DEVELOPMENT OF NON-PLANE HONEYCOMB SANDWICH COMPOSITE FOR STRUCTURAL USE

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ABSTRACT

Composite material honeycomb structures are being increasingly utilized in several types of structural configurations due to their low specific weight, high strenght and adequate rigidity. They are fabricated to plane or slightly curved surfaces without any major difficult; but, when cylindrical or even spherical surfaces are concerned considerable difficulties can arise due to the so called "saddleback effect"during the fabrication of those structures. Filament winding of a sandwich tube having a honeycomb cylinder as its core can represent quite a problem when accuracy comes into scene.

This paper shows the development of a new fabrication technique for non-plane honeycomb structures with hexagonall cells where dimensional accuracy are attained by the use of an appropriate "counter saddleback", which can be obtained by means of a PC computer program together all set of necessary data to fabricate the desired honeycomb structure.

Keywords: Composites; Core/Sandwich Materials; Non-plane honeycomb.

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1. Introduction

Honeycomb represents one of the most sophisticated existing sandwich structures and it is mainly composed by two face sheets and a cellular core wich can be made by such materials like:

a) cellulose paper;

b) aramid paper;

c) several plastics like PVC, ABS and others;

d) GRP, and

e) metallic materials like aluminum

As to the core materials where wood and foam are sometimes employed, honeycomb shows a great advantage of being lighter for the same level of stiffness. However, there are some practical drawbacks which make them only suitable for high performance structures like as airspace vehicles, racing cars and boats, among others.

The drawbacks above refered are as follow:

a) A critical point is the bonding of honeycomb cells to the fiber sheet face material, which requires careful technique to obtain a reliable adhesion;

b) Due to its very high rigidity this kind of structure may not be suitable for regions subjected to large impact loads;

c) Honeycomb structure is not well suited to curved surfaces, so that it is today rarely employed in non-plane shapes.

2. Development of non-plane honeycomb

The non-plane honeycomb shows several difficulties in its fabrication since the individual cells of the core do not exhibit regular geometry. On the other hand each cell can not have their walls twisted what can be very detrimental to its functional characteristics. However, the point of main concern is undoubtedly the so called "saddleback" effect which must be avoided in any curved honeycomb structure. This effect can be visualized when one attempts to bend a plane honeycomb sandwich trying to bring it into a cylindrical surface, for instance.

Due to increasing aplication of non-plane honeycomb structures, it was developed a kind of counter-saddleback theory, which allows honeycomb structures to be fabricated with the correct geometry. For this purpose a PC program was assembled utilizing adequate mathematical formulations so that, for a given set of requirements, it will be possible to obtain a non-plane honeycomb without the nondesirable effect, as show in figures 1 and 2.

The honeycomb core is composed of counter-saddleback strips bounded each other at appropriate spots so that the cells at mid-radius (R_m) surface show regular hexagons with sides equal to L, as presented in figure 3. It is important at this point to demonstrate that the resulting hexagons at the external and internal surfaces of the honeycomb keep such a relationship with the neighboring hexagons so that they form a repeating pattern without inducing any twisting of the cell walls. Figure 4 shows such pattern and one can realize that the cell wall is composed by two types of trapezoid, namely I and II, which are repeated alternatively.

To avoid the twisting action on the walls, trapezoid II must keep such a shape in order that trapezoid I has to be in the radial direction and paralell to the cylinder axis. In this condition figure 5 shows that length "x" must have the value:

$$x = \frac{t_c . L}{8 . R_m}$$

which will be used to determine the side lengths of inner and outer hexagons. From figure 6, the side lengths of trapezoid I are easily calculated. Now by observing figure 7, one can write for trapezoid II:

$$L_i = \left\{ \left(\frac{L}{2} - 2x \right)^2 + \left[\pi \frac{\left(R_m - \frac{t_c}{2} \right)^2}{n} \right] \right\}^{½} \quad (1)$$

and,

$$L_e = \left\{ \left(\frac{L}{2} + 2x \right)^2 + \left[\pi \frac{\left(R_m + \frac{t_c}{2} \right)^2}{n} \right] \right\}^{½} \quad (2)$$

3. <u>The unit strip with counter-saddleback</u>

Once obtained the side lengths of trapezoids I and II, it will be possible to compose them so they form alternatively a continuous strip as shown in figure 8. Those strips by their turn, will be placed and bonded accordingly so that they can form the honeycomb cells. The same figure also shows that the strips has a curved shape with a mean radius R_{CS} , and exactly to this curved shape is given the name of counter-saddleback so that when the honeycomb cells are formed in their final geometry no hollow or hump are presented.

