Comfort Optimization of the Slimline Seats On the Airplane

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Abstract

This paper mainly studies how to make the back of chair more comfortable without changing slimline seat structure. First of all,from the perspective of ergonomics to calculate the normal curvature radius of the lumber spine when hunman body in a comfortable sitting position,offer the reference datas for optimizing design of the seat center curve of the chair.Secondly, Data points-vertical curve-The back surface-Horizontal curve-the point from Transverse longitudinal intersection-Back of a chair surface model .Fitting data to get Human spinal curve and modeling human back surface figure .Get control points from the back surface figure, interpolating, using Matlab program get curve of shoulders, curve of back, curve of waist, curve of haunch, and by using the uniform B spline curve model to optimize the four curve, with optimized Human spinal curve get the point from Transverse longitudinal intersection ,then use Three-dimensional model software Proe get optimized back of a chair surface,we also get five matching equation, eqution (2-9, 2-10, 2-11, 2-12, 2-13). General scheme is given data points to get basic line production surface directly, this scheme is based on horizontal longitudinal intersection is created, each between transverse and longitudinal intersection with points, points and lines, line and line is connected, so that the generated surface is more accurate and effective, and can get the optimal solutionquickly. Finally using Proe to people - chair CAD model adaptive matching, realizes human "virtual ride" CAD seat request, thin backrest surface optimization design scheme is given.

Keywords

Energy least-square method , Three B-spline, Back of a chair surface , Optimization.

1. Introduction

With the rapid development of the world science and technology, people's demand for the quality of life is getting higher and higher. Fast and efficient "air flying" has become one of the preferred means of transport for people to travel. Seat is a very important part of the aircraft, the aircraft in the course of the ride, comfortable seats can provide a safe and comfortable environment for passengers to reduce passenger fatigue in the journey. Therefore, the seat design depends mainly on the comfort of the seat provided to the passengers.

In 2006, Hubei, China, set up Hubei Hangyu Ewell commercial aircraft seating limited company, marking China's development of civil aircraft seat for the global. From 2007 to 2009, aviation aerospace industry, in line with international standards of the latest airworthiness KKY400 type 16G economy class passenger seat is successfully developed, through the review of the airworthiness of Civil Aviation Administration of China, followed by compiling a full set of English apply FAA airworthiness Certificate.[1] At home and abroad for the civil aviation seats research focuses on three aspects: to reduce seat area and increase the aircraft cabin space utilization, 2010, American companies has been designed to a saddle type aircraft seat; the second is the research to improve the passenger ride comfort, Delta Air Lines designed a new twists and turns of economy class seats; the third is for first and business class, the design of luxury seats for passengers more comfortable flying experience, in seat design research, foreign scholars mostly on seat comfort research is through research study seat backrest, a seat cushion, etc.[2] The study found that domestic and foreign civil aviation seats are the biggest problem lies in unreasonable design of the back of the chair and back the whole curve does not conform to the characteristic curve of the human body posture. Expliseat has designed a seat made of titanium metal materials only 4 kg of thin seats, by reducing the weight of the aircraft greatly reduced fuel consumption, the price is the sacrifice of their comfort. The new type of streamlined lightweight seats by the airline's favor, at the same time, how to improve the comfort of the new light seat has become a top priority, in the premise of not changing the thin seat structure, how to design the back curve is essential.

2. Analysis

When people are in a different position, the shape of the spine is different, and the pressure of the intervertebral disc is different, as shown in Fig. 2.7. From the figure can be found, free standing disc pressure minimum, and very correct posture "forward" disc pressure, also any a back bow sitting position, the pressure is relatively large. When the shape of the spine is close to normal physiological curvature, the smaller the pressure on the intervertebral disc. When the people lying on the side, the thigh and the lower leg slightly bent, spine were physiological bending, at this time, intervertebral discs, with initial and muscle force minimum, people feel the most comfortable. When people sit and lumbar support on the backrest, the trunk and thigh forms the angle, lumbar curvature shape close to normal physiological condition, so it is the most comfortable posture (in the sitting position, the pressure of the intervertebral disc close to free standing the pressure). The sitting position of the trunk and the forward bending of the trunk lead to the large deformation of the spine, and the load of the spine is increased, the position of the back support is different, and the pressure of the intervertebral disc is different. [3]

