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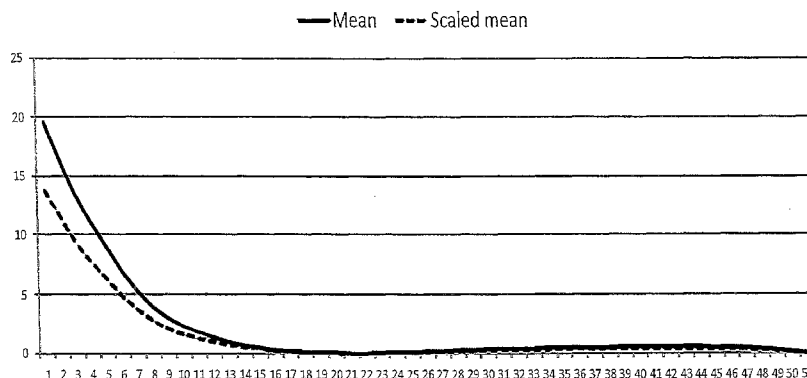


Fig. 1

(57) Abstract: A method of mathematically defining seat surface contours from quantitative definitions of relevant back, buttock and under-thigh surfaces of a sample of individuals, the method including adjusting a mathematical summary of the surfaces of the sample of individuals by means of a mathematical function of a summary statistic of the surfaces of the sample of individuals.

METHOD OF DETERMINING OPTIMAL SEAT SURFACE CONTOURS AND SEAT HAVING AN OPTIMIZED SEAT SURFACE CONTOUR

TECHNICAL FIELD AND BACKGROUND OF THE INVENTION

The present invention relates to methods for deriving seat surface contours optimized to provide maximum comfort for a population of varying anthropometry, and provides a method of defining an optimum seat surface contour in the prior art of airline passenger seating as well as in residential, office and other seating. The invention also relates to a seat having an optimized seat surface contour.

Seat cushions employed in the prior art are necessarily thick to fill the substantial differences between the contours of the firm supporting surface and the passengers' bodies. The cushion thickness required to provide comfort under the prior art has several significant disadvantages. First, they occupy space that reduces the personal space available to adjacent passengers. The cushion thickness behind a passenger's buttocks and lower back reduces the legroom available to passengers seated behind the seat. Second, the cushion weight increases with cushion thickness, increasing the operating weight of the airplane resulting in reduced range, greater fuel burn and other increased costs. In addition, cushions degrade over time leaving passengers seated without substantial cushioning on the rigid supporting surface of the prior art which is sub-optimal from a comfort standpoint.

The prior art in seats with rigid supporting surfaces is also characterized by rigid supporting surfaces that do not optimally conform to the corresponding surfaces of the occupant's bodies.

BRIEF SUMMARY OF THE INVENTION

It is therefore an object of the present invention to provide a more accurate and

reliable method of determining the optimal seating surface contours.

It is another object of the present invention to provide a significant improvement in the simple “mean surface” approach of the prior art in residential, commercial and other seating.

It is another object of the present invention to provide a seat having a seating surface optimized using the methods disclosed in this application.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention is best understood when the following detailed description of the invention is read with reference to the accompanying drawings, in which:

Figure 1 is a graph showing mean and scaled mean bottom support profiles in accordance with a method of the invention;

Figure 2 is a graph showing a zeroed transverse support rib defined by scaling mean values, illustrated by a solid line in accordance with a method of the invention;

Figure 3 is a graph showing a family of zeroed transverse support ribs spaced at 5 centimeter increments of y in accordance with a method of the invention;

Figure 4 is a graph showing a family of optimized bottom surface rib positions spaced at 5 centimeter increments of y in accordance with a method of the invention;

Figure 5 is a flow chart illustrating an example of the method according to invention; and

Figure 6 is a seat having an optimized bottom surface seating area according to the method of the invention.

DETAILED DESCRIPTION OF THE INVENTION

The method described in this application blends quantitative descriptions of the back, buttock and back-of-thigh surfaces of a variety of individuals into a single surface.

Research conducted using surfaces developed using the described method of the present invention has shown that surfaces based on a simple average of the anthropometric surfaces are sub-optimal. Research conducted using surfaces developed using the method of the present invention has also shown that employing coefficients or functions in the seventh step set out below that are substantially different from the coefficients or functions employed in the fifth and sixth steps of the preferred embodiment described below results in more comfortable seat surface contours. The preferred method described provides an enabling step-by-step method to define an optimum seat surface contour.

The method of the present invention treats the seat back surface which supports the occupant's back and back of buttock as a first surface and the seat bottom surface which supports the bottom of the occupant's buttocks and thighs as a second surface. One of ordinary skill in mathematics can combine the first back surface and the second bottom surface into a single unified surface comprising the back and bottom. The present invention further includes seat surfaces defined using the method of the present invention.

Conventional three dimensional x, y, z, data are used to describe the back, back of head, back of neck, buttock and lower thigh surfaces of a sampling of target population in postures of interest. The postures of interest may include seated upright with the lower legs upright, seated upright with legs extended, reclined to various degrees with legs extended or other foreseeable postures.