Therefore, in order to generate the unit strips like the one shown in figure 9, taken from an actual example, it will be necessary to obtain the value of counter-saddleback mean radius, R_{CS} , as shown in figure 10. For this purpose the internal and external sides of trapezoids I and II are considered as doing part of the inner and outer perimeter of the curved strips, since the arch and chord, as presented in figure 10, are very approximated. It is reminded that in actual configurations this really happens as the number of honeycomb cells is increased.

The calculation of R_{CS} can then be done utilizing figure 10 by means a simple triangle relationship.

$$\frac{\frac{p_e}{2}}{R_i + t_c} = \frac{\frac{p_i}{2}}{R_i} \qquad (3)$$

where R_i is calculated by (4) as:

$$R_i = \frac{p_i . t_c}{p_e - p_i} \qquad (4)$$

From the same figure 10, one can obtain:

$$R_{cs} = R_i + \frac{t_c}{2} \qquad (5)$$

Therefore,

$$R_{cs} = t_c\left(\frac{1}{2}+\frac{1}{\frac{p_e}{p_i}-1}\right) \qquad (6)$$

or

$$R_{cs} = \frac{t_c}{2}+t_c\left(\frac{p_e}{p_i}-1\right)^{-1} \qquad (7)$$

With R_{CS} and the thickness of the honeycomb t_C , the strip with a counter-saddleback configuration can be assembled since all others elements are now available.

4. Final Comments

From a pure economical viewpoint maybe the honeycomb structure would be as costly as a monocoque; however, when technical aspects are considered there is the great advantage of having lighter structures associated with strength and stiffness. In this aspects the present paper may be a contribution so that honeycomb can be also extended to non-plane curved structures where fabrication problems are considered as a main concern.

As a proposal to continue this study the research group is now trying to develop the fabrication process going through the manufacture of appropriate tools which are needed to the erection of cylindrical honeycomb for advanced structural use.

5. References

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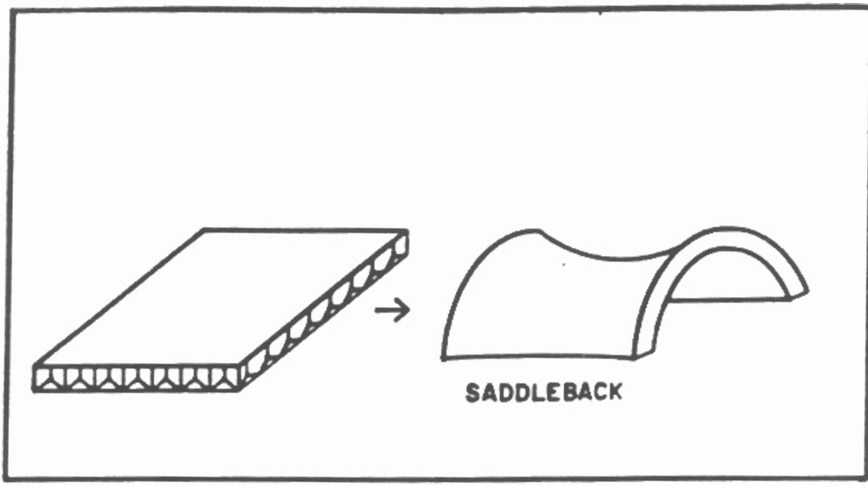