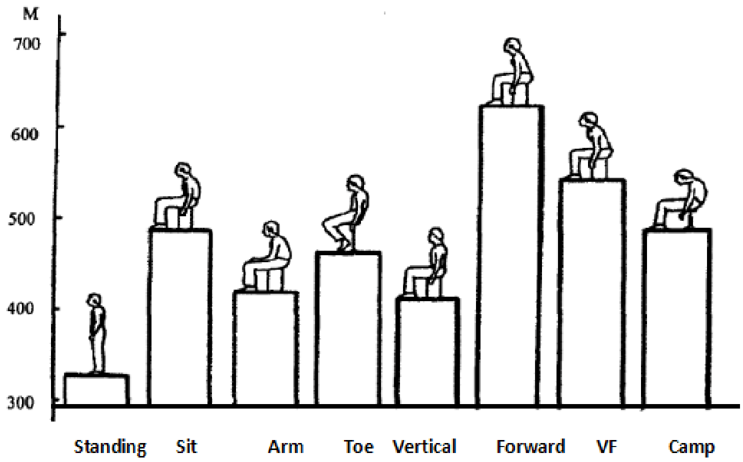

Fig.1 The pressure of lumbar intervertebral disc in different postures

From the above analysis, it can be known that the comfortable sitting posture of lumbar intervertebral disc is the lowest. And according to experimental statistics.[4] The average height of the spine (C7 to S1, as shown in Fig. 3.1) can be obtained from a vertical position, as shown in figure (430.2mm = 26.8), and the male is 483.8min (25.7). Table 3-1 shows a part of the vertebrae height relative to the spine height (SH) percentage. If from S1 to C7 height is known, is a small standard deviation shows the numerical provides a more reliable method to describe the position of the spinal vertebrae. In addition, female and male thoracic height (C7-T12) and lumbar spine height (L1-LS) were also listed in Table 1:

Table 1. the vertical position of vertebrae relative to SI (Units: SH)

	Average female	Female standard deviation	Average female	Male average	Male standard deviation	Male average（mm）
C7	1.00	0.00	430.2	1.00	0.00	483.8
T2	0.901	0.018	387.6	0.906	0.016	438.2
T4	0.778	0.037	334.5	0.790	0.028	384.2
T6	0.649	0.045	279.0	0.662	0.036	320.4
T8	0.543	0.041	229.8	0.539	0.038	260.8
T10	0.449	0.031	193.3	0.437	0.036	211.3
T12	0.364	0.032	156.7	0.345	0.030	167.0
L1	0.304	0.032	130.4	0.286	0.030	167.0
L2	0.235	0.034	101.0	0.219	0.030	106.0
L3	0.167	0.033	72.0	0.155	0.028	74.9
L4	0.100	0.025	43.0	0.096	0.026	46.4
L5	0.046	0.016	19.7	0.042	0.015	20.5
S1	0.000	0.000	0.0	0.000	0.000	0.0
Thoracicheight（C7-T12）	0.637	0.033	274.0	0.622	0.030	316.8
Lumbarheight（L1-L5）	0.257	0.033	110.7	0.243	0.028	117.7

Based on the above data and the study of the curvature of the spine, the normal curvature radius of the lumbar vertebra in the comfortable sitting posture of the human body is about 251mm, while the male is about 360mm.

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3. Optimal design of curves and surfaces

This paper mainly studies the mathematical optimization model of the curved surface of the slimline seat. Through reverse engineering to measure back curve and surface data points, combined with ergonomic requirements of seat design, analysis and sorting out the need of the original data, on the basis of the energy method and the least square method, combined with the constraints of the corresponding curve and surface optimization model.

