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Vertical Deformation Analysis of LEP in CERN*

Der Large Electron Collider (LEP) beim CERN in Genf ist der größte Teilchenbeschleuniger der Welt. Es werden Verfahren zur Durchführung der Deformationsanalyse des Tunnels vorgestellt, wobei Eigenbewegungen der Maschinen herausgefiltert werden können.

1 Introduction

The dynamic situation of LEP is greatly concerned by CERN. Some research about the movement and deformation of accelerators were done in the past [5] [6] [7] [8] [9]. The key problem in the vertical deformation analysis of LEP is to find or establish a stable and reliable vertical reference, which is relatively stable during the interesting period. This procedure could be divided into three steps: Firstly to find the deformed zones, then to find the displaced zones, third to establish the reference. The order of those three steps is also important for getting the correct results. For the first step a theoretical deformation model was developed based on the situation of LEP. For the second and the third another theoretical displacement model was also established.

2 Theoretical Deformation Model

The general model of the vertical deformation of LEP is given as follows

$$(Model)_h = (Model)_{tr} + (Model)_{ro} + (Model)_{\Delta h} \tag{1}$$

Where

$(Model)_h$ ----- The vertical model of a spatial curve

$(Model)_{tr}$ ----- The model for translation of its mean plane

$(Model)_{ro}$ ----- The model for Rotation of its mean plane

$(Model)_{\Delta h}$ ----- The model for vertical difference (vertical offset) about its mean plane

The model can be mathematically expressed as follows

$$D_h\,(T, R, P) = D_t\,(T) + D_r\,(R) + D_{\Delta h}\,(P) \tag{2}$$

Where D_h (T, R, P), D_t (T), D_r (R) and $D_{\Delta h}$ (P) are correspondent to $(Model)_h$, $(Model)_{tr}$, $(Model)_{ro}$, $(Model)_{\Delta h}$. The T, R, and P are subsets of the parameter set (T, R, P), which could be correspondent to different models. For example, $T = (C)$, C is the translation parameter of the mean plane, it is a constant with this problem. $R = (\alpha)$, α is the rotation parameter. P is the displacement and deformation parameter subset.

Suppose this model describes a smoothing spatial curve, (D, X, Y) or (D, L). L is the accumulated distance from the original point. The first differential of the model with respect to L could be written as

$$\frac{\partial(D_h)}{\partial L} = \frac{\partial(D_t)}{\partial L} + \frac{\partial(D_r)}{\partial L} + \frac{\partial(D_{\Delta h})}{\partial L} \tag{3}$$

Where $\frac{\partial(D_t)}{\partial L}$ is zero, and $\frac{\partial(D_r)}{\partial L}$ is a constant. The first differential value at the point i is

$$\left.\frac{\partial(D_h)}{\partial L}\right|_{L=L_i} = \left.\frac{\partial(D_r)}{\partial L}\right|_{L=L_i} + \left.\frac{\partial(D_{\Delta h})}{\partial L}\right|_{L=L_i} \tag{4}$$

L_i is the accumulated distance of the point i from the original point. In fact, (4) is the vertical inclination of the curve at the point i. In the same principle, the second differential of the model could be gotten as

$$\frac{\partial^2(D_h)}{\partial^2 L} = \frac{\partial^2(D_r)}{\partial^2 L} + \frac{\partial^2(D_{\Delta h})}{\partial^2 L} \tag{5}$$

Where $\frac{\partial^2(D_r)}{\partial^2 L}$ would be zero. For the point i, we could get the value

$$\left.\frac{\partial^2(D_h)}{\partial^2 L}\right|_{L=L_i} = \left.\frac{\partial^2(D_{\Delta h})}{\partial^2 L}\right|_{L=L_i} \tag{6}$$

So (6) is the vertical deformation of the curve at the point i.

2.1 Features of the Differentials

For well understanding and practically using the models, their actual signification and features should be discussed in detail. The formula (4) and (6) show us

- The first differential means that the inclination of the mean plane adds to the local inclination of the curve from the mean plane. The inclination of the plane reflects the inclination degree from the horizontal. The local inclination reflects locally that of the curve from the mean plane.
- In the case that the first one is much smaller than the second one, the first differential mainly reflects the local inclination of the curve. So its change with time would present the change of the curve shape and stability. Certainly, it could be used to find the unstable zones.
- The second differential means the local inclination change. It reflects the local change of the curve shape

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(deformation). So its change with time would well present the curve shape variation and the stability. Of cause it could be used to detect the deformed zones.

- The first differential and the second differential have their evident physical meanings. A very good differential relationship exists between them. This will offer much more useful information for distinguishing the displacement and the deformation, and for determining the deformation pattern. Their very important features would bring us some good chance on our deformation analysis.

