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Technical note

Tangential goniometry-ANGULATOR

M. POKORA and L. OBER*

UL Gubinowska 7–115, Warsaw, Poland,

**UL Brzechwy 6, Poznan, Poland.*

Abstract
Tangential goniometry based on the principle of mechanical strain measurement is proposed for evaluating human body deformities or mobility. This features continuous body contour matching; defined measuring plane P2 due to rigidity in measured surface P1 (Fig. 1); stable physical characteristics; simple mechanical structure; ease of transformation of the measured angle into electric signal for CAD contour and shape reconstruction; can be integrated into orthopaedic appliances for monitoring activity.

The novel design of ANGULATOR — flexible polycentric goniometer is presented.

Principle

Two identical elastic steel flat strips (Fig. 2A) are joined together at the one end (B). The flat strips are kept in continuous contact by holders (C) in such a manner that the sliding of one element in respect to another is assured (exception: point B).

Bending such a structure (Fig. 2B) by the angle $\Delta\varphi$ causes a linear relative displacement $\Delta L_{\widehat{AB}}$ of both free ends of the strips. The amplitude of occurred displacement is proportional to the angle of bending $\Delta\varphi$ and the thickness of the single flat b as follows:

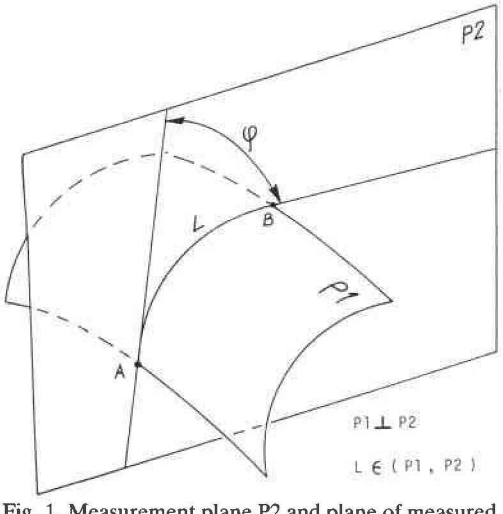

Fig. 1. Measurement plane P2 and plane of measured surface P1.

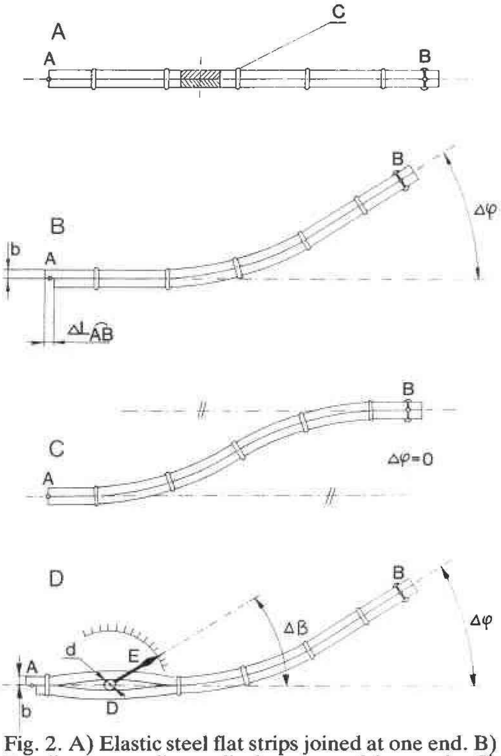

Fig. 2. A) Elastic steel flat strips joined at one end. B) Bending causes linear displacement of free ends. C) With A and B parallel the displacement is zero. D) Simple means of reading angle. Indicator E attached to shaft D.

All correspondence to be addressed to Mr. M. Pokora, UL Gubinowska 7–115, 02–956, Warsaw, Poland.

* The name ANGULATOR suggested by Dr. Per Udden.

$$\Delta L_{\widehat{AB}} = b \cdot \int_A^B d\varphi \qquad (1)$$

or $$\Delta L_{\widehat{AB}} = b \cdot \Delta\varphi \text{ [rad]} \qquad (2)$$

When distal parts (A and B) are parallel (Fig. 2C) the displacement $\Delta L_{\widehat{AB}} = 0$.