(1)curve and surface energy optimization and improvement based on physical constraints

Energy optimization method is a variety of geometric and physical constraints of the curve and surface of the physical energy to achieve the minimum, so that the purpose of optimization can be achieved. In mechanics, the physical sample is like the elastic thin beam, which is subjected to concentrated load and its own properties, and its objective is to minimize the strain energy. Its mathematical expression is:

$$E = \beta \int k^2 ds \tag{1}$$

In the formula, the stiffness coefficient is beta spline, is a constant; K and s respectively the curvature and arc length. This mathematical model, which takes into account the energy minimum and the expression parameters of these two aspects, it has the nature of natural light. The physical energy model consists of bending resistance and tensile stretch of two parts of energy, as follows:

$$E = \int \left(\alpha E_s + \beta E_b \right) d\sigma \tag{2}$$

Which is the weight coefficient. There is no excess of curves and surfaces generated by this model.

Wrinkles, you can also say that it is smooth. From the point of view of physical deformation, the elastic deformation equation of thin plate in elastic mechanics, Terzopoulos and Gossard proposed the following model:

$$E_{curve} = \int \left(\alpha w_u^2 + \beta w_{uu}^2 - 2\, fw \right) du \tag{3}$$

$$E_{surface} = \iint \left[\begin{pmatrix} \alpha_{11} w_u^2 + 2\alpha_{12} w_u w_v + \alpha_{22} w_v^2 \\ +\beta_{11} w_{uu}^2 + 2\beta_{12} w_u w_v + \beta_{22} w_{vv}^2 \end{pmatrix} - 2wf\left(u,v\right) \right] dudv \tag{4}$$

W is the curve (surface) of u and V as the parameters, and the F is a given parameter. Through the three coordinate measuring instrument to measure the back point cloud, the data points of the curve of the spine are constructed and analyzed, which is shown in Table 2.

Table 2. The spine curve data

x	y	z	x	y	z	x	y	z
0	22.0641	117.7385	0	11.5938	363.2042	0	28.3832	603.5548
0	20.7413	131.4715	0	12.2445	376.5631	0	29.6606	632.7142
0	19.3669	147.0902	0	13.4156	391.7716	0	29.8282	646.8449
0	17.0155	161.5851	0	14.3175	405.4604	0	30.3444	665.861
0	14.9536	176.3051	0	14.798	419.4914	0	30.7444	675.3326
0	14.3413	190.2627	0	15.296	435.3138	0	31.2113	689.7497
0	13.7496	204.1988	0	16.8711	448.5375	0	31.1775	704.6932
0	12.7582	217.8805	0	17.9705	463.927	0	30.0647	732.9776
0	11.9322	233.4013	0	19.0921	477.504	0	29.9387	747.1165
0	11.0628	246.9091	0	19.657	491.4902	0	29.4606	762.5122
0	10.7362	262.5714	0	20.7603	506.9273	0	28.781	776.07
0	10.6769	275.4409	0	21.9047	520.4416	0	28.2339	791.6859
0	10.7827	318.8821	0	25.4703	564.3949	0	26.79909	834.4803
0	11.1182	334.5435	0	26.4625	578.1967	0	26.29458	848.9439
0	11.2466	348.7806	0	27.2986	593.7138	0	24.5264	859.3918

Programming of these raw data points to fit the specific procedures are as follows:

〉〉 x=[65.4103 73.0397 81.7168 89.7695 97.9473 … …];

〉〉 y=[22.0641 20.7413 19.3669 17.0155 14.9536 … …];

〉〉 xx= 60:10:500;

〉〉 yy= spline(x,y,xx);

〉〉 plot(x,y,'*',xx,yy);

〉〉 grid;

The fitting results are shown in Fig.5 below:

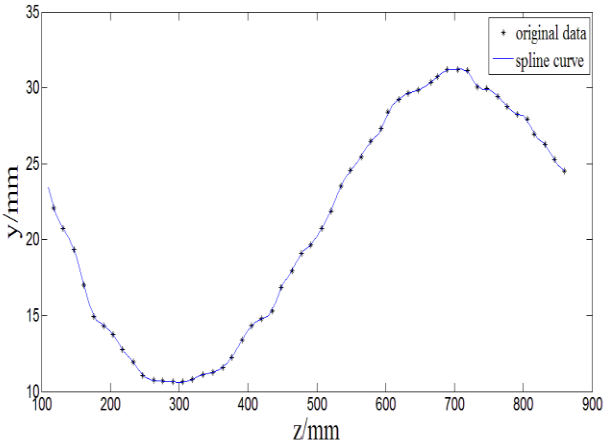

Fig. 2 spinal column

(2) curve and surface optimization

Back surface data[3] are shown in Table3:

Table 3. The back surface of the data

x	y	z	x	y	z	x	y	z
-202	-9.3	840	-50	23.9987	250	113	22.9189	840
-198	-6.4	840	-46	24.0764	250	123	22.2774	840
-195	-2.6662	840	-30	24.0374	250	136	21.6	840
-190	1.35	840	0	24.23	840	140	20.82	840
-185	4.78	840	20	24.11	840	153	19.87	840
-180	7.51	840	30	23.85	840	……	…..	……
--170	5.88	670	-10	31.48	670	150	30.15	670
-167	7.51	670	-20	31.33	670	147	30.19	670
-160	5.88	670	-9	31.35	670	135	29.54	670
-157	7.42	670	0	31.32	670	126	28.49	670
--153	9.95	670	7	31.43	670	145	26.48	670
-147	11.17	670	19	31.34	670	……	…..	……
-142	12.6114.62	400	30	12.97	400	110	12.45	400
-135	-15.63	400	40	12.89	400	134	11.74	400
-130	-12.01	400	20	12.9	400	123	10.66	400
-125	-8.88	400	0	13.1	400	158	9.44	400
-120	-6.06	400	19	13.2	400	149	8.45	400
-115	-4.01	400	20	12.54	400	…..	……	……
-110	-2.7	180	-11	27.9	180	167	26.83	180
-100	-7.92	180	-20	28.21	180	178	26.39	180
--95	-5.38	180	20	28.49	180	189	25.84	180
-87	-2.99	180	0	28.76	180	194	25.12	180
-70	-0.85	180	13	29.25	180	190	24.16	180
-69	0.91	180	25	29.47	180	…..	……	……

In the table data, we can used Proe make models to get back surface Fig.3

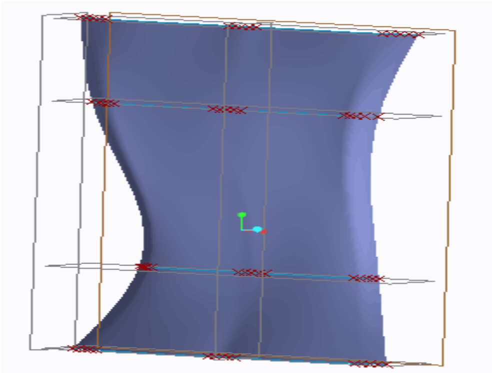

Fig.3 original back surface

The control points of the surface are obtained by means of mathematical method, and the program is as follows:

```
>>A=[9 -3 0 0; 1/4 7/12 1/6 0; 0 1/6 7/12 1/4; 0 0 -3 9];
>>V1=inv(A)*[6* V11;  V12;  V13;  V14]……
>>A=[9 -3 0 0; 1/4 7/12 1/6 0; 0 1/6 7/12 1/4; 0 0 -3 9];
>>Va=inv(A)*[6*V12;  V13;  V14; 6* V15] ……
```

Procedures see Appendix 1 is show how to get Fig.4. From the graph we can be seen in the middle zero coordinates is the center of the seat and the back curve of the intersection point, the basic is Cheng Zhengtai distribution, in line with the principle of symmetry, meet the requirements of the human body for comfort