2.2 Practical Calculation

From the differential definition, we have the first differential expression

$$\left.\frac{\partial(D_h)}{\partial L}\right|_{L=L_i} = \lim_{\Delta L\to 0}\left.\frac{\Delta D_h}{\Delta L}\right|_{L=L_i} = \lim_{\Delta L\to 0}\frac{D_h(L_i+\Delta L)-D_h(L_i)}{\Delta L} \tag{7}$$

The second differential expression is

$$\left.\frac{\partial^2(D_h)}{\partial^2 L}\right|_{L=L_i} = \lim_{\Delta L\to 0}\left.\frac{\Delta D'_h}{\Delta L}\right|_{L=L_i} = \lim_{\Delta L\to 0}\frac{D'_h(L_i+\Delta L)-D'_h(L_i)}{\Delta L} \tag{8}$$

Where D_h is the first differential.

For the practical realization the formulas (7) and (8) could be written as follows

$$\left.\frac{\partial(D_h)}{\partial L}\right|_{L=L_i} \approx \left.\frac{\Delta D_h}{\Delta L}\right|_{L=L_i} = \frac{D_h(L_i+\Delta L)-D_h(L_i)}{\Delta L} \tag{9}$$

$$\left.\frac{\partial^2(D_h)}{\partial^2 L}\right|_{L=L_i} \approx \left.\frac{\Delta D'_h}{\Delta L}\right|_{L=L_i} = \frac{D'_h(L_i+\Delta L)-D'_h(L_i)}{\Delta L} \tag{10}$$

3 Optimization of ΔL

Theoretically, the smaller ΔL is, the better a curve's description. But usually it depends on the necessity and budget. For a reasonable distance, some measuring errors and other random movements should be carefully studied. For LEP there are two kinds of random factors. They are surveying errors and random movements of the points [1] [4]. In order to get a better signal, the ratio of the signal to the random error must be perfected following their features. For LEP the bigger ΔL is, the better the ratio is. It is because the random error and the random movement are not relevant to the distance. So their influence on the inclination and the deformation would be reduced with the ΔL's increasing. Therefore we should chose the minimum value of ΔL that could permit us to correctly get the desired signal from the observations (noise and signal) with a minimum signal loss. This procedure is especially dependent to the inclination and deformation precision and the magnitude of the random movement of the points (quadrupoles of LEP).

3.1 Random Inclination

3.1.1 Leveling Precision

The precision of height difference between two successive quadrupoles has been well estimated and verified by the leveling carried out every year. It is 0.04 to 0.05 mm [5]. **Here 0.04 mm is considered as the basic error parameter.** On considering the accumulated distance of two successive quadrupoles as Δ, being 40 m, and ΔL = nΔ (n being the number of intervals between two quadrupoles considered for the calculation of the inclination and deformation, see the definition formula later). The mean square error of an inclination is

$$m_{\Delta L_1} = \pm\frac{0.04\sqrt{n}}{n\times 40000} = \pm\frac{1}{\sqrt{n}}\times 10^{-6} \quad \text{(rad)} \tag{11}$$

3.1.2 Random Movement of the Points

Statistically [1] [4], the mean absolute mean value of the inclination between two successive quadrupoles caused by random movements is $1{,}42\times10^{-6}$ rad. Suppose the random movements be of a normal distribution, its root mean square value is $1{,}77\times10^{-6}$ rad (1.42 is multiplied by 1.25). For the distance of ΔL we have

$$m_{\Delta L_2} = \pm\frac{1.77}{n}\times 10^{-6} \quad \text{(rad)} \tag{12}$$

3.1.3 Random Inclination

We consider comprehensively the two factors for the inclination precision, it would be

$$m_{\Delta L} = \pm\sqrt{m^2_{\Delta L_1}+m^2_{\Delta L_2}} = \pm\sqrt{(\frac{1}{n}+\frac{1.77^2}{n^2})}\times 10^{-6} \quad \text{(rad)} \tag{13}$$

The tolerance would be

$$M_{\Delta L(in)} = 2m_{\Delta L} = \pm 2\sqrt{m^2_{\Delta L_1}+m^2_{\Delta L_2}} = \pm 2\sqrt{(\frac{1}{n}+\frac{1.77^2}{n^2})}\times 10^{-6} \quad \text{(rad)} \tag{14}$$

3.2 Random Deformation

The formula used for the deformation calculation is

$$De = \frac{In_2 - In_1}{\Delta L} \tag{15}$$

From that we could get the tolerance of deformation from (14)

$$M_{\Delta L(de)} = \frac{\sqrt{2}M_{\Delta L(in)}}{\Delta L} = \pm\frac{2\times\sqrt{2}\times\sqrt{m^2_{\Delta L_1}+m^2_{\Delta L_2}}}{n\times 40} = \pm\sqrt{(\frac{1}{2n^3}+\frac{1.77^2}{2n^4})}\times 10^{-7} \quad \text{(rad)} \tag{16}$$

3.3 ΔL from the Inclination Tolerance

So the optimal distance (ΔL = 4xΔ) was derived under the condition that RMS of the measured inclination is identical with that of random inclinations. That would be found in Figure.1. Its minimum interesting vertical displacement between two points of a distance ΔL is S_0 (S_0 = 0.21 mm if ΔL = 4xΔ). This would be determined from formula (17) and (18).

