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PRINCIPLES AND APPLICATIONS OF THE ARTIFICIAL SENSITIVE SKIN (ASS)

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ABSTRACT :

Biomechanical studies on gait and human prehension have shown the important role of the tactile sensibility of the skin in different regulating functions and in the recognition of the forms. This research has led to the development of a sensitive deformable artificial skin in our laboratories. The first experimental measurements made on samples of sensitive , artificial skin suggest the possibilities of several applications in the spheres of medicine and robotery.

INTRODUCTION :

The biomechanical research carried out at Unité 103 of INSERM was based on the functional exploration of human locomotion and prehension. Some prototype measuring systems have been prepared for the analysis of these human functions.

Gait has been analysed starting from dynamics measures of the force composants that come into use at different points of contact between the foot and the ground.

The study of the hand and the function of prehension have led to an evaluation of the performances of the biological system for regulating the gripping force.

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Elsewhere a cinematographic study of the tactile exploration (palpation) of the form of objects has been carried out with the goal of determining the type of elementary tactile informations necessary, in the absence of visual feedback.

All of this research has proved the essential role of the skin in the different functions studied.

The skin possesses some remarkable physical qualities :

- a great plasticity enabling the hand to adapt perfectly to the forme of an object held or of the foot to adapt to the ground.

- an excellent non-slip quality ; this minimizes the gripping force necessary to keep the object from slipping.

-the skin contains very great number of different types of sensors placed at different layers, constituting a tridimensional matrix. They relay to the brain, information on contact, pressure, slipping and of temperature, all of which are necessary to perform the three following principal functions.

- form recognition and the physical qualities of objects, including the state of the ground relief under the foot.

- Regulation of the grip force in prehension and of equilibrium during gait.

- protection of the underlying structures by stimulation of defence circuits, producing rapid withdrawal reactions, in particular when the skin is subjected to a zone of excessive strain concentration (sting, injection) or when the object touched is thermatically or chemically active.

The close collaboration between INSERM and LAAS has made it possible to design a deformable artificial skin of high sensitivity which can furnish several types of tactile information.

By considering both the mechanical and physiological properties of human skin, the LAAS has developed and perfected some artificial skin prototypes.

EXPERIMENTAL PROTOTYPE

A layer of deformable material (elastomere) correctly loaded with carbon, iron aluminium... is placed on an insulating flexible support, containing a matrix of regularly distributed conductive electrodes .
The application of a force on a point on the exterior surface produces a deformation of the conductive elastomere, which results in a local variation of transversal electrical resistance.

A voltage V is applied between the metalic exterior face and the metalic guard ring which is situated on the support (see figure 1).

If the charged elastomere used is homogeneous, the currents coming from the measuring electrodes are all equal. The deformation of the pliant coating under the external force, P, produces a variation of current at a measurement point (see figure 2). The intensity of the current on electrode 2 becomes I_1 . The variation of the current depends on the kind of elastomere used, and on the pressure exerted at the measure point.

A study of electrical and mechanical properties has been made on several kinds of elastomeres with different types of loading compositions. The results of these studies are to be found in table 1.

Table 2 gives the variation of the electrical resistance as a function to the pressure exerted. The graph of figure 3 shows linear relation that exists between the measured current and the force applied for a typical sample of conducting rubber.

TREATMENT OF INFORMATIONS

A sensing plate covered with pliant conductive material and using a matrix of 25 x 25 points on 3 mm centers has been made. Using a simple scanning system it is possible to determine the force at the contact points of an object with a matrix. With this system the imprint of an object can be recorded and reproduced on a visual display.

Illustrated in figure 4 is the principle of operation. A multiplexer followed by an amplifier which is connected to one hand to an analog-to-digital convertor for recording magnetic tape and on the other hand directly to the visual display. Intensity modulation of an oscilloscope beam, by the output signal of the amplifier, gives the imprint of the analysed object on the screen. Some easily recognisable imprints are represented in figure 5.

From the analog measure taken at each matrix point we can obtain a precise quantitative definition of the surface contact.