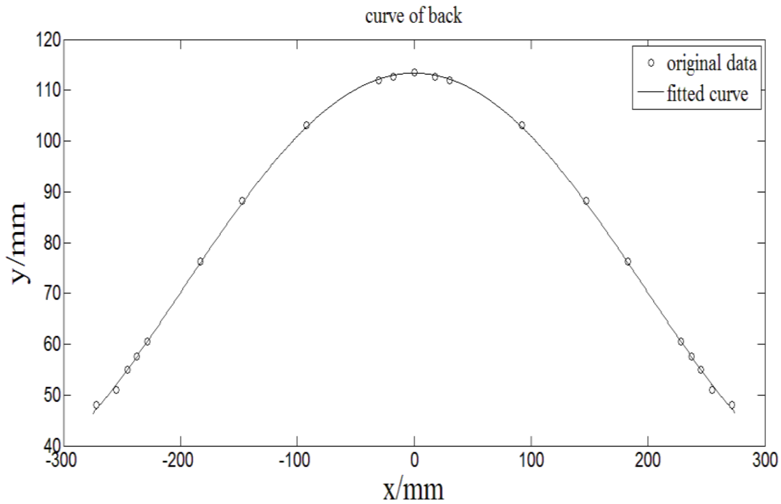

Fig. 4 curve of back seat

With the same method, (Fig.2.4)C1,T12 and L1,L5 and S1 were used to extract the data. The control points were analyzed by interpolation, and we get Fig.5,Fig6, Fig.7 . This is basically in line with the second chapter analysis about the position of the spine comfort requirements.