$$\frac{S_0}{n \times 40 \times 1000} \geq 2m_{\Delta L} = \pm 2\sqrt{(\frac{1}{n} + \frac{1.77^2}{n^2})} \times 10^{-6} \text{ (rad)} \quad (17)$$

$$S_0 \geq 2m_{\Delta L} = \pm 2n \times 40 \times 1000 \times \sqrt{(\frac{1}{n} + \frac{1.77^2}{n^2})} \times 10^{-6} \text{ (mm)} \quad (18)$$

The value S_0 = 0.21 mm (correspondent to 0.04 mm) is chosen as the value of S_0. It is correspondent to n = 4 (i.e. ΔL = 160 m).

4 Calculation and Presentation

For obtaining the maximum information from the data, the inclination and the deformation at every point have been calculated with the definite distance of 4 intervals (shown in Figure 2).

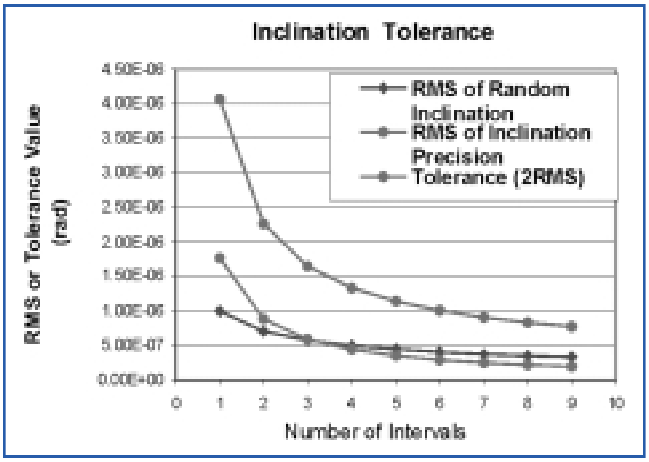

Fig. 1

4.1 Definitions of Calculation Formula

INCLINATION: The value of inclination on the point E_i is written as In_{E_i}. It could be expressed as

$$In_{E_i} = \frac{\Delta H_{E_{i-2}} - \Delta H_{E_{i+2}}}{D_{E_{i-2}-E_{i+2}}} \quad (19)$$

Namely, on the point S_i is written as In_{S_i}. It could be expressed as

$$In_{S_i} = \frac{\Delta H_{S_{i-2}} - \Delta H_{S_{i+2}}}{D_{S_{i-2}-S_{i+2}}} \quad (20)$$

Where ΔH is the vertical of offset, D is the distance.

DEFORMATION: The value of deformation on the point E_i is written as De_{E_i}. It could be expressed as

$$De_{E_i} = \frac{In_{E_{i-2}} - In_{E_{i+2}}}{D_{E_{i-2}-E_{i+2}}} \quad (21)$$

Namely, on the point S_i is written as De_{S_i}. It could be expressed as

$$De_{S_i} = \frac{In_{S_{i-2}} - In_{S_{i+2}}}{D_{S_{i-2}-S_{i+2}}} \quad (22)$$

From (14) the tolerance on inclination difference between two years is

$$M_{in} = \sqrt{2} M_{\Delta L(in)} = \pm 2\sqrt{2}\sqrt{(\frac{1}{n} + \frac{1.77^2}{n^2})} \times 10^{-6} \quad \text{(rad)} \quad (23)$$

For n = 4, it is ± 1.88 x 10^{-6} **(rad).** From (16) the tolerance on deformation difference between two years is

$$M_{de} = \sqrt{2} M_{\Delta L(de)} = \pm\sqrt{(\frac{1}{n^3} + \frac{1.77^2}{n^4})} \times 10^{-7} \quad \text{(rad)} \quad (24)$$

For n = 4, it is ± 1.67 x 10^{-8} **(rad/m).**

4.2 Graphical Presentation

Following (19)–(22), inclinations and deformations were calculated and presented graphically. Some deformation zones were found and listed in Table 1 and two examples of the deformed zones are shown in Figure 3 – Figure 6.

5 Establishment of a Mean Plane

In order to correctly find the displaced zones of the tunnel, it is absolutely necessary to establish a vertical reference, which is relatively stable, the points supporting this reference should be much more relatively stable than others. This reference would serve as the base of rotation. This procedure should be realized based on the points relatively stable from 1992 to 1998. So the indispensable step is to reasonably find the zones having deformation, and then to eliminate them before all.