Fig.1 - Plane honeycomb

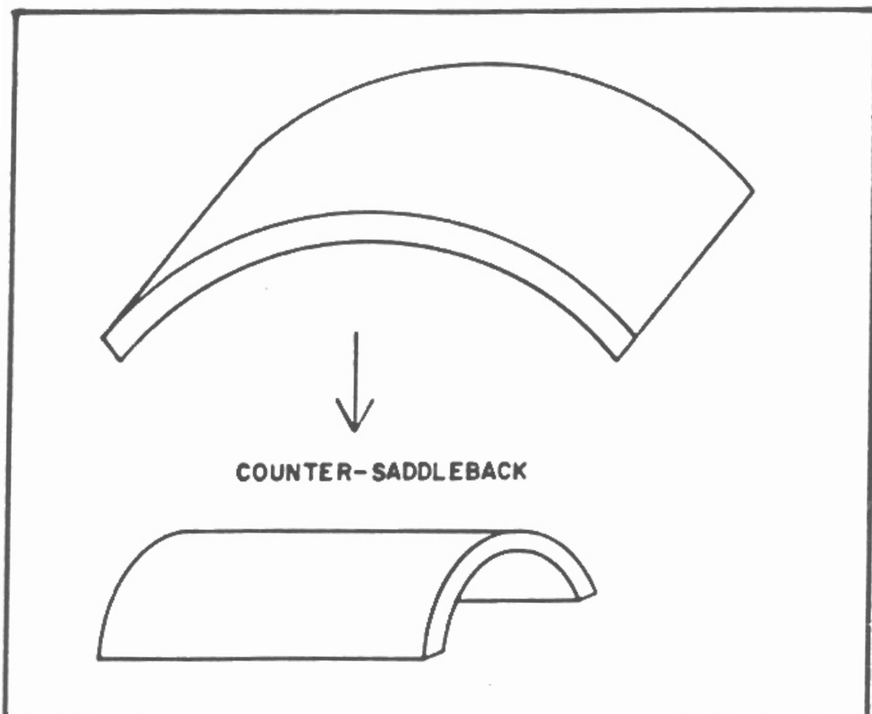

Fig.2 - Non-plane honeycomb

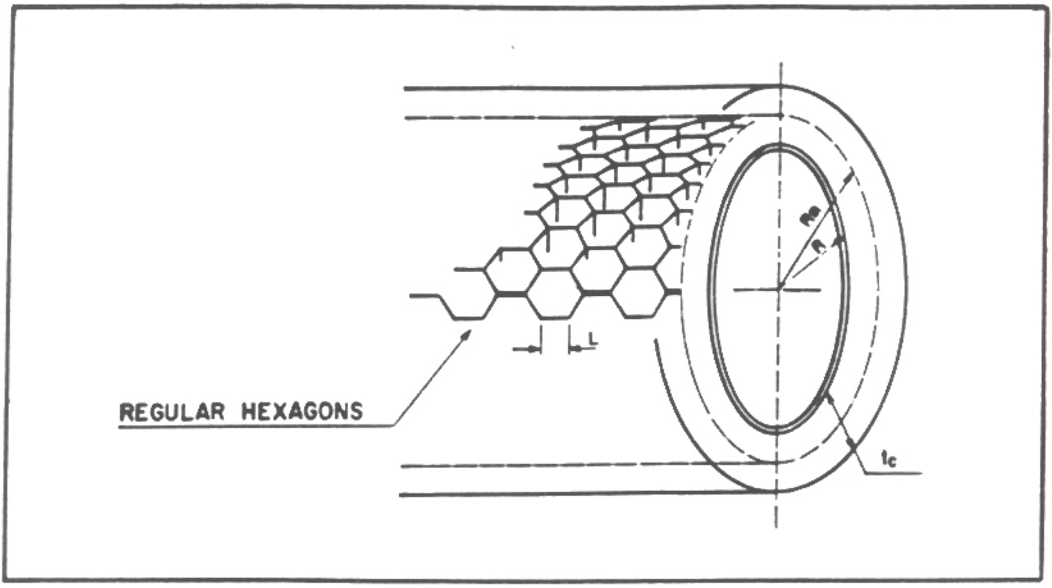

Fig. 3 - A section of a cylindrical honeycomb structure showing regular hexagons at its mid radius-R_m

