the other was calculated with the help of the data of the material model applied as an input for the mathematical model.

Measuring the volume took place by taking photographs of the top views of the model in the various load-situations.(fig. 6).

Deficiences of this material model, such as bulging of the end faces from which variations as to volume arise, may be the cause of the differences between both measurements.

After the reconstruction of the model and the addition of the springs S1 and S2, again comparative measurements are carried out, after which autopsy specimen can be put to the test.

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