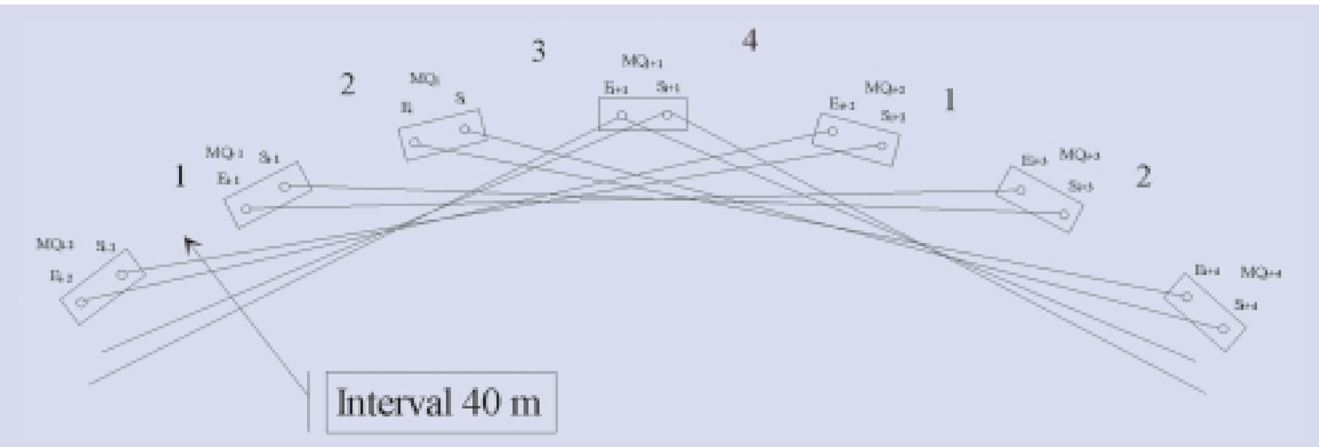

Fig. 2

Table 1: Deformed Zone of LEP

Name	Accumulated Dist.		Number of MQ		Inclination(Year) (significant)	Deformation(Year) (significant)
	From	To	From	To		
S1-A1-D1	1152.09	1587.73	186500	197500	93,98	93,98
S2-A1-D1	4997.98	6184.12	301500	331500	92-98	92-98
S45-A1-D3	11623.20	15075.17	499500	602500	93-98	92-98
S5-A2-D2	16306.28	16561.31	634500	644500	93-96, 98	93-96, 98
S6-A1-D2	17497.91	17736.05	679500	685500	93, 94, 96, 98	93, 94, 96, 98
S7-A1-D1	21027.74	22648.38	783500	825500	92-98	92-98
S8-A1-D2	23965.13	24321.77	874500	883500	92-98	92-98
S81-A1-D3	25742.63	599.09	120500	172500	92-98	92/98

5.1 Deformation Zones

The zones of deformation have been found by the method described here. They were listed in Table 1 and presented graphically. After the elimination of the deformed zones, 864 points were kept among 1362 points. Those 864 points are considered the original basic points for the vertical base plane (vertical reference) to be-found. It should be noted that there are probably some areas of vertical block displacement, which could not be found with their inclination and deformation variation. This problem will be discussed next.

5.2 Zones of Vertical Block Displacement

The zones of vertical block displacement means that some zones have been only displacing vertically the study period, their deformation was not evident. These zones should be also eliminated for establishing a relatively stable plane as the vertical reference. This procedure is progressively realized by an iterative computation procedure. During this iterative calculation a weight for every point would be renewed according to its rotated offset scatter (such as variance) during this period. The bigger its scatter is, the smaller its weight is. Therefore the points in the zone of vertical block displacement their weights become smaller and smaller, finally, they become zero, equivalent to be eliminated.

5.3 Establishment of A Relatively Stable Plane

5.3.1 Parameter Estimation of Plane

For each year the vertical offsets could be regressed by a plane. Such as

$$A_i x_j + B_i y_j + C_i z_j = 0 \qquad (25)$$

Where $i = 1, 2, \ldots, N$ (number of leveling); $j = 1, 2, \ldots, n$ (number of points);

A_i, B_i, C_i are parameters of the plane i.

x_j, y_j, z_j are the centralized coordinates of point j.

It can also be transformed into the following form if the coordinate z_i is considered as an observation.