It can be noted that these types of conductive pliant material can be used to give angle information. Increasing the resolution of the sensing matrix is not a very important technological problem. The limitation is imposed by the volume of the data to be treated.

APPLICATIONS

The use of the ASS are evidently numerous particularly in the medical and industrial fields.

The mechanical properties of the sensitive coating and quality of the informations it gives, open up interesting medical uses in the field of functional exploration of gait and prehension. In particular, the possibility of designing a sensorized shoe-sole should lead to a further and more complete study of the force distribution on the foot during the gait and upright station, as well as a better analysis of the equilibrium regulation system in man.

This information from the sole of the foot thus obtained could be used for the control of a stabilization system for a paraplegic's orthesis.

It would be possible too, to design a sensitive glove covering the hand prothesis giving informations of contact, pressure and cutting.

The artificial tactile sensitivily could control the force grip and give information concerning the quality of the grip.

In industry and particularly in the field of telemanipulators it could be equally interesting to use a pliant coating possessing an artificial sensitivity.

By covering the telemanipulator's end effectors with this soft and non-slip coating the quality and stability of the grip could be improved.

The signals furnished by the matrix of sensors in the skin can also be used to control the force grip and send back information to the central control system on the quality and the stability of the grip.

Moreover, tactile artificial detection offers an interesting solution to the problem of recognizing forms.

The signals issuing from the sensor matrix can be used for a visual representation of the objects imprint. But this information can be recorded numerically for later analysis and the possibility of the genuine recognition of forms.

SUMMARY AND FUTURE DEVELOPEMENT.

The ASS shows mechanical and functional analogs to the human skin, and this makes it possible to try to utilize it in the prothesis and orthesis field, as well as for industrial telemanipulators. The research being carried out arms to improve the electrical and mechanical performances of the sensitive coating. The combined effort of LAAS and Unité 103 of INSERM should eventually lead to a more precise model of skin.

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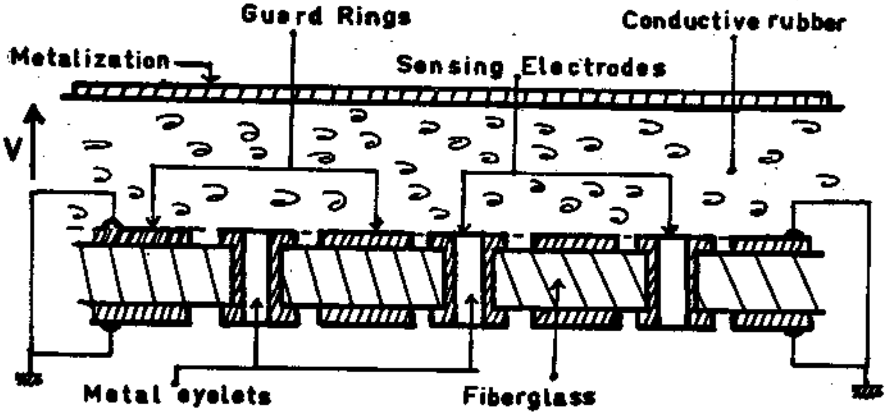