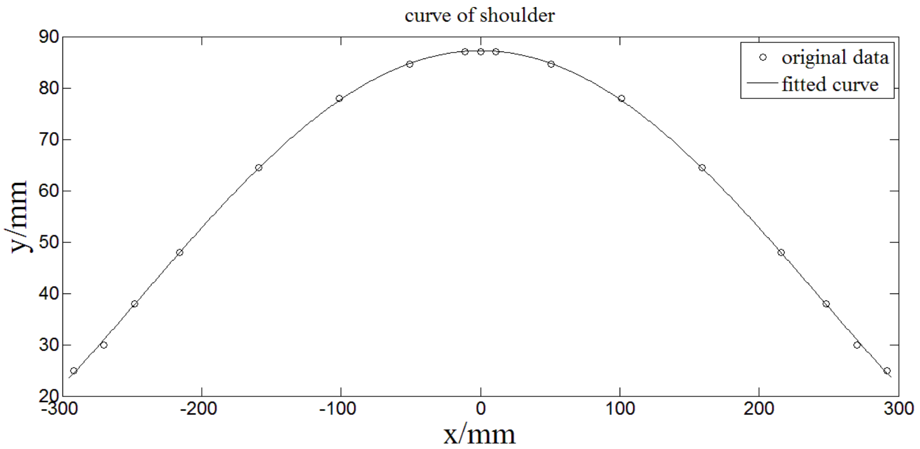

Fig. 5 the curve of the lateral seat of the shoulder

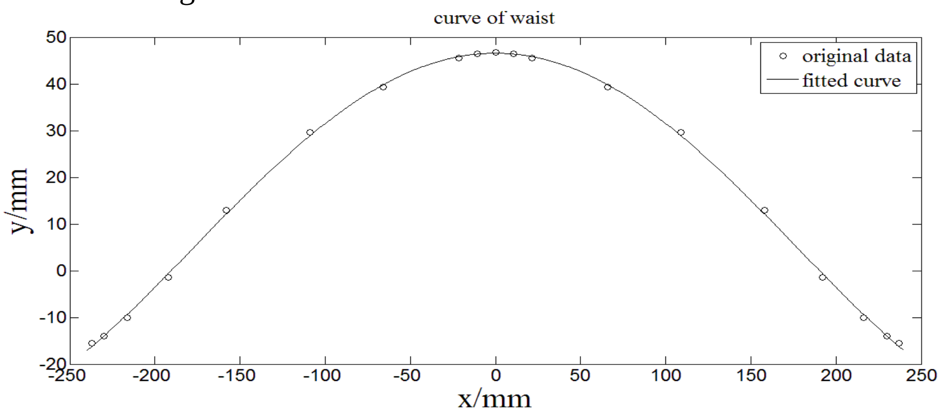

Fig. 6 lumbar lateral seat curve diagram

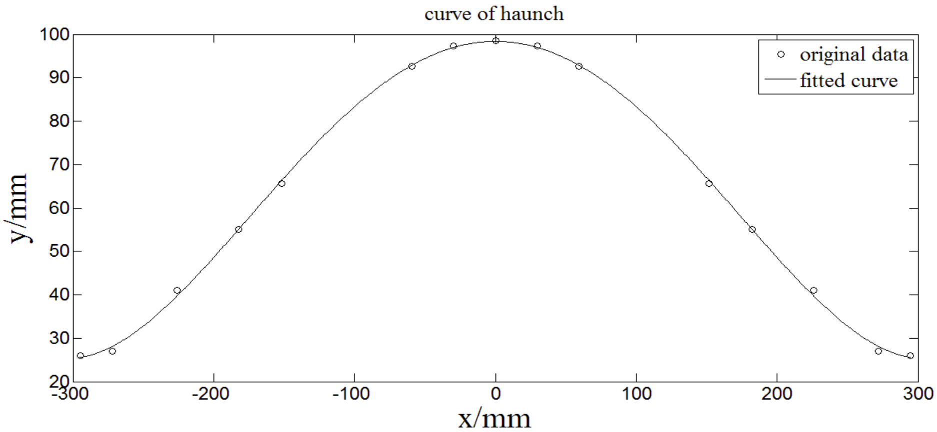

Fig. 7 Hip lateral seat curve

From Fig.4, Fig.5, Fig.6, Fig. 7, The formula is shown below.

$$y = 2.7\times10^{-7}x^4 - 6.8\times10^{-20}x^3 - 5\times10^{-2}x^2 + 3\times10^{-15}x + 70 \tag{5}$$

$$y = 5\times10^{-9}x^4 - 3\times10^{-20}x^3 - 3\times10^{-2}x^2 + 1\times10^{-15}x + 57 \tag{6}$$

$$y = 6\times10^{-9}x^4 - 10\times10^{-24}x^3 - 3\times10^{-2}x^2 + 7.5\times10^{-15}x + 46 \tag{7}$$

$$y = 8.99\times10^{-9}x^4 - 10\times10^{-22}x^3 - 1.78\times10^{-2}x^2 + 7.5\times10^{-15}x + 89 \tag{8}$$

In order to make the seat of the back seat better meet the requirements of comfort in a sitting position, now equation 2-5, 2-6, 2-7, 2-8 type use of the three uniform B spline curve is optimized, the optimized equation is obtained:

$$y = 2.7783\times10^{-9}x^4 - 9.5434\times10^{-23}x^3 - 9.74\times10^{-4}x^2 + 1.9530\times10^{-17}x + 87.248 \tag{9}$$

$$y = 5.46\times10^{-9}x^4 - 3.5766\times10^{-22}x^3 - 1.2987\times10^{-3}x^2 - 4.0648\times10^{-17}x + 113.37 \tag{10}$$

$$y = 8.4010\times10^{-9}x^4 - 9.4219\times10^{-23}x^3 - 1.589\times10^{-3}x^2 + 3.5639\times10^{-18}x + 46.557 \tag{11}$$

$$y = 8.6731\times10^{-9}x^4 + 7.8301\times10^{-22}x^3 - 1.5913\times10^{-3}x^2 - 8.4489\times10^{-18}x + 98.361 \tag{12}$$

On the same section of the spine curve fitting, the original fitting equation is obtained, with three uniform B spline curve, the optimization, get spinal curve fitting equation in three times as follows:

$$y = -5.1872\times10^{-7}z^3 + 7.8296\times10^{-4}z^2 - 3.2207\times10^{-1}z + 50.724 \tag{13}$$

Fig.4 and Fig.5 and Fig.6 and Fig. 7 and the final optimization form of spinal curve, using the energy method of least square modeling, get the Fig.8.

Fig. 8 transverse longitudinal seat figure curve integration

To analysis the transverse longitudinal seat figure curve integration, modeling, the 3 D computer software ProE to get the optimized seat back surface figure as shown in Fig. 9

