"DYNAFORM" - A NOVEL SYSTEM TO SUPPORT THE HUMAN BODY

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ABSTRACT

A new concept for support of the human body by seat cushion, chair or bed is presented. A mechanical system of 3-dimensional levers is designed to support the body with uniform pressure dis- tribution. When sat on, the surface dynamically forms a contour that, against body tissue, produces uniform pressure everywhere, hence the name "DynaForm". A prototype seat cushion composed mainly of plastic molded parts was constructed, tested and found to perform as predicted by theory.

KEY WORDS: Seatcushion, Pressure Sore, Dicubiti, Bed

BACKGROUND

Since the beginning of time, man has sought to be more comfortable when sitting or lying by providing a resilient material to act between his body and a hard supporting surface. The body weight must be borne by and through the soft tissues that surround the skeleton. These tissues inevitably compress and deform and can cause capillary blood vessels to collapse under increased surrounding pressure and/or shear. The squeezing off of blood vessels is called ischemia and occurs at a pressure of about 25 millimeters of mercury (mm. Hg) [about 0.5 psi]. When the blood supply is cut off from tissue for an extended period of time, the tissue may be damaged and ultimately necrose (die). The result is the notorious pressure sore or decubitus ulcer. Normal sensate humans protect themselves by shifting position in a chair or turning when lying down to relieve areas of high pressure. They are warned to do this by discomfort that acts mostly below their level of consciousness.

The person who is paralyzed is continually at high risk from excess tissue pressure. He cannot feel the discomfort warning and he may not have the muscle control to move. As a result, many kinds of seat cushions have been developed for wheelchairs and many special mattresses and beds have been designed for lying down. Most of these operate to distribute and reduce tissue pressures and/or to reduce the time that any body portion is kept at higher than ischemic pressure.

It should be noted that the average pressure (body weight divided by area of support) for a sitting person is usually between 30 and 50 mm Hg. [0.6-1.0 psi] depending on total body weight, body build and weight borne by the feet, while for a person when lying, the pressure is below 25 mm. Hg [0.5 psi]. Thus a mattress or bed system that creates a uniform pressure distribution on the body throughout its support surface will protect a person lying down from pressure sores. However, a passive wheelchair cushion can only retard the effects of pressure or, by redistribution, place higher pressure where it is less likely to be harmful.

Support systems now available use a variety of concepts that employ foam plastics, air, fluids, rubber, etc. in both passive support cushions and mattresses and in active configurations that alternate pressure distributions, move the person, or even support him on fluidized particles or air itself. Many of these approaches do not create a completely uniform pressure distribution, are subject to failure (e.g. puncture or loss of air pressure), are very expensive or may have limited useful life.

Finally, in this introduction, the author would like to point out that while "soft", "springy" or "resilient" materials have universally been sought for body support materials, it is only the resulting shape of the interface between the body and the support surface that determines the pressure distribution in the tissue. In any given static situation, the resulting surface of a person's body on a resilient cushion could be replaced with a hard shell of exactly the same shape without the person being aware of any difference. Of course, the slightest shift in body position would "give away" the presence of a hard surface. These comments are relevant to the DynaForm system to be presented since it has an essentially hard surface, but one that continuously reforms and conforms its shape to produce uniform pressure as the body shifts in position. When sat on, the surface dynamically forms a contour that, acting against body tissues, produces uniform pressure distribution everywhere. Hence the name "DynaForm"

CONCEPT

The DynaForm concept is very simple. It is based on the fact that when forces are applied to the arms of a lever with a fulcrum at its midpoint, these forces must be equal if the system is in static equilibrium. The DynaForm system employs a large number of three dimensional multiple levers that support the body at a great many points. Each point lies at the end of a lever supported at its midpoint by the end of another lever and so on until only one or two levers are left to support the entire system. The concept is shown in 2-dimensional form in figure 1. For a seat system, the "lever trees" are brought down to two points of support so that the seat will have stability in the vertical plane. This establishes two semi-independent half portions of a seat support. The pressure distribution will then be uniform throughout each half but, depending on the location of the body c.g., will not necessarily be identical for each. This configuration conforms well to the seating portion of the human body where the long femurs and ischia mainly carry the body weight while little support is required or desired along the centerline.

Three dimensional lever systems may take two simple forms. The first, called the "H" form, consists of three levers and four forces as shown in figure 2. Inspection of the figure shows that all four forces must be equal. A second possibility is that of a triangle or "Delta" form with its fulcrum at the point of intersection of its medians. Three forces at the corners must be equal as shown in figure 3. The delta system is preferred since three forces may be supported with one part while the H system supports 4 forces with three parts. Also the delta is stable with point support at its center. The H system requires bearing type support at each fulcrum for stability of the levers.