The preferred method maps each first back surface with regard to an arbitrary reference plane generally parallel to the aft-most points on the occupant's back and buttocks. The x-axis runs from side to side on the occupant's body and precisely parallel to the reference plane. For convenience, zero on the x-axis can be the centerline of the back. The y-axis of the back runs generally parallel to the spine and runs precisely parallel to the

reference plane. For convenience, zero on the y-axis can be the point of intersection between the reference plane for the first back surface and the reference plane for the second bottom surface. The z-axis of the back is perpendicular to the reference plane for the back surface. For convenience, zero on the z-axis for the back can lie on the reference plane and positive values lie in front of the reference plane for the first back surface.

Similarly, the preferred method maps each second bottom surface with regard to an arbitrary reference plane generally parallel to the lowest points on the occupant's buttocks and thighs. The x-axis in the preferred embodiment runs from side to side on the occupant's body and precisely parallel to the reference plane. For convenience, zero on the x-axis can be the centerline of the bottom between the legs. The y-axis of the bottom runs generally parallel to the thighs and precisely parallel to the reference plane. For convenience, zero on the y-axis can be the point of intersection between the reference plane for the first back surface and the reference plane for the second bottom surface. The z-axis of the bottom is perpendicular to the reference plane for the back surface. For convenience, zero on the z-axis lies on the reference plane and positive values lie above the reference plane for the second bottom plane.

In one preferred embodiment of the present invention, each first back and second bottom surface of interest is represented as a matrix of z values for regularly spaced locations on the x and y axes. One centimeter increments on the x and y axes have proven to provide adequate resolution while keeping the size of the database easily manageable.

In a first step of a preferred embodiment, matrices of z values are created for the first back surface and second bottom surface for each individual in a sample from the population of interest. The creation of the matrices can include laser scanning of the impressions left in soft material by seated sample subjects or any other measurement technique.

In a second step of a preferred embodiment, the mean z value for each combination of x and y in the sample is calculated and used to populate summary matrices of mean z -values for both the first back surface and second bottom surface. As an example, the z value in a matrix of mean values where $x=5$ and $y=10$ is the mean value of z where $x=5$ and $y=10$ for all individual sample subjects. The mean values can be weighted to reflect the frequency of occurrence of the anthropometry of each individual sample subject in the target population where the distribution of anthropometry in the sample does not adequately correspond to the distribution of anthropometry in the target population.

In a third step of a preferred embodiment, a second summary statistic, such as the standard deviation, of the z values for each combination of x and y in the sample is calculated and used to populate z -value second summary statistic matrices for both the first back surface and second bottom surface. As an example, the value in a second summary statistic matrix where $x=5$ and $y=10$ is the second summary statistic of z where $x=5$ and $y=10$ for all individuals in the sample. The second summary statistic can be weighted to reflect the frequency of occurrence of the anthropometry of each individual sample subject in the target population where the distribution of anthropometry in the sample does not adequately correspond to the distribution of anthropometry in the target population.

In a fourth step of a preferred embodiment of the method of the present invention, a mean spine support profile is defined by identifying the minimum z value for all values of x at each value of y in the matrix of mean z values for the first back surface created in the second step of the preferred embodiment. Similarly, a mean bottom support profile is defined by identifying the minimum z value for all values of x at each value of y in the matrix of mean z values for the second bottom surface. A mean bottom support profile is illustrated by a solid line in Fig 1.

In a fifth step of a preferred embodiment of the method of the present invention, an adjusted spine support profile is defined by multiplying each value of z by a scaling coefficient or function. Coefficients greater than zero and less than one have proven appropriate to improving the comfort of the seat surface. As an alternative to multiplying the mean z values by a scaling coefficient or function, the adjusted spine support profile can be defined by subtracting from or adding to each z value on the mean spine support profile a function of the second summary statistic calculated in the third step of the present embodiment for the value of x at which the minimum value of z was found for the relevant value of y . As yet a further alternative, the adjusted spine support profile can be defined by both multiplying all z values by a scaling coefficient or function and adding or subtracting a function of the second summary statistic. The selection of the scaling coefficient or functions or the functions to be applied to second summary statistics can be guided by human subject testing of surfaces in which the z values of the adjusted spine support profile are employed as the z values for all values of x at the corresponding value of y .

Referring to Figure 1, in a sixth step of a preferred embodiment of the method of the present invention, an adjusted bottom support profile is defined by multiplying each value of z by a scaling coefficient. Coefficients greater than zero and less than one have proven appropriate to improving the comfort of the seat surface. As an alternative to multiplying the mean z values by a scaling coefficient or function, the adjusted bottom support profile can be defined by subtracting from or adding to each z value on the mean bottom support profile a selected function of the second summary statistic calculated in the third step of the present embodiment for the value of x at which the minimum value of z was found for the relevant value of y . As yet a further alternative, the adjusted bottom support profile can be defined by both multiplying all z values by a scaling coefficient or function and adding or subtracting a

function of the second summary statistic. The selection of the scaling coefficient or functions or the functions to be applied to second summary statistics can be guided by human subject testing of surfaces in which the z values of the adjusted bottom support profile are employed as the z values for all values of x at the corresponding value of y. An adjusted bottom support profile defined by scaling all values of z by a coefficient is illustrated in Figure 1 by a dashed line.

In a seventh step of the preferred embodiment of the method of the present invention two-dimensional, in x and z, adjusted transverse support rib profiles are defined for each value of y on the first back surface and the second bottom surface by multiplying each mean z value by a scaling coefficient or function, or as an alternative by subtracting from or adding to each z value a selected function of the second summary statistic calculated in the third step of the preferred embodiment for the same values of x and y; or as yet another alternative both multiplying each z value by a scaling coefficient or function and adding or subtracting a selected function of the second summary statistic calculated in the third step the preferred embodiment.