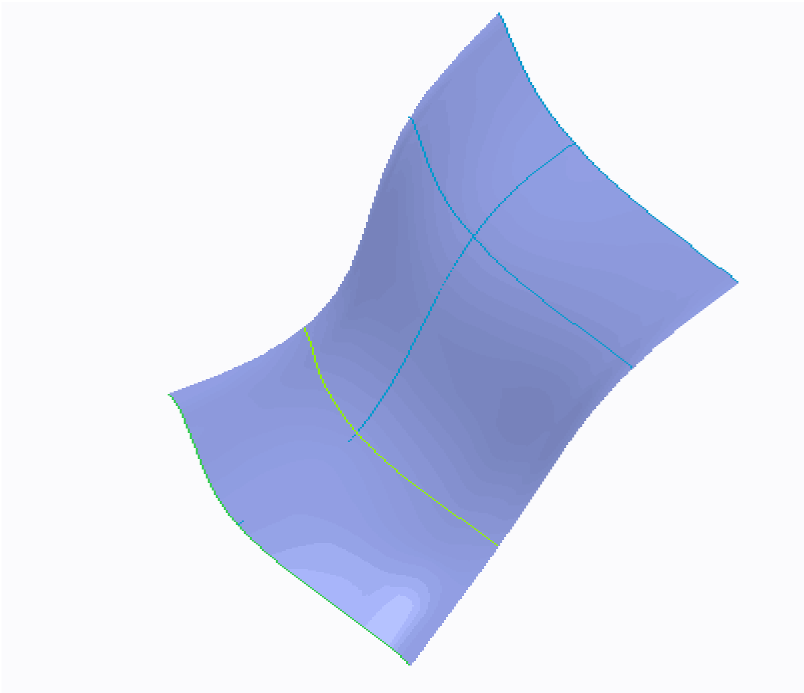

Fig. 9 seat backs to optimize surface figure

(3)Man chair adaptation model

On the basis of the above work, the realization of human body model in ProE environment in virtual "ride" on the seat model, namely the human body 3 D model of seat model adaptive matching. In order to realize the process to consider the following:

1) The ProE virtual environment, the human body model "ride" on the seat model simulation behavior should be consistent with the real human body to take action.

2) A simulation performance only in considering longitudinal symmetry plane of the body. The human body, the longitudinal symmetry plane and seat of longitudinal Symmetry plane. For the realization of the three-dimensional human body model in PROE "virtual ride" requirement, using a circular interference inspection Chad method Implement a chair model adaptive matching, makes one chair adaptive matching interface with high fidelity,Specific steps are as follows:

SETP1: The three-dimensional CAD model of the human spine center line and the center line of the center line, as shown in Fig.10;

Fig. 10 person - chair adaptive matching graph

SETP2: Set the initial value of the human torso inclined Angle, initial value condition not intervene with the back of the chair and torso;

SETP3: Make the trunk with a small Angle increment to the back of the chair "tilt", each "tilt" a point of view, on a human body 3 d CAD models and seat (back) interference between surfaces; SETP4: repeat SETP3 until does not produce interference, which fit to do the torso and back of the chair; finally get the best comfort back surface as follows in Fig.11

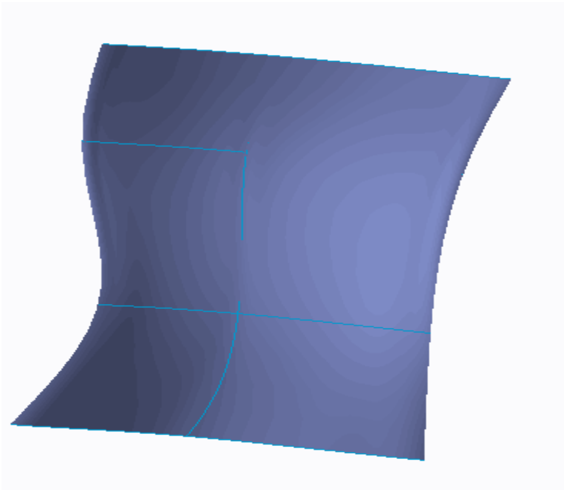

Fig. 11 The optimal back surface figure

4. Conclusion

From Fig 11, you can see that using horizontal longitudinal line intersection to surface synthesis, this method is compared with the basic method is more accurate, more realistic, through the prophase data processing, curve fitting, finally get the optimal back surface model.

General scheme is given data points to get basic line production surface directly, this scheme is based on horizontal longitudinal intersection is created, each between transverse and longitudinal intersection with points, points and lines, line and line is connected, so that the generated surface is more accurate and effective, and can get the optimal solutionquickly.

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