The actual design of a seat support system employed both the Delta form and the H form. The Delta form results in essentially hexagonal arrays while the H form lends itself to rectangular shape. Delta elements comprise the top three layers of the DynaForm while the remaining support is in the H form. This allows the advantages of the Delta units for the layers with many parts but the H form levers produce a generally rectangular seat shape which is desirable for support of the body. Figure 4 shows the arrangement with the lines of all elements visible and Figure 5 is an enlargement of one corner.

PROTOTYPE FABRICATION

A prototype has been designed and built of molded plastic parts to simulate a form that could be produced at low cost. The lever units have ball shaped supports at their ends that are designed to "pop" or "snap" into cavities on the underside of the Delta elements as shown in Figure 6. Figure 7 is a photograph of one branch of Delta elements showing the form of these plastic parts (unit is inverted). Three layers are shown. The top layer is composed of 144 petal shaped plastic parts each connected to rock freely on the ends of 48 2nd-layer Delta elements. Each of these 2nd-layer elements is attached to rock freely on ball extensions of 16 larger Delta elements. Note that these 3rd-layer elements

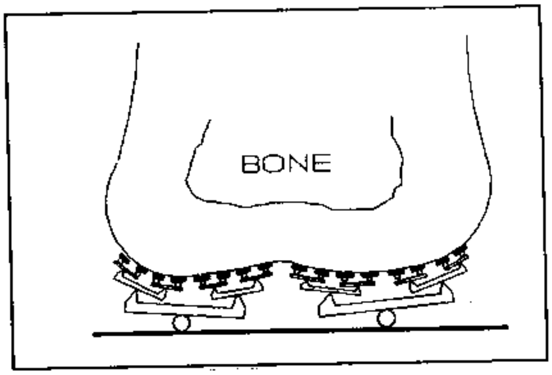

Figure 1. DynaForm Multiple Lever Support System

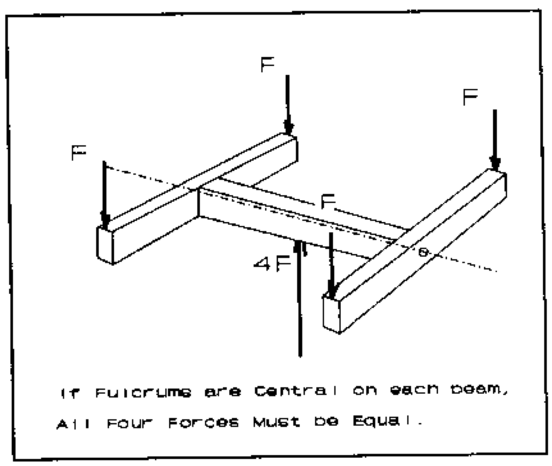

Figure 2. "H" Array of Three Levers and Four Equal Forces

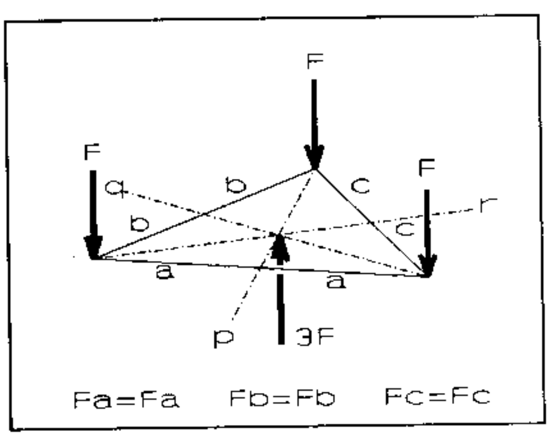

Figure 3. "Delta" Element with Three Equal Forces

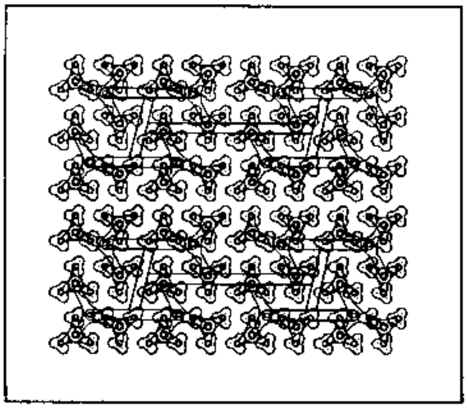

Figure 4. DynaForm Seat Parts Arrangement

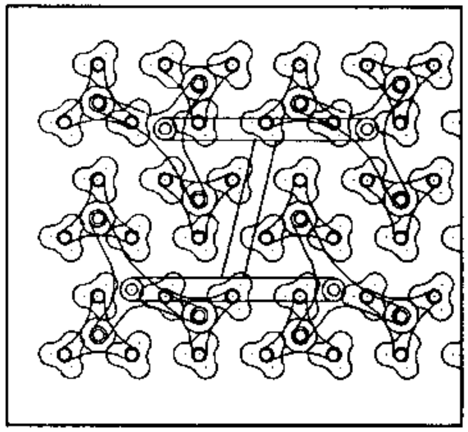

Figure 5. Enlarged View of Lower Left of Fig 4.