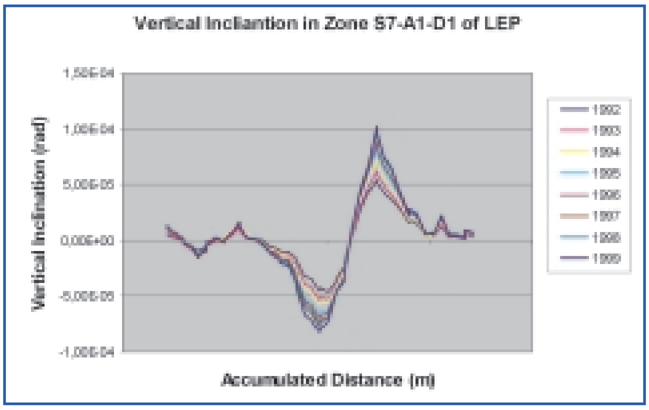

Fig. 3

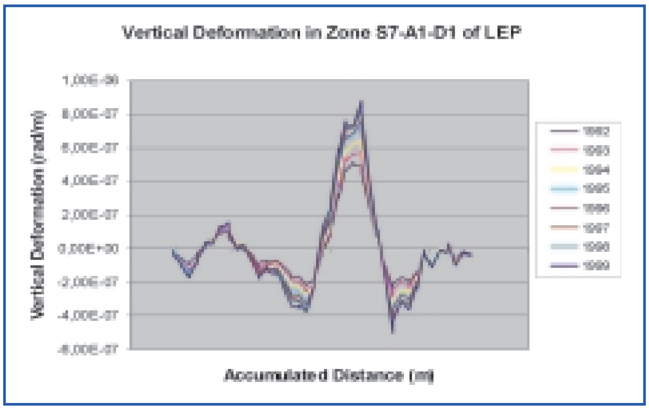

Fig. 4

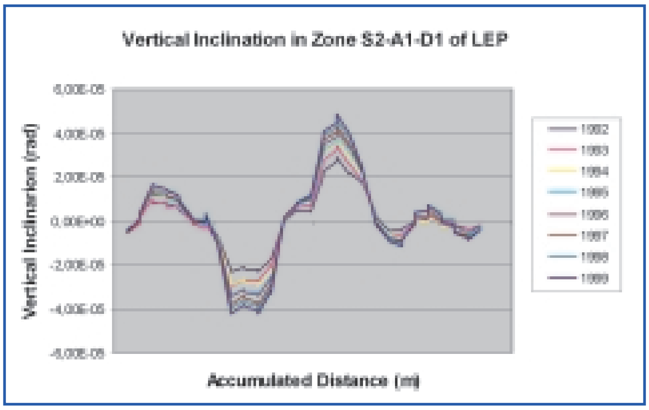

Fig. 5

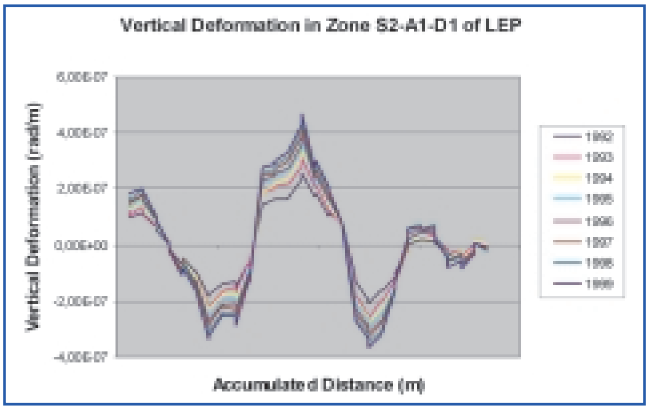

Fig. 6

$$\underset{n\times 1}{V} = \underset{n\times p}{D}\underset{p\times 1}{\beta} - \underset{n\times 1}{Z} \qquad P_j \tag{26}$$

Where $V_, = \begin{pmatrix} v_1 \\ v_2 \\ . \\ . \\ v_n \end{pmatrix}$, $D = \begin{pmatrix} x_1 & y_1 \\ x_2 & y_2 \\ . & . \\ . & . \\ x_n & y_n \end{pmatrix}$,

$\beta = \begin{pmatrix} a \\ b \end{pmatrix}$, P_j is the weight of point j.

Following Least Square Method the parameters can be estimated and F-Test [10][11] could be used for the test of the parameter's significance. This test can offer us the information about whether the regression is effective. If parameters are significant the state parameters of the plane, such as its normal direction in space and in horizon, would be calculated in order to let us understand it geometrically.