As illustrated in Figure 2, in an eighth step of a preferred embodiment, zeroed transverse support rib profiles are defined for every value of y in the first back surface and the second bottom surface by subtracting the minimum z value identified in each adjusted transverse support rib profile defined in the seventh step of the preferred embodiment from all z values of that same adjusted transverse support rib profile. A zeroed transverse support rib defined by scaling mean values is illustrated by a solid line in Figure 2. An unadjusted zeroed transverse support rib defined by mean z values is illustrated for comparison as a dashed line in Figure 2.

As shown in Figure 3, convex areas in the zeroed transverse support ribs that will be

present between the buttocks, legs and typically along the spine between the musculature of the back can be bridged by multiplying all z values between the two lowest (zero) z values on each zeroed transverse support rib by a coefficient of less than one. Such a bridge using a coefficient of zero is illustrated by a dotted line in Figure 2. A family of zeroed transverse support ribs spaced at 5 centimeter increments of y is illustrated in Figure 3.

In an ninth step of a preferred embodiment of the present invention, a complete optimized first back surface contour is defined by adding the z value of the adjusted spine support profile to all z values of each zeroed transverse support rib at the corresponding value of y. Similarly, a complete optimized second bottom surface contour is defined by adding the z value of the adjusted bottom support profile to all z values of each zeroed transverse support rib at the corresponding value of y.

Figure 4 illustrates the transverse support ribs of Figure 3 displaced in the manner of defining the optimized second bottom surface contour.

The method described above is summarized in Figure 5.

Referring now to Figure 6, seats 10, as illustrated, are of a type with which the method is useful in optimizing the seat bottom contour. The seats 10 each include a seat back 12, a headrest 14, a seat bottom 16 and an extendable legrest 18. The seats 10 are separated by a center console 20 and are each provided with an end bay 22. The method is also useful on any type of aircraft passenger seat, including commuter, short haul and long haul aircraft seating products, as well as other types of transportation seating and office seating products.

A method of determining optimal seat surface contours and seats optimized according to the method according to the invention have been described with reference to specific embodiments and examples. Various details of the invention may be changed without

departing from the scope of the invention. Furthermore, the foregoing description of the preferred embodiments of the invention and best mode for practicing the invention are provided for the purpose of illustration only and not for the purpose of limitation, the invention being defined by the claims.

What is claimed is:

1. A method of mathematically defining seat surface contours from quantitative definitions of back, buttock and under-thigh surfaces of a sample of individuals, the method comprising adjusting a mathematical summary of the surfaces of the sample of individuals by means of a mathematical function of a summary statistic of the surfaces of the sample of individuals.
2. The method according to claim 1, wherein the seat surface contours includes a seat bottom contour defined from quantitative definitions of buttock and under-thigh surfaces of a sample of individuals, and the method includes adjusting a mathematical summary of the surfaces of the sample of individuals by means of applying one mathematical function of a summary statistic of the surfaces of the sample of individuals on a fore and aft axis of the seat bottom surface and a second, different mathematical function of a summary statistic of the surfaces of the sample of individuals on a side-to-side axis of the seat bottom surface.
3. The method according to claim 1, wherein the seat surface contours includes a seat back contour defined from quantitative definitions of back, back of head, back of neck and buttock surfaces of a sample of individuals, and the method includes adjusting a mathematical summary of the back surfaces of the sample of individuals by means of applying one mathematical function of a summary statistic of the surfaces of the sample of individuals on a fore and aft axis of the seat back surface and a second, different mathematical function of a summary statistic of the surfaces of the sample of individuals on a side-to-side axis of the seat

back surface.

4. A method of mathematically defining seat surface contours, comprising the steps of:
 - (a) defining an x-axis as a centerline of a back of the seat and a y-axis parallel to a spine angle of the seat parallel to a pre-defined reference plane;
 - (b) creating matrices of z-values for a first back surface and a second bottom surface for a plurality of individuals in a sample selected from a population of interest;
 - (c) calculating the mean z-value for each combination of x and y in the sample and populating summary matrices of mean z-values for both the first back surface and second bottom surface with the mean z values;
 - (d) calculating a second summary statistic of the z-values for each combination of x and y in the sample and populating z-value second summary statistic matrices for both the first back surface and second bottom surface;
 - (e) defining a mean spine support profile by identifying the minimum z-value for all values of x at each value of y in the matrix of mean z values for the first back surface;
 - (f) defining a mean bottom support profile by identifying the minimum z value for all values of x at each value of y in the matrix of mean z values for the second bottom surface;
 - (g) defining an adjusted spine support profile by multiplying each value of z by a scaling coefficient;
 - (h) defining an adjusted bottom support profile by multiplying each value of z by a scaling coefficient;
 - (i) defining two-dimensional x and z, adjusted transverse support rib profiles for

each value of y on the first back surface and the second bottom surface by multiplying each mean z-value by a scaling coefficient or function, or as an alternative by subtracting from or adding to each z-value a selected function of the second summary statistic calculated in the third step of the preferred embodiment for the same values of x and y;

(j) defining zeroed transverse support rib profiles for every value of y in the first back surface and the second bottom surface by subtracting the minimum z value identified in each adjusted transverse support rib profile from all z-values of that same adjusted transverse support rib profile;

(k) bridging convex areas in the zeroed transverse support ribs present between the buttocks, legs and typically along the spine between the musculature of the back by multiplying all z-values between the two lowest z-values on each zeroed transverse support rib by a coefficient of less than one;

(l) defining a complete optimized first back surface contour by adding the z-value of the adjusted spine support profile to all z-values of each zeroed transverse support rib at the corresponding value of y; and

(m) defining a complete optimized second bottom surface contour by adding the z-value of the adjusted bottom support profile to all z-values of each zeroed transverse support rib at the corresponding value of y.