are not equilateral but shaped with different length arms so that the transition from Delta elements to the H array can be made resulting in a rectangular seat support. Since each 3rd-layer element is supported at its median intersection point on a ball joint at the end of each 4th-layer lever, the condition for equal forces is met. The 4th-layer is composed of straight two-force levers arranged in H- type arrays to bring the body force to 2 fulcrums, one on each side on a base platform, and create the desired rectangular array. These fulcrums allow the assembly to rock in the sagittal plane (forward and backward). Final assembly is completed by cementing each of the 144 1st-layer petal shaped parts to a 2-way stretch fabric cover. The cover serves to maintain the location of these parts which in turn hold the whole assembly in alignment.

The completed DynaForm seat is shown in figures 8 and 9 with a seated subject. The cover is folded out of the way to expose the Delta and H elements to show the positions they assume when conforming to a person's body. Figures 10 and 11 show a chair on which the cushion of figures 8 and 9 has been installed. The back of the chair is composed of the same elements as the seat but with only half. Thus the back represents one side of a seat and is shown in figure 12 to exemplify the construction.

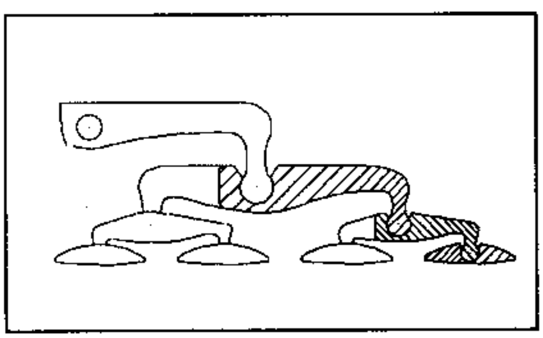

Figure 6. Cross Section Through 3-Arm "Delta" Elements

PRELIMINARY RESULTS

In figure 8 may be seen a pressure measuring device manufactured by Gaymar Industries. It uses a single transducer and reads out the pressure between the body and the support surface over a small area. Pressures at a number of points were measured under the author and under his wife by carefully placing the transducer over many of the supporting plastic "petals". Under the author, (155 lbs. weight) pressures measured were between 45 - 50 mm. Hg and under his wife (105 lbs. weight) they were between 30 - 35 mm. Hg. While these results appear to confirm the theory in these two cases, it is clear that no definitive results can be accepted as valid for only two cases. A number of subjects should be tested by unbiased researchers under clinical conditions for results to be meaningful. As of this writing, the chair is in daily use by the author's wife who is able, for the first time, to sit for hours where before she could sit for only about 15 minutes without having to stand up.

DISCUSSION

The DynaForm cushion is based on very simple scientific concepts and appears to function as intended. It is easy to construct and when the parts are molded in large quantities, it should be relatively inexpensive to manufacture. Noteworthy, perhaps, is the synergistic result of the simple hemispherical elements that "pop" together forming a bearing and providing stable support without any additional parts. When made from appropriate materials it should have a long useful life. The Dynaform concept has been presented as a means to better prevent the onset of pressure sores in persons at risk. For chairs in general, it may provide the basis for a more ergometric chair for the workplace. It may even find application in general purpose furniture including beds.

Figure 7. Three Layer "Branches" of Delta-parts (inverted).