Fig 1 - Technology of ASS

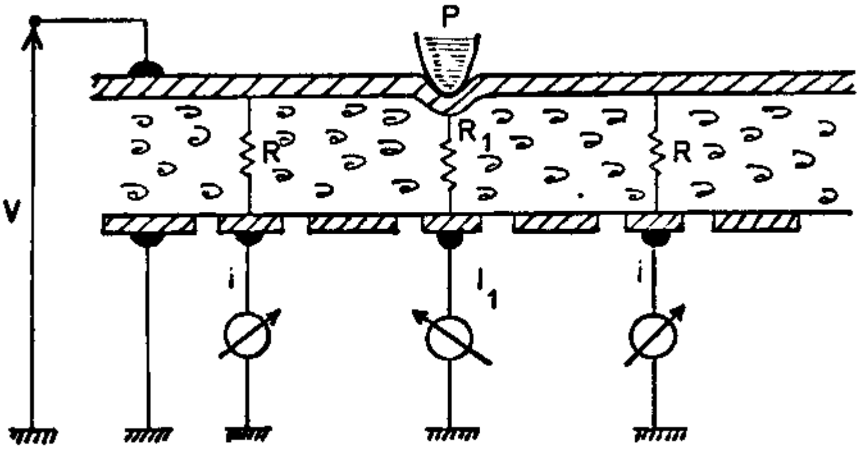


Fig 2 - Principle of measurement

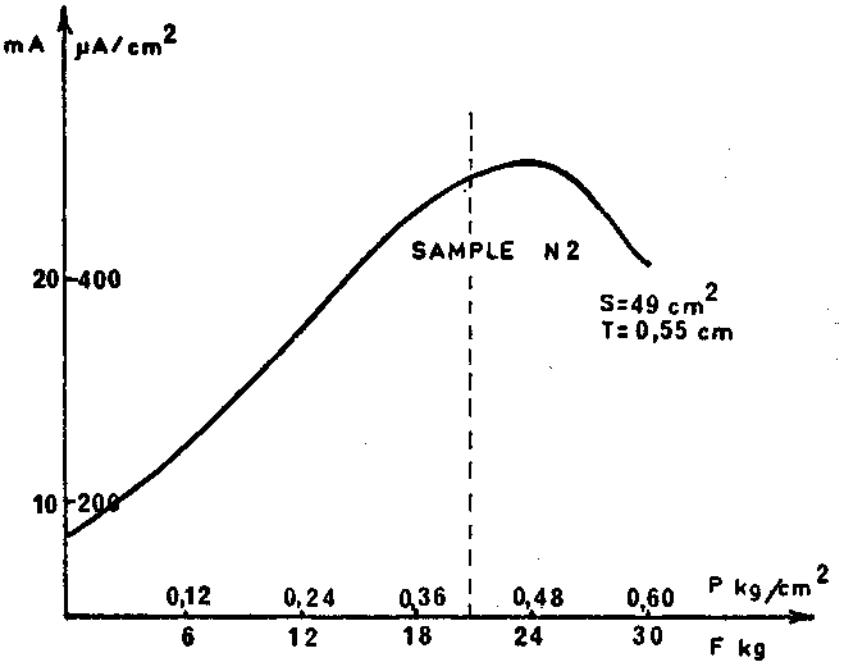


Fig 3 - Current as a function of pressure. Composition of the sample : RTV 141 A 20g, RTV 141 B 2g, Iron 27 g Carbon activated 12g, Nickel 1,5g.

TABLE I

ELECTRICAL AND MECHANICAL CHARACTERISTICS OF DIFFERENT COMPOSITIONS

ELASTOMERES : Rhône-Poulenc R.T.V. 141 - 730 - 147			
Loading material	Weigh	Electrical properties	Mechanical properties
Graphite	< 20%	High resistivity	Good
Graphite	> 20%	High resistivity	Bad, no polymerisation
Carbon (activated)		Low resistivity Low hysteresis	Medium (bubbles)
Iron	> 800%	High resistivity Low hysteresis	Low elasticity Low tearing resistance
Nickel	500%	Low resistivity Large hysteresis	Medium
Zinc	700%	High resistivity Large hysteresis	Medium

TABLE II

VARIATION OF THE RESISTANCE AS A FUNCTION OF THE PRESSURE
WITH DIFFERENT COMPOSITIONS

ELASTOMERE	LOADING MATERIAL	$\Delta R / \Delta P$
R. T. V. 141 14g	Graphite coke 15g	$\underline{0,1\ M\ \Omega/cm > R > 8000}\ \Omega/cm$ $0,75\ kg/cm^2 < P < 5\ kg/cm^2$
R. T. V. 141 12g	Graphite Madagascar 7g	$60\ 000\ \Omega/cm > R > 10\ 000\ \Omega/cm$ $0,1\ kg/cm^2 < P < 12\ kg/cm^2$
R. T. V. 141 14g	Graphite 7g	$300\ M\ \Omega/cm > R > 8\ M\ \Omega/cm$ $1kg/cm^2 < P < 7\ kg/cm^2$
R. T. V. 141 11g	Iron 80g	$280\ M\Omega/cm > R > 1M\Omega/cm$ $0,15\ kg/cm^2 < P < 3,6\ kg/cm$
R. T. V. 141 11g	Iron 40g	$50\ M\ \Omega/cm > R > 350\ M\ \Omega/cm$ $0,2\ kg/cm^2 < P < 4\ kg/cm^2$