5. The method according to claim 4, wherein the matrices are created by laser scanning impressions left in soft material of a seat by seated sample subjects.
6. The method according to claim 4, and including the step of weighting the mean values

reflect the frequency of occurrence of the anthropometry of each individual sample subject in the target population where the distribution of anthropometry in the sample does not adequately correspond to the distribution of anthropometry in the target population.

7. The method according to claim 4, wherein the step of creating the adjusted spine support profile includes the step of defining the adjusted spine support profile by subtracting from or adding to each z-value on the mean spine support profile a function of the second summary statistic for the value of x at which the minimum value of z was found for the relevant value of y.

8. The method according to claim 4, wherein the step of creating the adjusted spine support profile includes the step of multiplying all z-values by a scaling coefficient or function and adding or subtracting a function of the second summary statistic, wherein the selection of the scaling coefficient or functions or the functions to be applied to second summary statistics is determined by human subject testing of surfaces in which the z- values of the adjusted spine support profile are employed as the z-values for all values of x at the corresponding value of y.

9. The method according to claim 4, wherein the adjusted bottom support profile is defined by subtracting from or adding to each z-value on the mean bottom support profile a selected function of the second summary statistic calculated for the value of x at which the minimum value of z was found for the relevant value of y.

10. The method according to claim 4, wherein the adjusted bottom support profile is

defined by multiplying all z-values by a scaling coefficient or function and adding or subtracting a function of the second summary statistic.

11. An aircraft passenger seat having a plurality of seat surfaces configured for a target population of varying anthropometry, wherein the optimization is carried out according to a method of mathematically defining seat surface contours from quantitative definitions of back, buttock and under-thigh surfaces of a sample of individuals, the method comprising adjusting a mathematical summary of the surfaces of the sample of individuals by means of a mathematical function of a summary statistic of the surfaces of the sample of individuals.

12. The aircraft passenger seat according to claim 11, wherein the aircraft passenger seat includes a seat bottom contour defined from quantitative definitions of buttock and under-thigh surfaces of a sample of individuals according to a method including adjusting a mathematical summary of the surfaces of the sample of individuals by means of applying one mathematical function of a summary statistic of the surfaces of the sample of individuals on a fore and aft axis of the seat bottom surface and a second, different mathematical function of a summary statistic of the surfaces of the sample of individuals on a side-to-side axis of the seat bottom surface.

13. The aircraft passenger seat according to claim 11, wherein the aircraft passenger seat includes a seat back contour defined from quantitative definitions of back, back of head, back of neck and buttock surfaces of a sample of individuals according to a method including adjusting a mathematical summary of the back surfaces of the sample of individuals by means

of applying one mathematical function of a summary statistic of the surfaces of the sample of individuals on a fore and aft axis of the seat back surface and a second, different mathematical function of a summary statistic of the surfaces of the sample of individuals on a side-to-side axis of the seat back surface.

14. The aircraft passenger seat according to claim 11, wherein the seat surfaces are configured according to a method comprising the steps of:

- (a) defining an x-axis as a centerline of a back of the seat and a y-axis parallel to a spine angle of the seat parallel to a pre-defined reference plane;
- (b) creating matrices of z-values for a first back surface and a second bottom surface for a plurality of individuals in a sample selected from a population of interest;
- (c) calculating the mean z-value for each combination of x and y in the sample and populating summary matrices of mean z-values for both the first back surface and second bottom surface with the mean z values;
- (d) calculating a second summary statistic of the z-values for each combination of x and y in the sample and populating z-value second summary statistic matrices for both the first back surface and second bottom surface;
- (e) defining a mean spine support profile by identifying the minimum z-value for all values of x at each value of y in the matrix of mean z values for the first back surface;
- (f) defining a mean bottom support profile by identifying the minimum z value for all values of x at each value of y in the matrix of mean z values for the second bottom surface;
- (g) defining an adjusted spine support profile by multiplying each value of z by a

scaling coefficient;

(h) defining an adjusted bottom support profile by multiplying each value of z by a scaling coefficient;

(i) defining two-dimensional x and z, adjusted transverse support rib profiles for each value of y on the first back surface and the second bottom surface by multiplying each mean z-value by a scaling coefficient or function, or as an alternative by subtracting from or adding to each z-value a selected function of the second summary statistic calculated in the third step of the preferred embodiment for the same values of x and y;

(j) defining zeroed transverse support rib profiles for every value of y in the first back surface and the second bottom surface by subtracting the minimum z value identified in each adjusted transverse support rib profile from all z-values of that same adjusted transverse support rib profile;

(k) bridging convex areas in the zeroed transverse support ribs present between the buttocks, legs and typically along the spine between the musculature of the back by multiplying all z-values between the two lowest z-values on each zeroed transverse support rib by a coefficient of less than one;

(l) defining a complete optimized first back surface contour by adding the z-value of the adjusted spine support profile to all z-values of each zeroed transverse support rib at the corresponding value of y; and

(m) defining a complete optimized second bottom surface contour by adding the z-value of the adjusted bottom support profile to all z-values of each zeroed transverse support rib at the corresponding value of y.