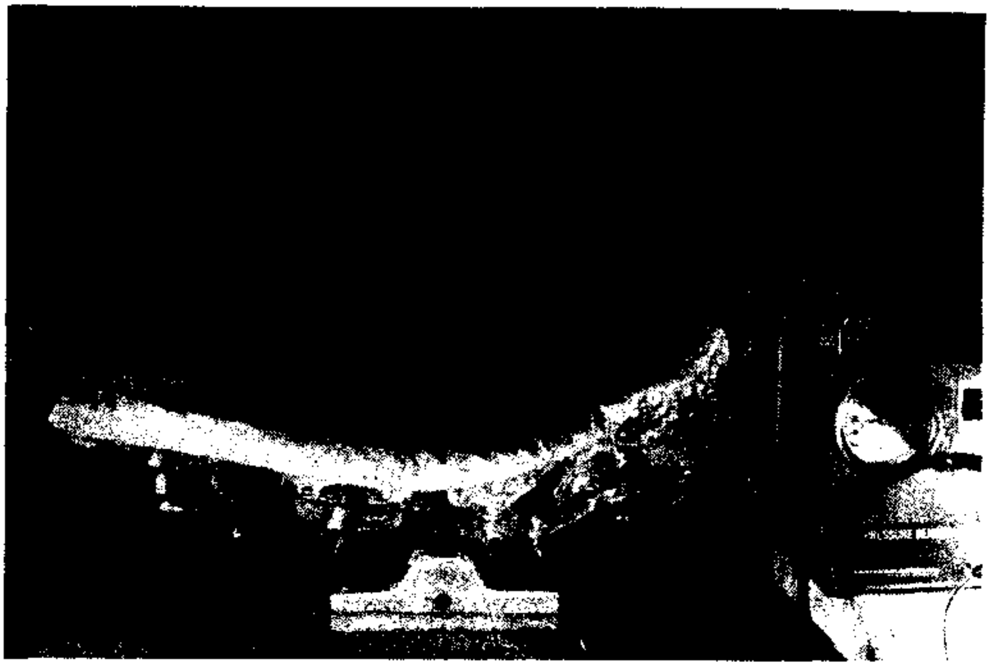

Figure 8. Subject Seated on DynaForm Cushion (Side View).

Figure 9. Subject Seated on DynaForm Cushion (Back View).

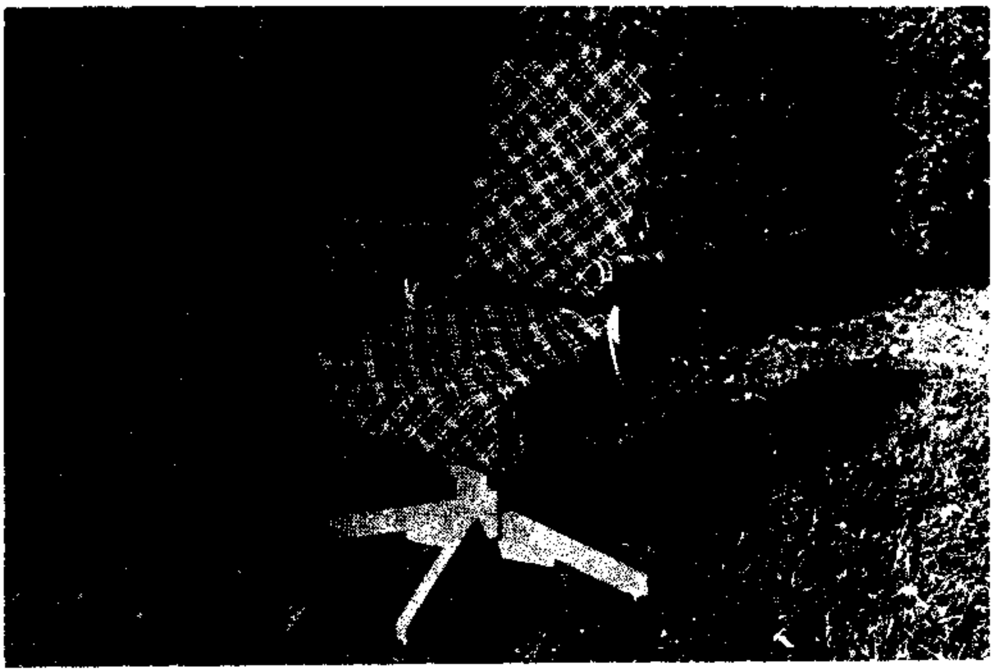

Figure 10. Prototype Chair with DynaForm Cushion Installed.

CONCLUSION

A new concept for supporting the human body has been presented. A mechanical system of 3-dimensional levers is designed to support the body with uniform pressure distribution. When sat on, the surface dynamically forms a contour that, against body tissue, produces uniform pressure everywhere, hence the name "Dyna-Form". A prototype seat cushion composed mainly of plastic molded parts was constructed and incorporated in a chair. Initial tests on two subjects showed uniform pressure distributions in values that were predicted by theory.