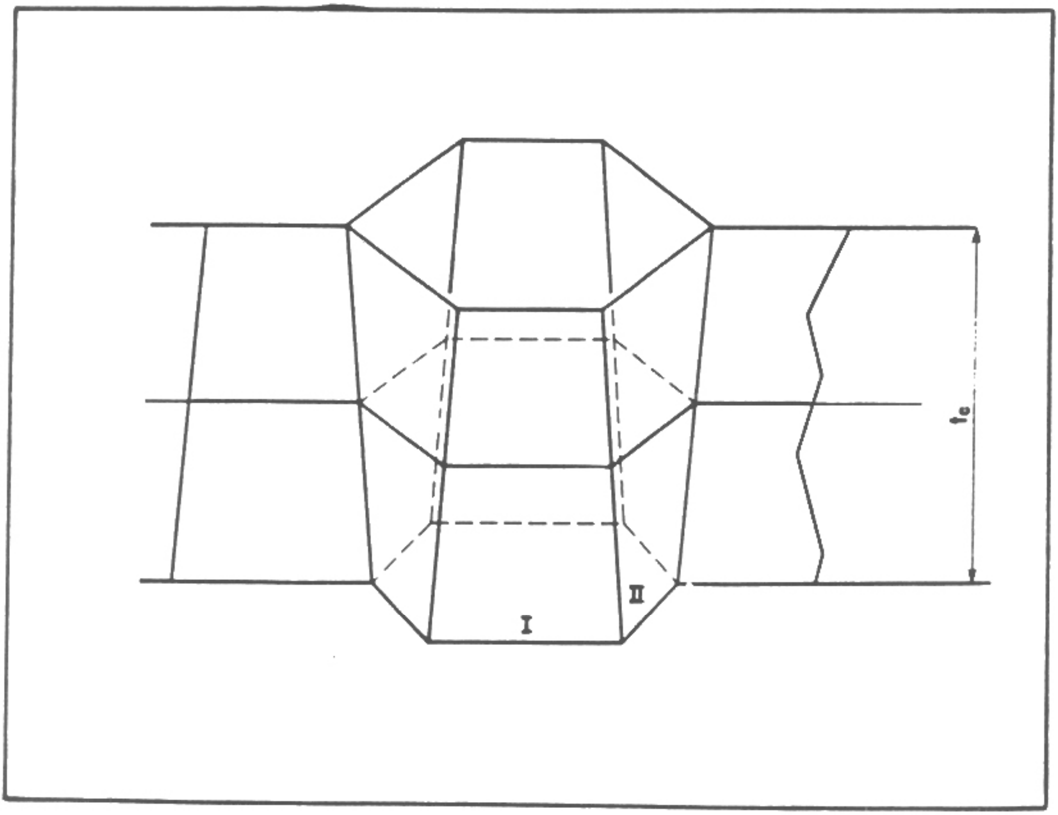

Fig. 4 - Geometric shape of trapezoids I and II

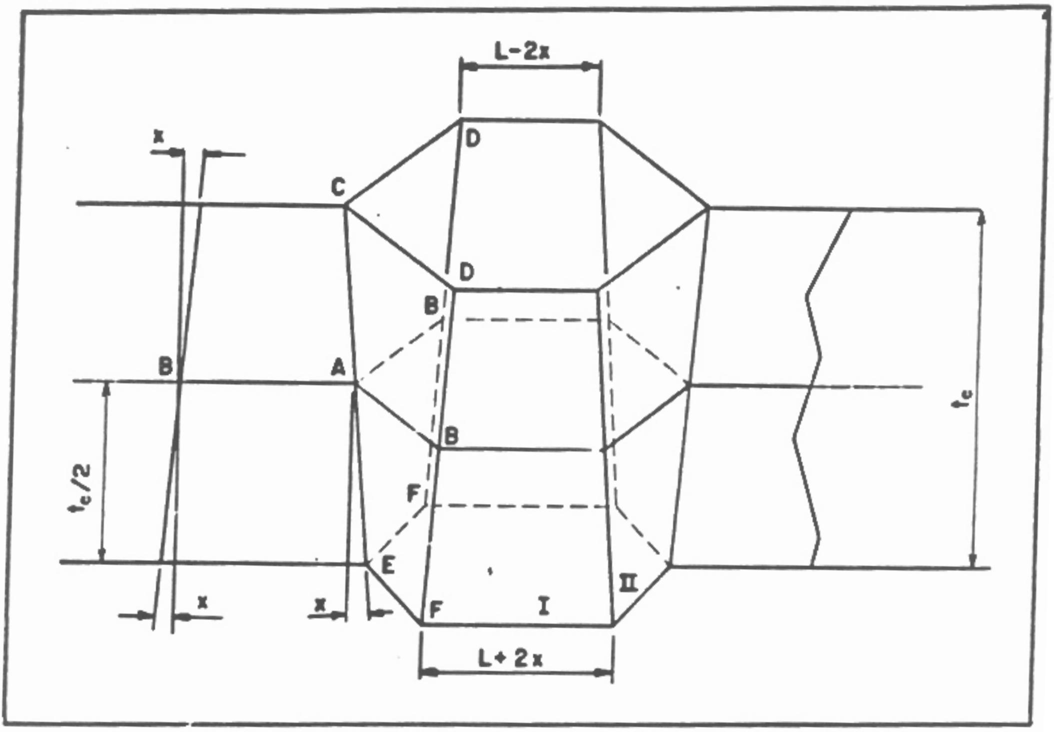