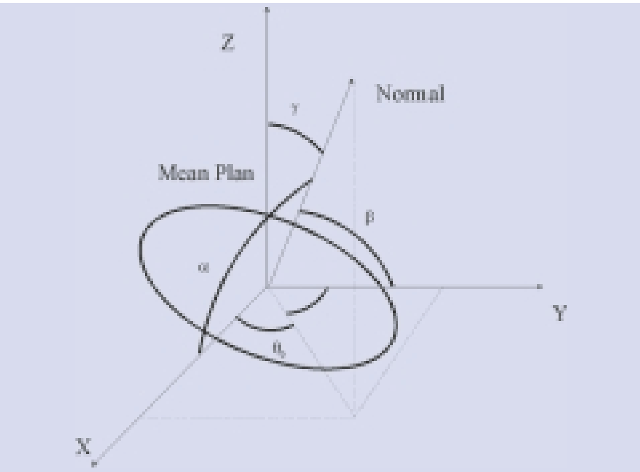

Fig. 7

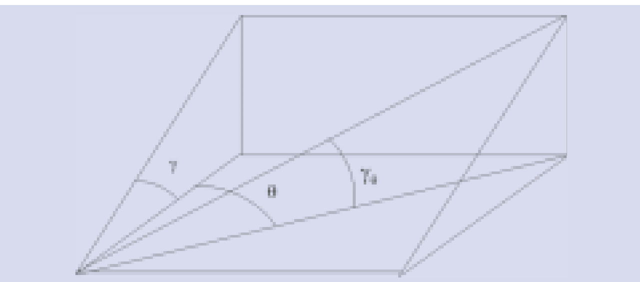

Fig. 8

$$\alpha = \arccos(\frac{-a}{\sqrt{1+a^2+b^2}}) \tag{27}$$

$$\beta = \arccos(\frac{-b}{\sqrt{1+a^2+b^2}}) \tag{28}$$

$$\gamma = \arccos(\frac{1}{\sqrt{1+a^2+b^2}}) \tag{29}$$

$$\theta_0 = \arccos(\frac{a}{\sqrt{a^2+b^2}}) \tag{30}$$

Those parameters would be used for rotation of the mean plane.

5.3.2 Rotation

From Figure 8 the relation between the maximum vertical angle of the plane and the vertical angle in the horizontal direction θ is like that.

$$\tan\gamma_\theta = \cos\theta \tan\gamma \tag{31}$$

We would obtain a plane for vertical offsets each year. And then its parameters could be used for rotating all the points to same horizontal plane for comparison of the same point in different years. So the rotated value of the vertical theoretical offsets could be written as

$$\overline{z_{ij}} = z_{ij} + \sqrt{(x_j^2 + y_j^2)} \times \tan(\gamma_i) \times \cos(\theta_j) \tag{32}$$

For every point the statistic parameters of the $\overline{z}_j$, (such as the maximum likelihood estimation of its variance, mean absolute error and extreme difference), are also computed for evaluating the chosen plane and for renewing the weight of the point in the next iteration during plane establishment.

5.4 Procedure of Realization

The following flow-chart (Figure 9) explains the realization procedure. Three problems should be well considered in designing: firstly to make a reasonable criterion for the point selection, then to choice a weight function for the point selection, third to find a criterion for control the effective degree.

5.4.1 Principles for Point Selection

The principles for point selection are to keep the points used for this mean plane as many as possible under condition of meeting the stable criterion. It should be noticed that the acceptance threshold of the scatter for the iterative calculation is very important. If it is too large, the effectiveness would become less. If it is too small, the reliability would loss some. The acceptance threshold for LEP is 0.25 mm for the variance being scatter, 0.33 mm for the mean absolute error, and 0.9 mm for the extreme difference.

5.4.2 Weight Function

The weight function is considered as

$$P \propto 1/\sigma_z^2 \tag{33}$$

It means that the bigger the scatter is, the smaller its weight is in the next iteration. There are many definitions about the iteration weight of the point, such as HUBER and HAMPEL [16]. But here three functions are used for experiment. For $(k+1)$th iteration, they are

$$\text{A:}\quad P_j^{k+1} = \begin{cases} 0, & \sigma_{z_j}^k = \max\{\sigma_{z_1}^k, \sigma_{z_2}^k, \ldots, \sigma_{z_n}^k\} \\ 1, & else \end{cases} \tag{34}$$

$$\text{B:}\quad P_j^{k+1} = \begin{cases} 0, & \theta_{z_j}^k = \max\{\theta_{z_1}^k, \theta_{z_2}^k, \ldots, \theta_{z_n}^k\} \\ 1, & else \end{cases} \tag{35}$$

$$\text{C:}\quad P_j^{k+1} = \begin{cases} 0, & \phi_{z_j}^k = \max\{\phi_{z_1}^k, \phi_{z_2}^k, \ldots, \phi_{z_n}^k\} \\ 1, & else \end{cases} \tag{36}$$

Where $\sigma_{z_j}^k = \sqrt{\frac{\sum\left(\overline{z_{ij}^k} - \overline{\overline{z_j^k}}\right)^2}{N}}$, $\quad \overline{\overline{z_j^k}} = \frac{\sum_{i=1}^{N}\overline{z_{ij}^k}}{N}$

$$\theta_{z_j}^k = \sqrt{\frac{\sum\left|\overline{z_{ij}^k} - \overline{\overline{z_j^k}}\right|}{N}}, \quad \overline{\overline{z_j^k}} = \frac{\sum_{i=1}^{N}\overline{z_{ij}^k}}{N}$$

$$\phi_{z_j}^k = \overline{z_{\max,j}^k} - \overline{z_{\min,j}^k}, \quad \overline{z_{\max,j}^k} = \max\left\{\overline{z_{1j}^k}, \overline{z_{2j}^k}, \dots, \overline{z_{Nj}^k}\right\}$$

$$\overline{z_{\min,j}^k} = \min\left\{\overline{z_{1j}^k}, \overline{z_{2j}^k}, \dots, \overline{z_{Nj}^k}\right\}$$