For easy read out of the displacement (being angle equivalent) a linear displacement transducer can be applied. However the simplest mechanical solution is presented in Figure 2D. The shaft (D) with attached indicator (E) rolls between both ends of the strips at their free ends (point A). The angular displacement $\Delta\beta$ of the indicator is given by:

$$\Delta\beta = \tfrac{b}{d} \cdot \Delta\varphi \text{ where d – shaft diameter} \qquad (3)$$

or $$\Delta\beta = \Delta\varphi \text{ if } d = b \qquad (4)$$

Figure 3 displays the model of tangential goniometer ANGULATOR*.
Its measuring range is ± 195° with an error ± 1°.

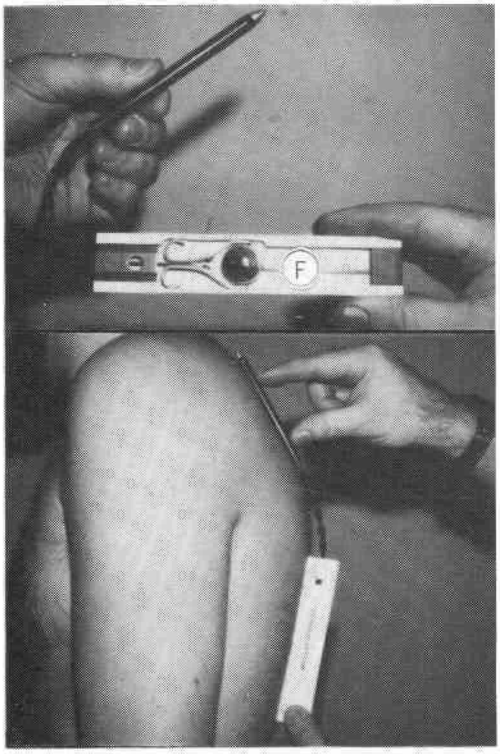

Fig. 3. Tangential goniometer ANGULATOR (see text).

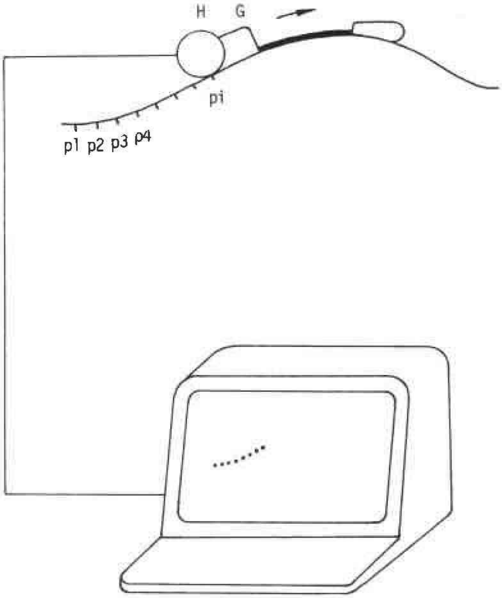

Fig. 4. Possible combination of the tangential goniometer and a microcomputer as an aid to deformity evaluation.

Within ± 90° the hysteresis is below 0.5°. To decrease the hysteresis within the range ± (90°–195°) the reverse spring (F) is applied acting above ± 90°. This device reduces the hysteresis to less than 1.5°. Having in mind the limited accuracy of positioning the goniometer arms in relation to the human body segments the ANGULATOR accuracy can be considered as adequate.

Future

Because of its flexibility and ease of application to follow the body contour, tangential goniometry will be helpful for deformity evaluation. A possible arrangement (Fig. 4) would combine the tangential goniometer with a photoelectric sensor (G); the coding wheel (H) supplies the system with a traced distance signal. Such a microcomputer based system can control the measurement and reconstruct the traced body contour to present it for evaluation.

This method could be an alternative to X-ray when used for assessment of scoliosis progression. It can also be a valuable aid for congenital deformity evaluation as well as in prosthetic and orthotic fitting.