Fig. 5 - Three dimensional representation of honeycomb cell

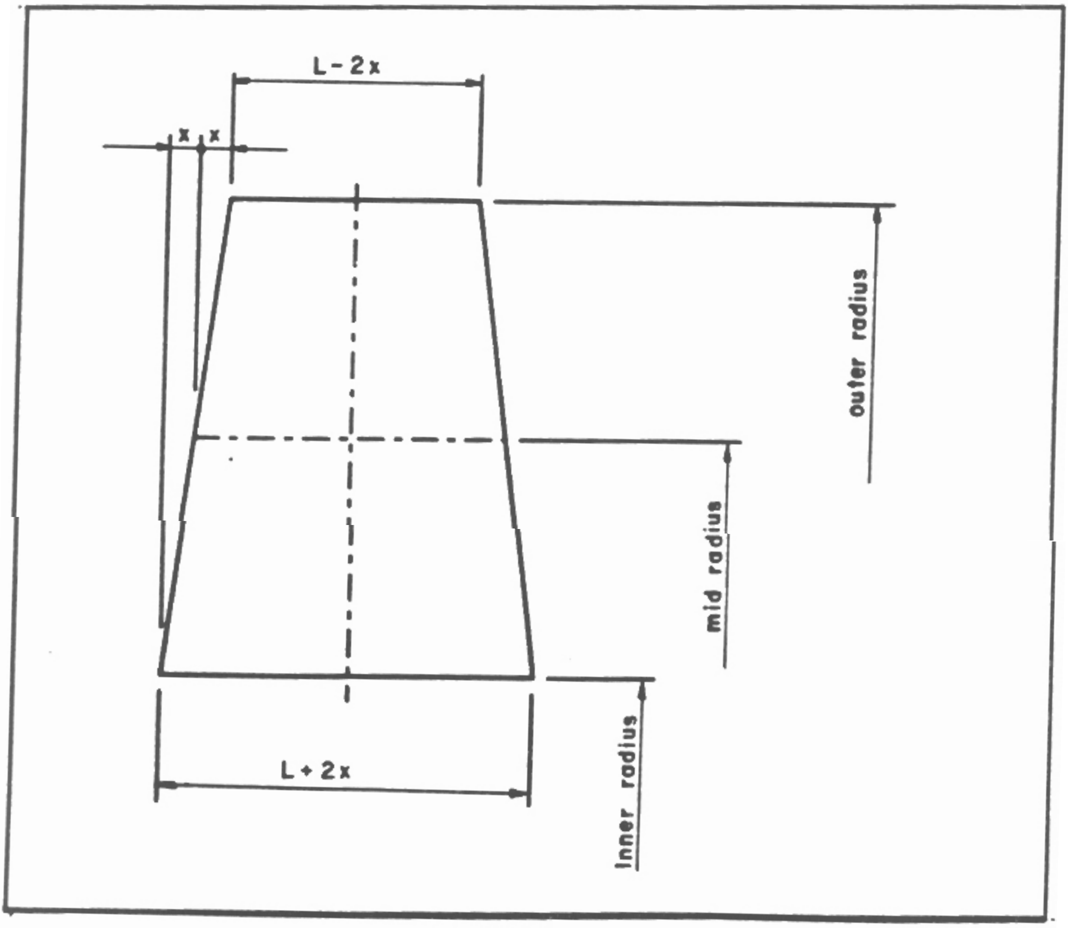

Fig. 6 - Edge corners of trapezoid I