5.4.3 Significance Test

The tests for significance [11] [12] [13] [14] include three aspects, **tests for the significance of the estimated parameters of the plane, tests for statistical consistency on precision among the measurements every year and tests for the significance of the difference among the established mean planes.** For the significance test of the estimated parameters the F-test has been used and its statistical is chosen as

$$F = \frac{\hat{\beta}^T Q_{\hat{\beta}\hat{\beta}}^{-1}\hat{\beta}}{N1 \times \hat{\sigma}^2} \sim F(N1, N2 - N1) \tag{37}$$

For the tests for statistical consistency on precision among the measurements every year F-test has been used and the statistical is chosen as

$$F = \frac{\hat{\sigma}_l^2}{\hat{\sigma}_m^2} \sim F(N2 - N1, N2 - N1) \qquad (l \neq m) \tag{38}$$

$\hat{\sigma}_l$, $\hat{\sigma}_m$ are respectively the estimators of the unit weight variance for l th and m th measurement. This is to verify the measurements for every year being of the same precision.

For the tests for the significance of the difference among the established mean planes, F-test is used and the statistical is as

$$F = \frac{\left(\hat{\beta}_l - \hat{\beta}_m\right)^T Q_{\hat{\beta}\hat{\beta}}^{-1}\left(\hat{\beta}_l - \hat{\beta}_m\right)}{N1 \times \hat{\sigma}^2} \sim F(N1, N2 - N1) \quad (l \neq m) \tag{39}$$

5.4 Rotation of All Offsets

For analyzing the deformation by comparison of offsets, the offsets of all points should be rotated to the theoretical plane (horizontal plane) based on the base plane every year.

$$\overline{z_{ij}} = z_{ij} + \sqrt{(x_j^2 + y_j^2)} \times \tan(\gamma_i) \times \cos(\theta_j) \tag{40}$$

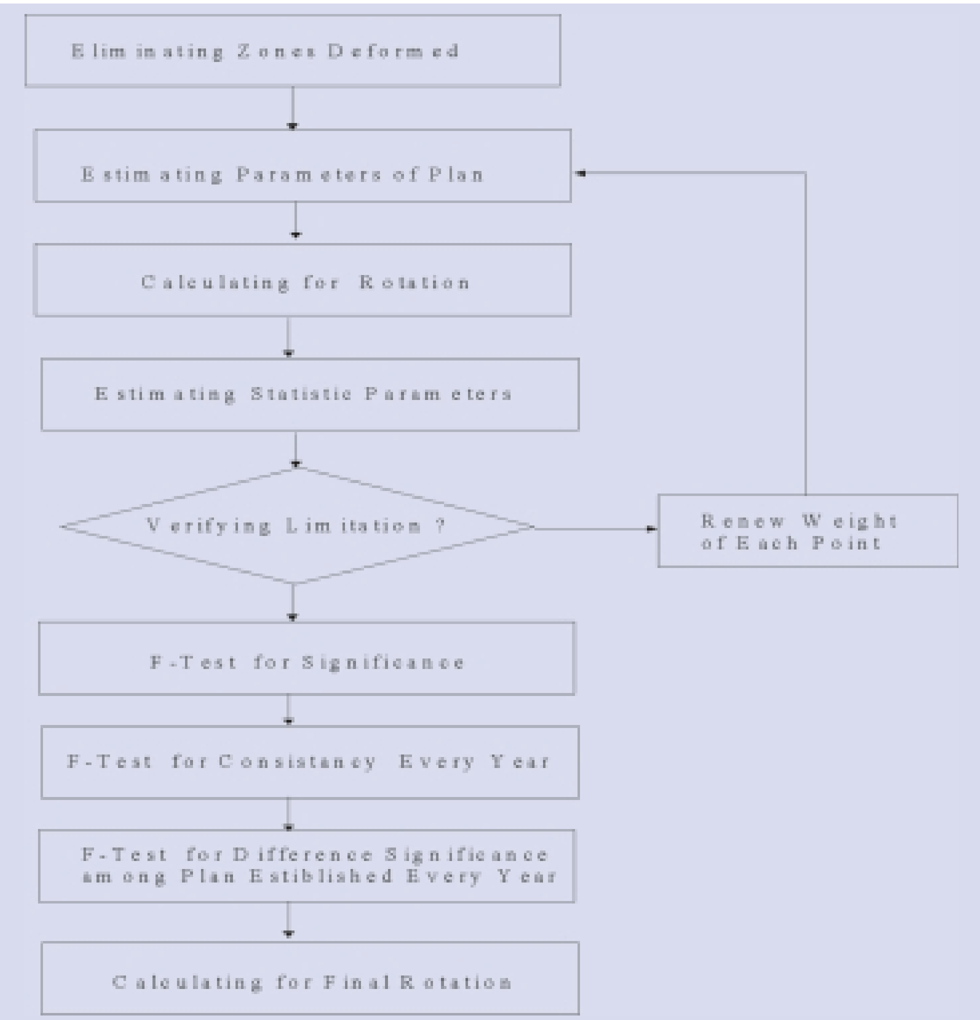

Fig. 9

5.5 Deformation Analysis

The estimated mean plane parameters and regression precision by three methods were carried out. They are approximately the same tendency for the vertical base plane of LEP. The estimated parameters for the scatter of variance (limit 0.25 mm) are shown in Table 2. There are 230 points are remained. From the tests for the significance of the estimated parameters of the plane (Table 3), the estimated parameters of the planes are significant. Tests for statistical consistency on precision among the measurements every year in Table 4 show a good consistency except that between 96 and 97. Tests for the significance of the difference among the established mean planes (Table 5) present the mean plane variable from year to year. The tolerance envelopes of double root mean square were compared each other among the different offsets. It has been shown the RMS of the vertical theoretical offsets could be used for further deformation analysis instead of that of the vertical rotated offsets.