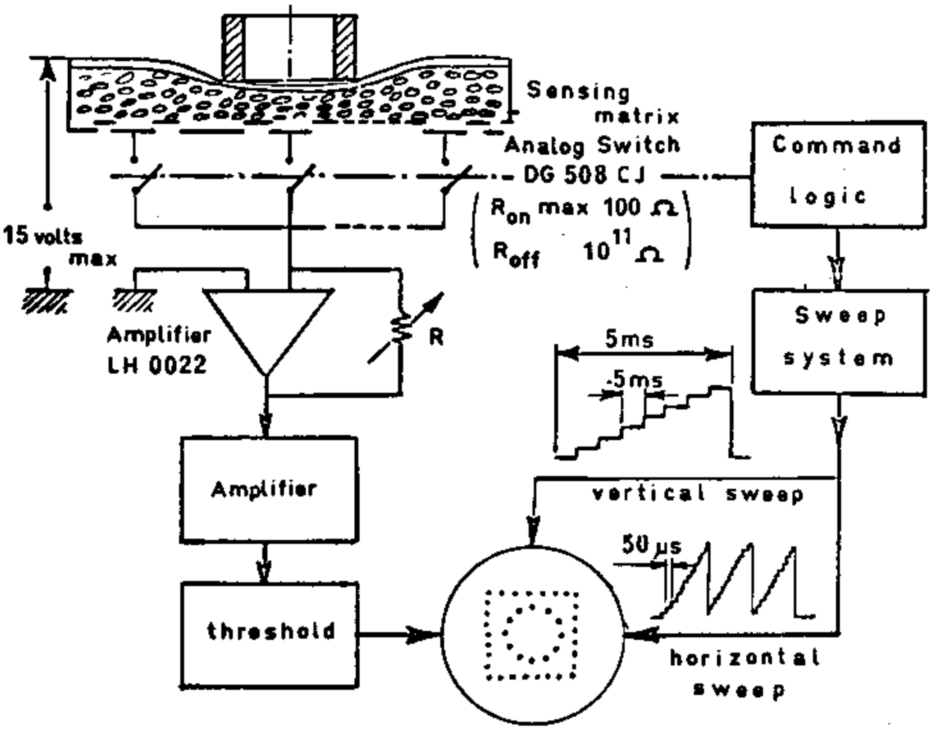


Fig 4 - Principle of operation

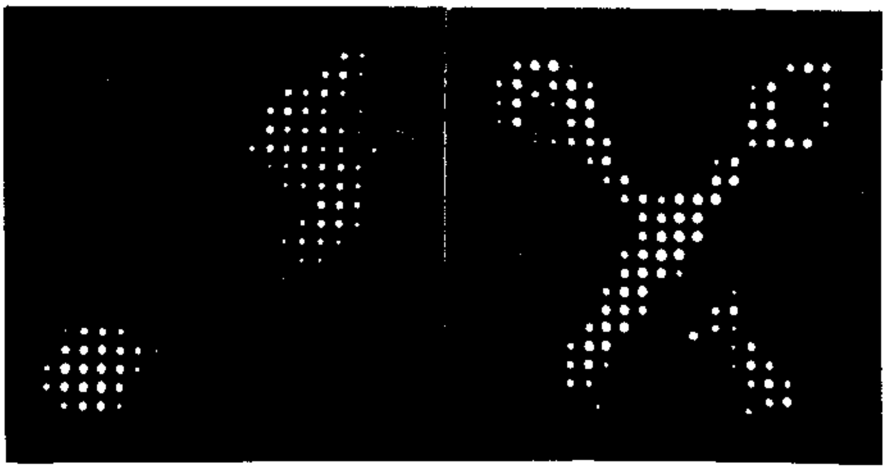
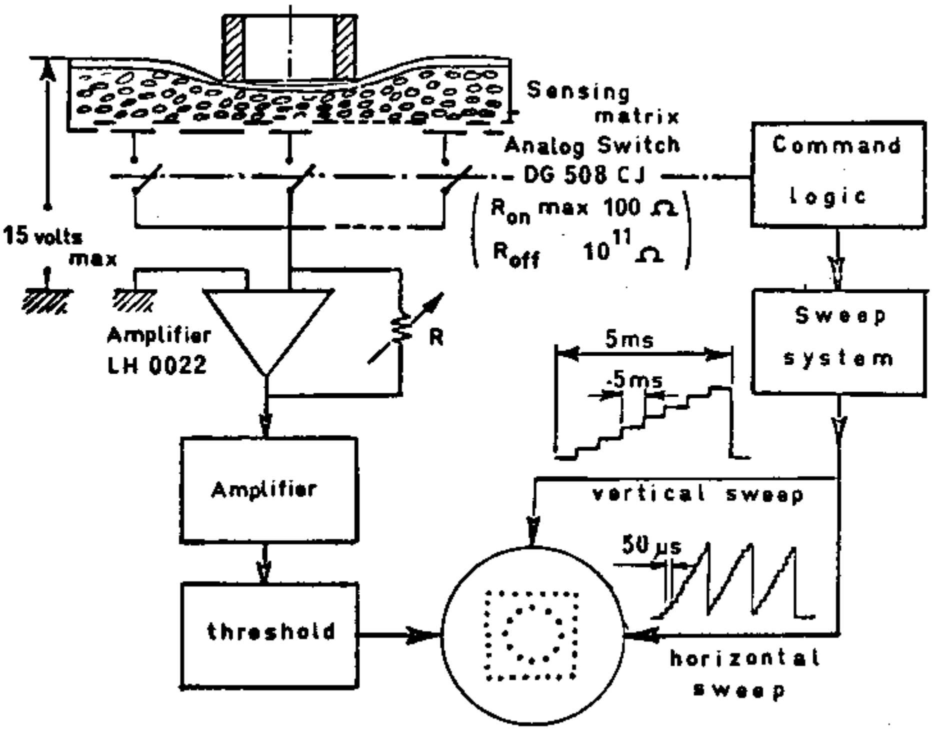