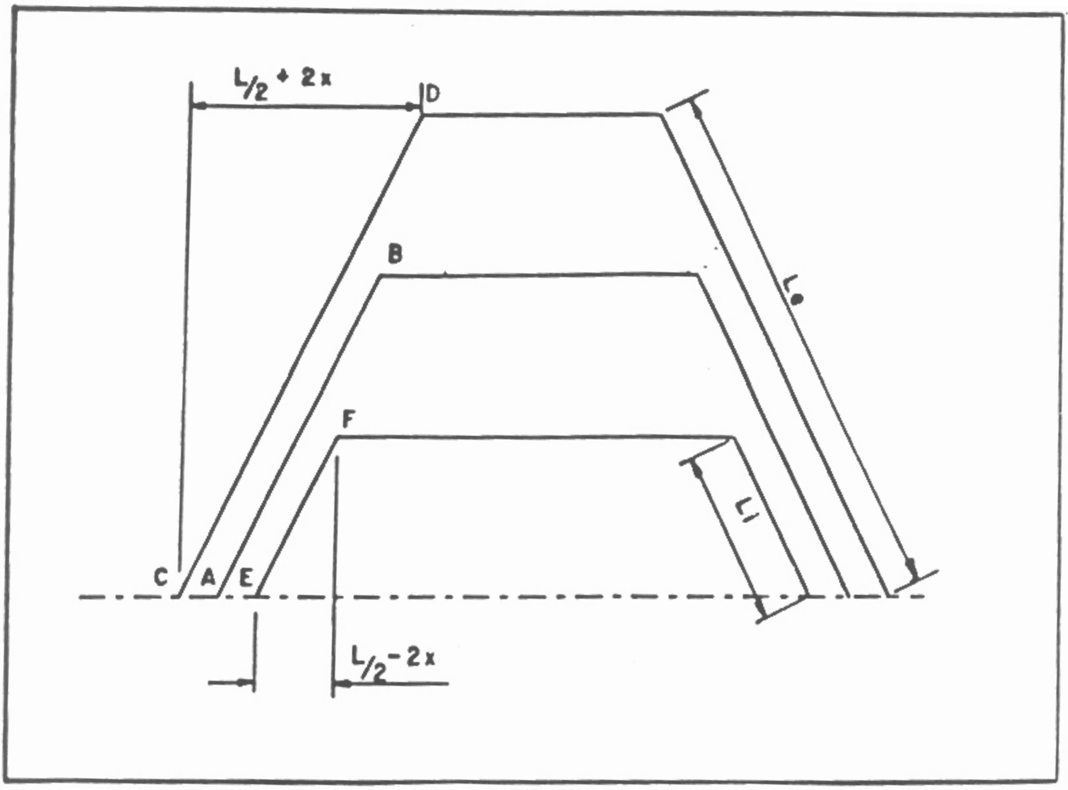

Fig. 7 - Inner, mid and outer radius hexagons projected into a same plane to determination of edge corners of trapezoid II.