15. The aircraft passenger seat according to claim 14, wherein the matrices are created by laser scanning impressions left in soft material of a seat by seated sample subjects.

16. The aircraft passenger seat according to claim 14, and including the step of weighting the mean values reflect the frequency of occurrence of the anthropometry of each individual sample subject in the target population where the distribution of anthropometry in the sample does not adequately correspond to the distribution of anthropometry in the target population.

17. The aircraft passenger seat according to claim 14, wherein the step of creating the adjusted spine support profile includes the step of defining the adjusted spine support profile by subtracting from or adding to each z-value on the mean spine support profile a function of the second summary statistic for the value of x at which the minimum value of z was found for the relevant value of y.

18. The aircraft passenger seat according to claim 14, wherein the step of creating the adjusted spine support profile includes the step of multiplying all z-values by a scaling coefficient or function and adding or subtracting a function of the second summary statistic, wherein the selection of the scaling coefficient or functions or the functions to be applied to second summary statistics is determined by human subject testing of surfaces in which the z-values of the adjusted spine support profile are employed as the z-values for all values of x at the corresponding value of y.

19. The aircraft passenger seat according to claim 14, wherein the adjusted bottom support

profile is defined by subtracting from or adding to each z-value on the mean bottom support profile a selected function of the second summary statistic calculated for the value of x at which the minimum value of z was found for the relevant value of y.

20. The aircraft passenger seat according to claim 14, wherein the adjusted bottom support profile is defined by multiplying all z-values by a scaling coefficient or function and adding or subtracting a function of the second summary statistic.