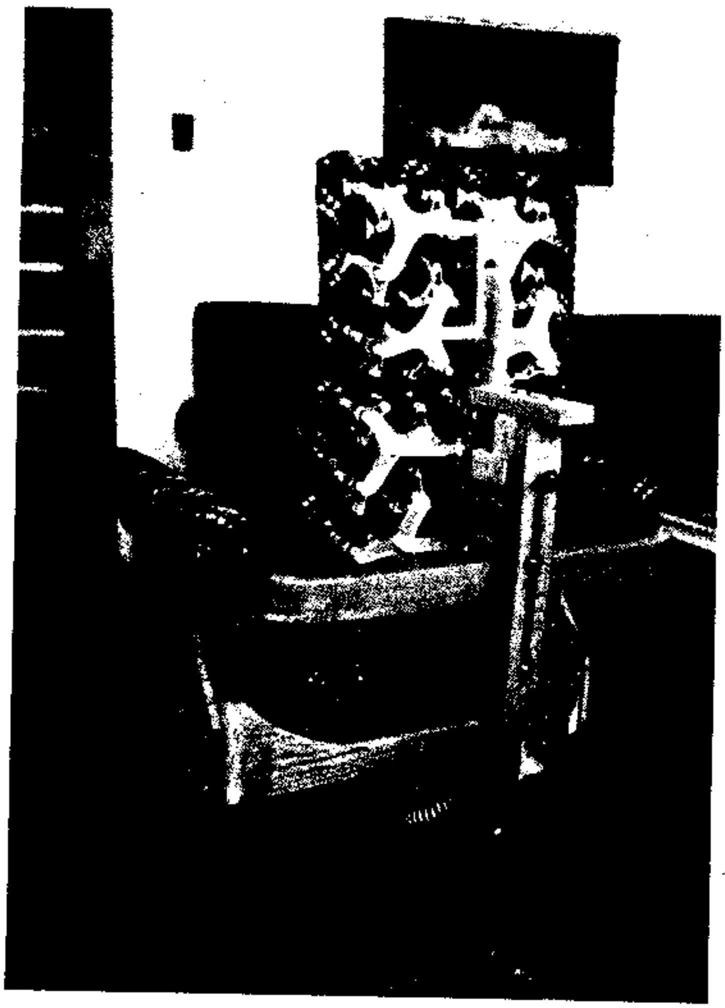

Figure 11. Back View of Prototype Chair.

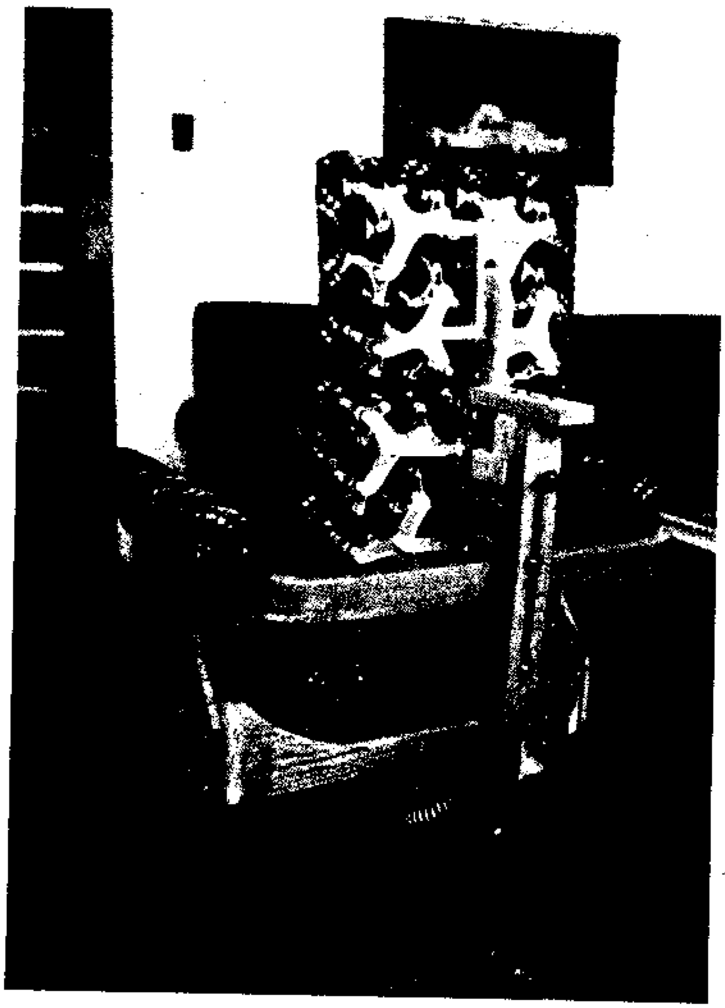

Figure 11. Back View of Prototype Chair.