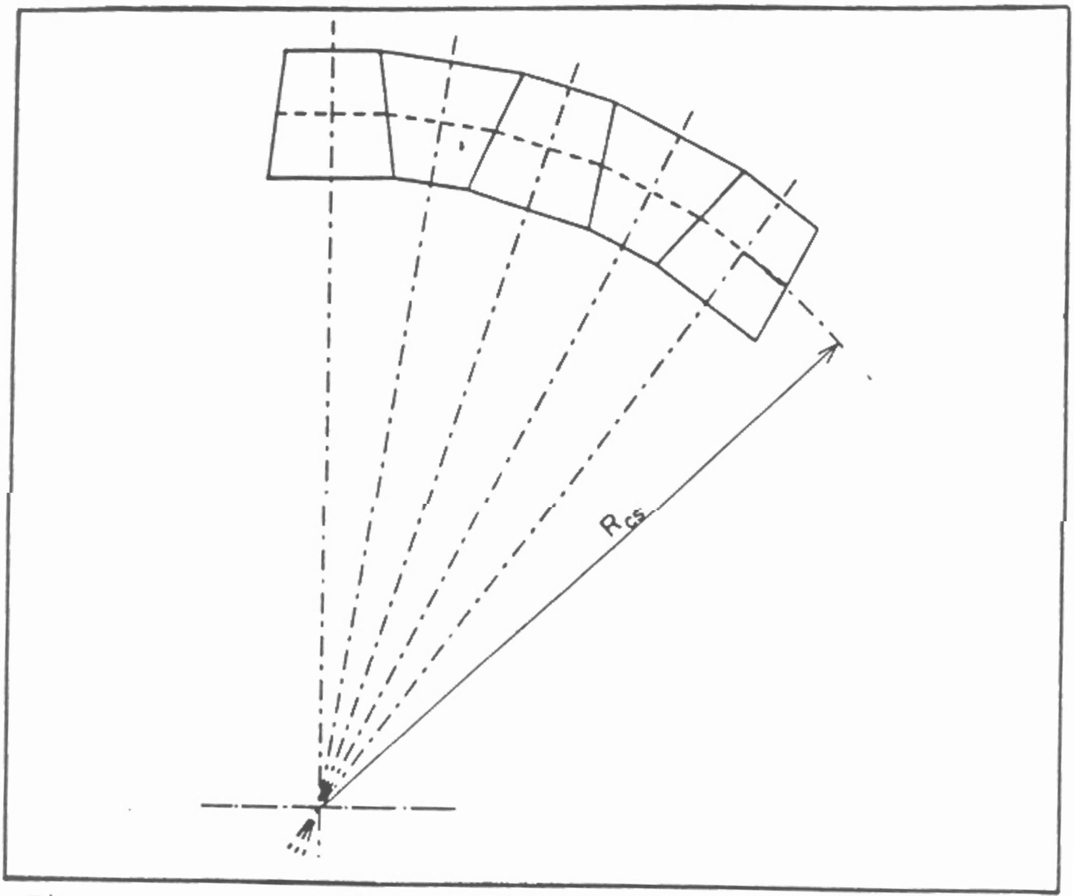

Fig. 8 - Counter-saddleback

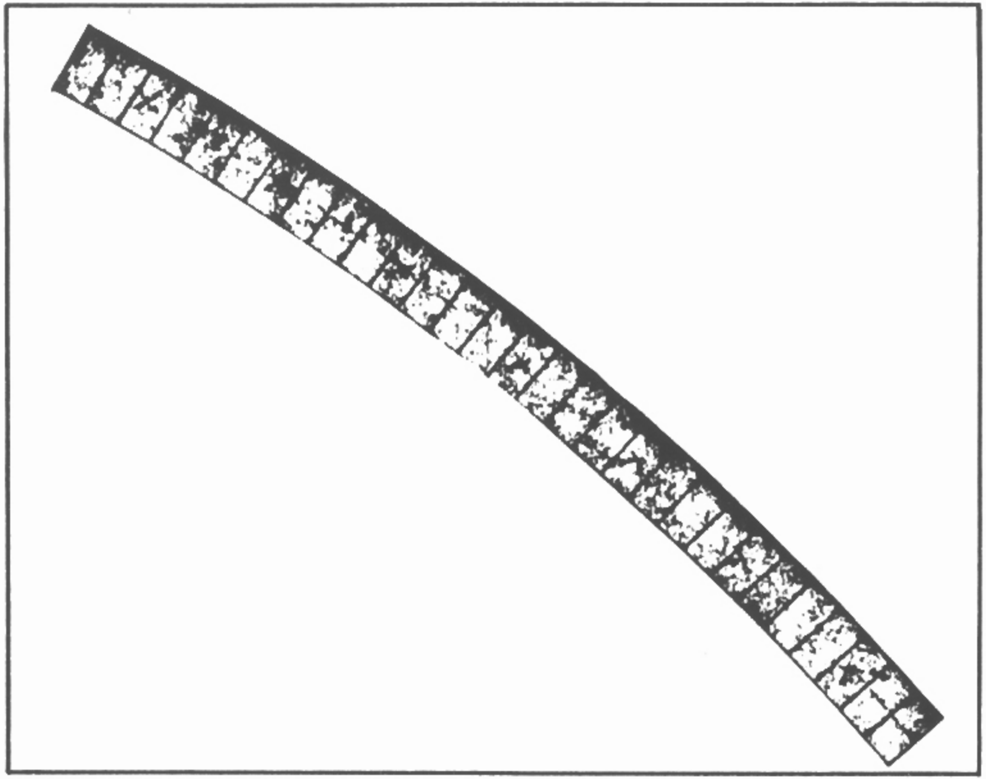

Fig. 9 - A sample of