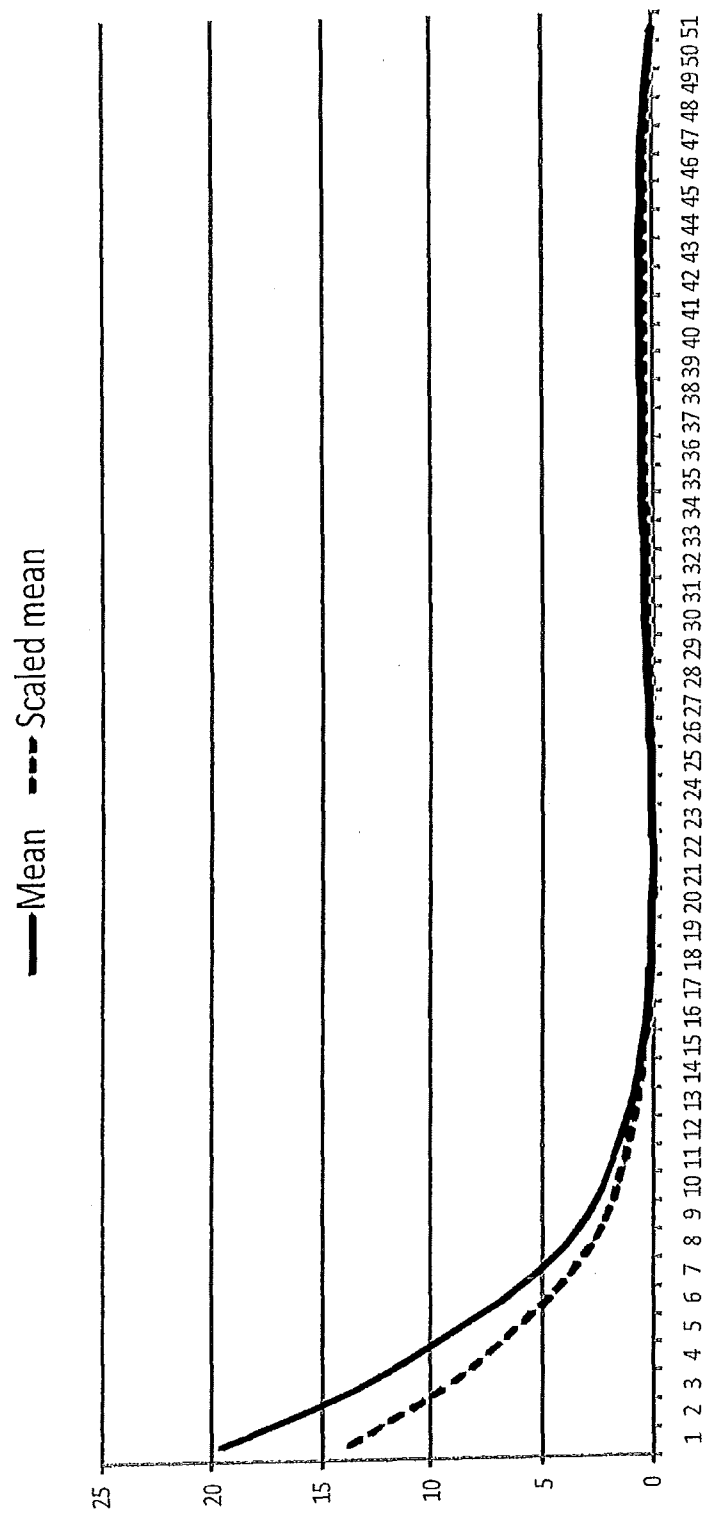


Fig. 1

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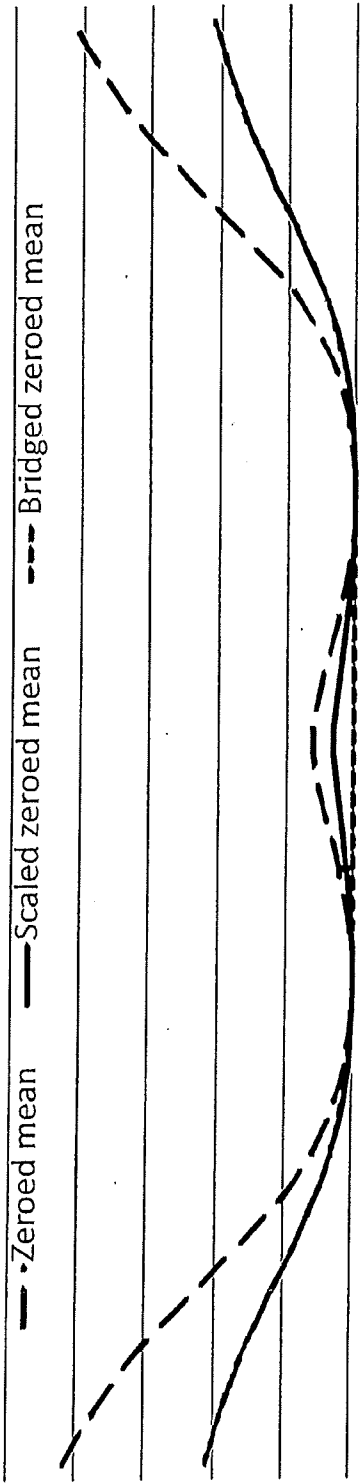


Fig. 2

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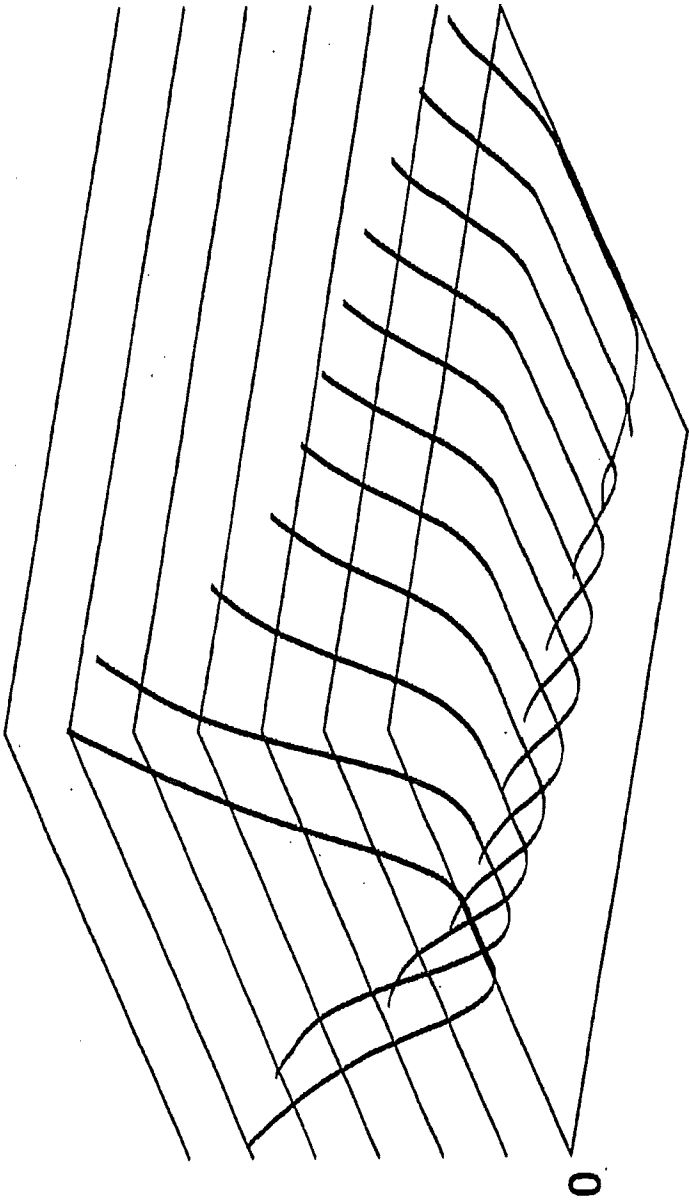