Fig 5 - Imprints of human foot and scissors



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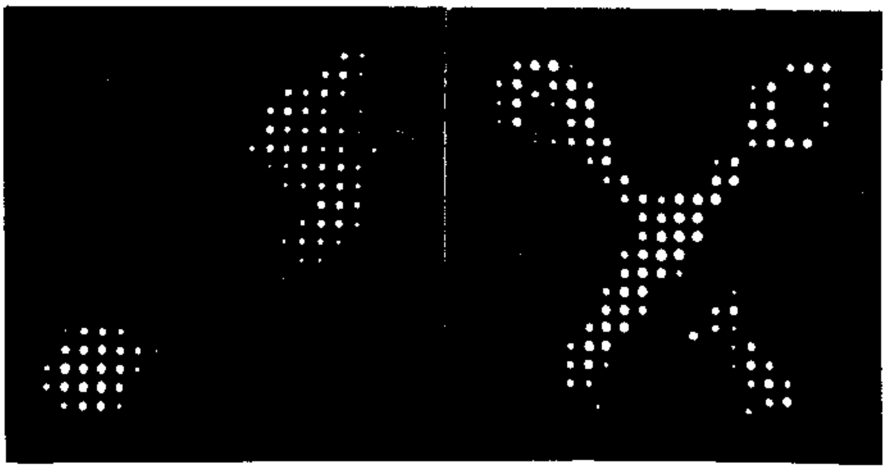

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