an actual counter-saddleback

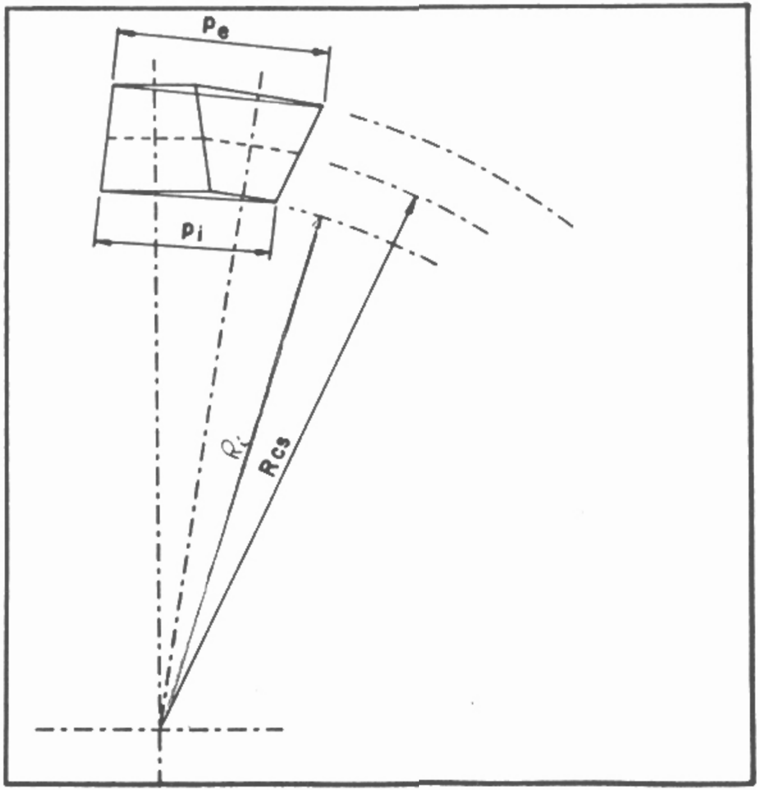

Fig. 10 - Indication of the radius of counter-saddleback (R_{cs})