Fig. 3

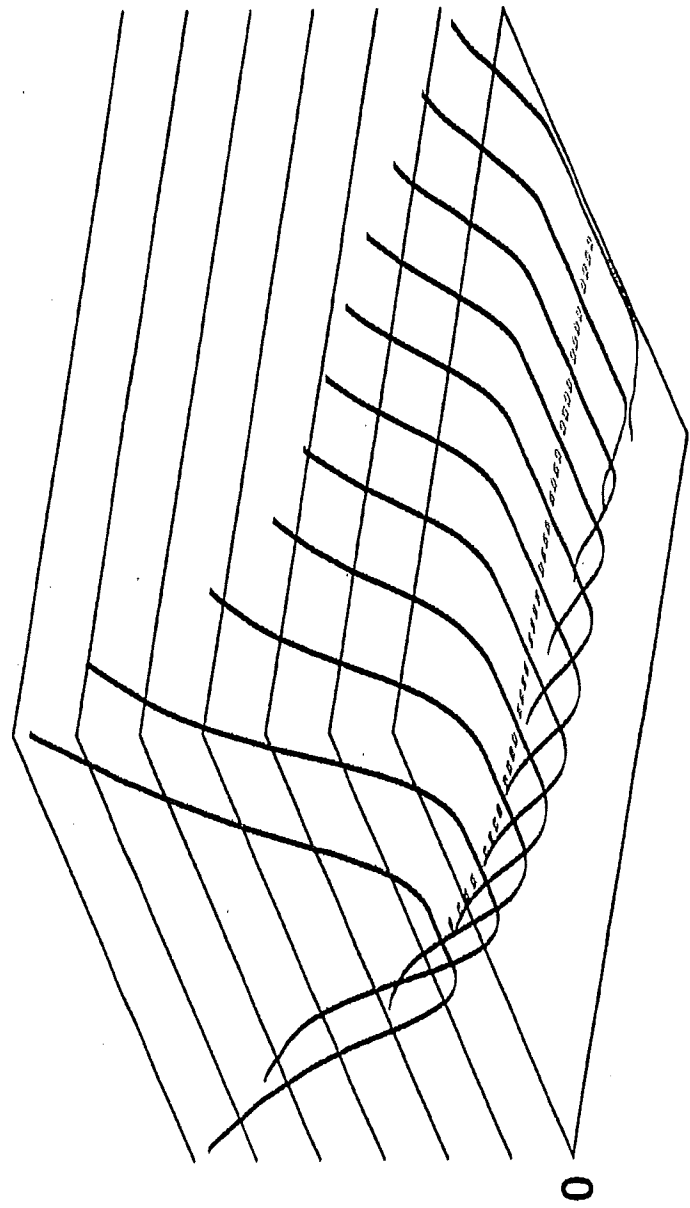


Fig. 4

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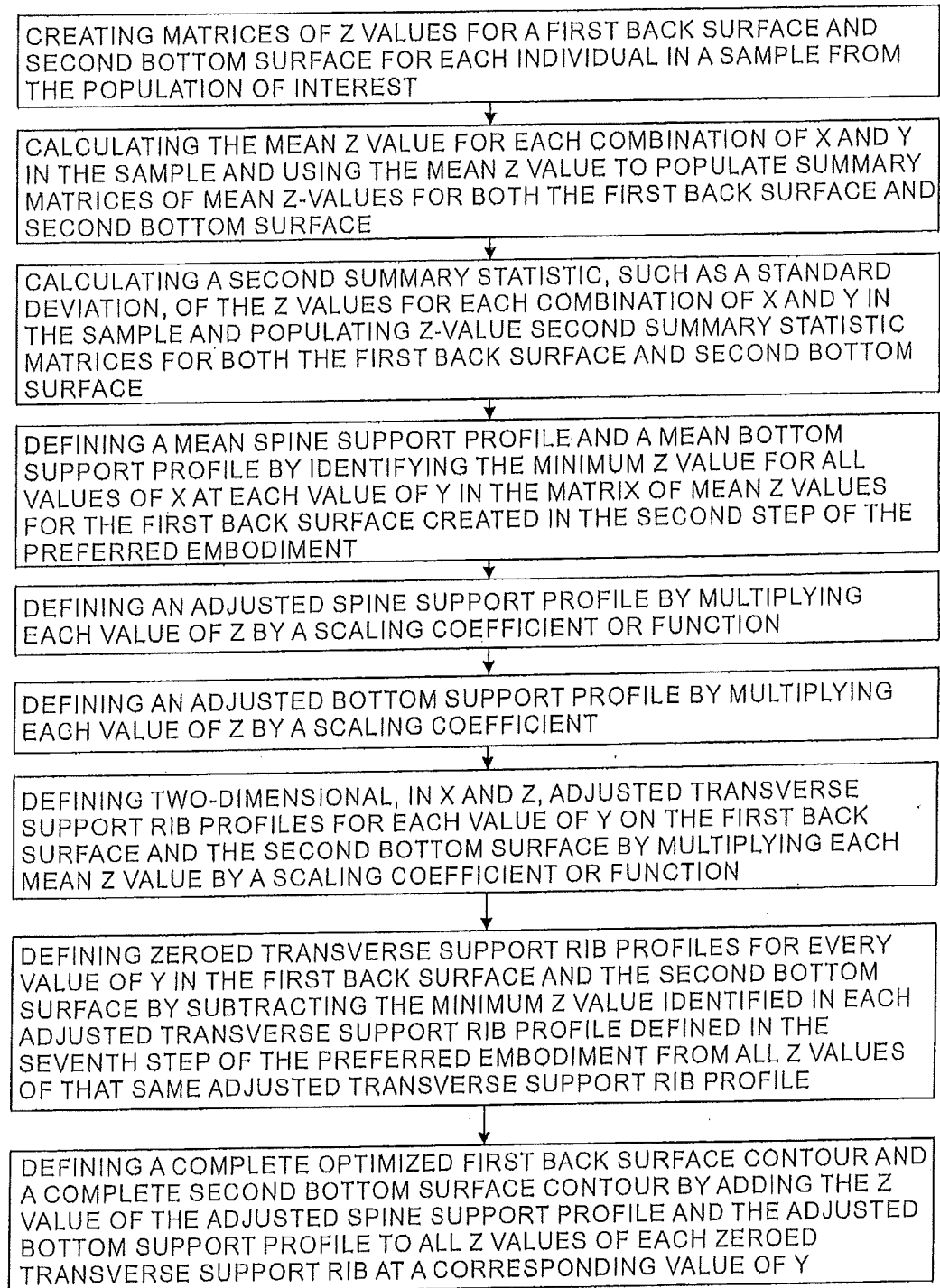


FIGURE 5

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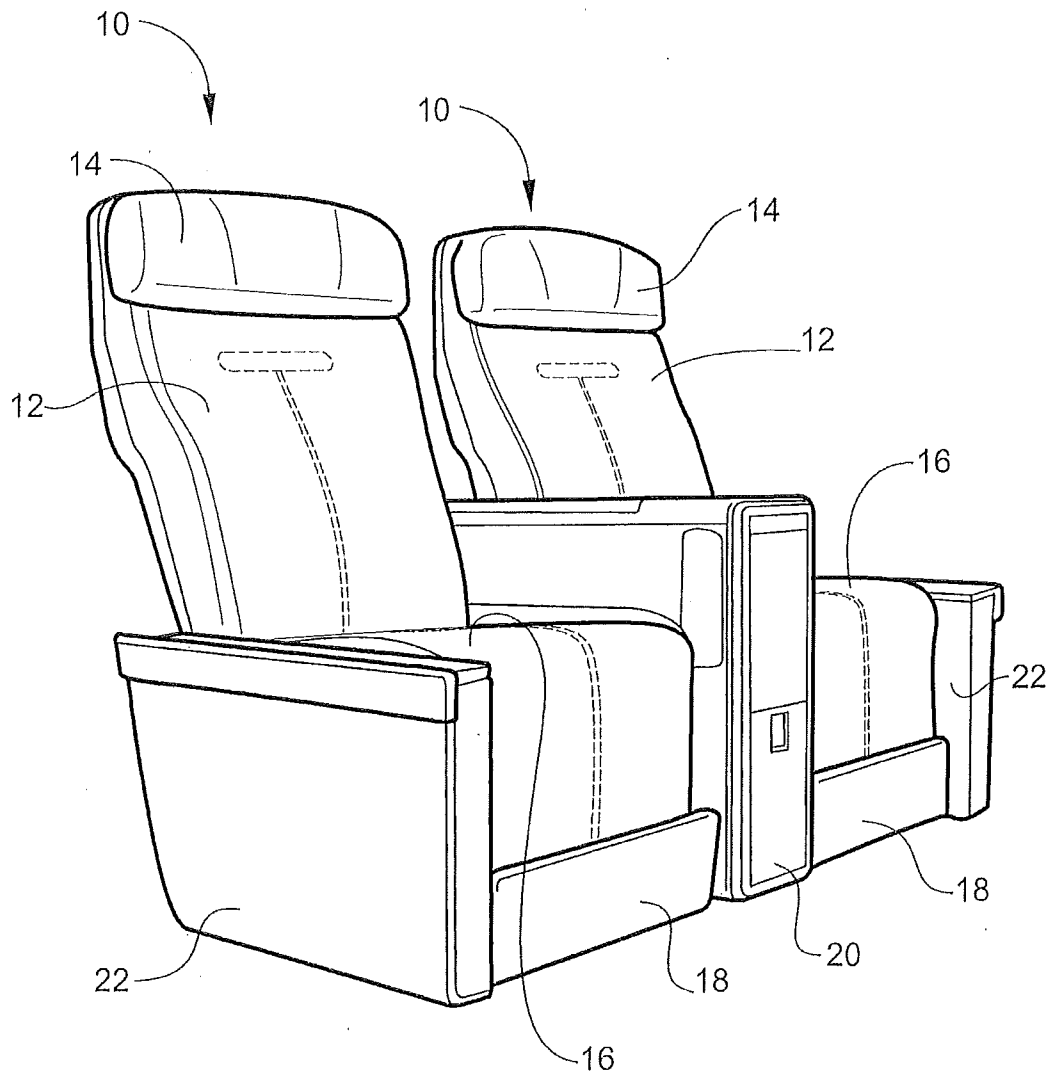


FIGURE 6

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US2014/032492

A. CLASSIFICATION OF SUBJECT MATTER

IPC(8) - A47C 7/02 (2014.01)

USPC - 297/452.1

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC(8) - A47C 3/00, 7/02; B60N 2/02; G01M 17/00 (2014.01)

USPC - 296/64; 297/284.1, 297/452.1; 73/866.4

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

CPC - A47C 3/00, 7/02; B60N 2/02 (2014.02)

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

PatBase, Google Patents, ProQuest

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2004/0011150 A1 (REYNOLDS et al) 22 January 2004 (22.01.2004) entire document.	1-3, 11-13
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A		4-10, 14-20
A	US 2007/0130750 A1 (MILOSIC et al) 14 June 2007 (14.06.2007) entire document.	1-20
A	US 4,696,516 A (YEUM) 29 September 1987 (29.09.1987) entire document.	1-20
A	US 5,129,704 A (KISHI et al) 14 July 1992 (14.07.1992) entire document.	1-20
A	US 5,737,845 A (MARASUS) 14 April 1998 (14.04.1998) entire document.	1-20
A	US 2007/0228800 A1 (TUBERGEN et al) 04 October 2007 (04.10.2007) entire document.	1-20

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"&" document member of the same patent family

Date of the actual completion of the international search

31 July 2014

Date of mailing of the international search report

25 AUG 2014

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