Table 2: Parameters of Mean Planes of LEP

(92-98, method of variance, 0.25 mm, 230)

Year	α(degree)	β(degree)	γ(degree)	θ_0 (degree)	RMS(m)
92	89.9999079	90.0000099	0.0000926	353.856503	0.000987
93	89.9999219	90.0000198	0.0000806	345.792731	0.000987
94	89.9999082	90.0000026	0.0000919	358.395512	0.00091
95	89.999907	90.000009	0.0000934	354.49176	0.00101
96	89.9999158	90.0000173	0.000086	348.412104	0.001044
97	89.9999148	90.0000169	0.0000869	348.753475	0.001127
98	89.9999004	90.0000395	0.0001072	338.345793	0.001018

Table 3: Significance Test of Estimated Parameters

(H_0: $E(\hat{\beta}) = 0$)

Year	f_2	f_1	F	$F_{0.05}$	Result
92	2	230	3039.53	3.03	Rejected
93	2	230	1985.64	3.03	Rejected
94	2	230	3777.96	3.03	Rejected
95	2	230	2987.04	3.03	Rejected
96	2	230	2124.53	3.03	Rejected
97	2	230	1874.07	3.03	Rejected
98	2	230	2815.80	3.03	Rejected

Table 4: Consistency Test of Regressed Planes

(H_0: $\sigma_1 = \sigma_2$)

Year		93	94	95	96	97	98	$F_{0.025}$
92		1	1.17	1.04	1.11	**1.30**	1.06	**1.29**
93	**($f_1 = f_2$ = 232) α = 0.051**		1.17	1.04	1.11	**1.30**	1.06	**1.29**
94				1.23	**1.31**	**1.53**	1.25	**1.29**
95					1.06	1.24	1.01	**1.29**
96						1.16	1.05	**1.29**
97							1.22	**1.29**

Table 5: Significance Test of Difference among Plane

(H_0: P1 = P2)

Year		93	94	95	96	97	98	$F_{0.025}$
92		140.86	12.76	**.80**	51.43	38.83	149.16	**3.74**
93	**(f_1 = 230 f_2 = 2) α = 0.05**		231.68	159.43	19.43	23.94	132.72	**3.74**
94				7.97	108.64	24.67	258.55	**3.74**
95					63.47	49.11	159.64	**3.74**
96						**.42**	90.97	**3.74**
97							81.52	**3.74**

6 Provisional Results

- The 8 deformed zones have been found by the method described in 2 and listed in Table 1. The information relevant was graphically and comprehensively presented graphically.
- Based on the vertical offsets from 1992 to 1999, the establishment of the planes has been realized by three different methods, the results obtained for three methods presented the same features. The result obtained by variance was considered as final result. So 232 points were selected as the relatively stable points. 7 basic planes (one plane every year) were established.
- The significance test of estimated parameter shows the selected points well defined the plane every year. The consistency test shows the precision of regressed planes from the measurements every year being almost the same. The difference significance test of planes presents that there are no significant difference between 1992 and 1995, between 1996 and 1997, but significant for else. It means that the mean plane is variable from year to year.
- Table 1 and Table 6 show the unstable areas of LEP's tunnel. The results presented that some zones more and more stable, such as zone under Jura. Some zones are always unstable, such as S81-A1-D3 and S2-A1-D1. Some zones are from stable to unstable, such as zone after P5.
- The results obtained from LEP have proved that the methods could provide an excellent view on what happened with the monitored object in the study period.
- This study will help in designing surveying process of the next accelerator (LHC) to be installed in the same tunnel.
- Such a deformation and displacement analysis model, is a powerful tool for finding the deformed zones on any curvilinear object. Other applications can be found for other kinds of long construct works: galleries, bridges etc.

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Table 6: Unstable Areas of LEP's Tunnel

Area	Model	Accumulated Dist.		Number of MQ		Inclination (significant)	Deformation (significant)
		From	To	From	To		
1	No	25268	355	108500	165500	92-98	93-98
2	Yes	1270	1706	189500	201500	92, 93, 98	92, 98
3	No	2574	7185	223500	370500	92-98	92-98
4	Yes	8646	15588	408500	615500	92, 97	92, 97
5	No	15666	16990	616500	665500	92, 97	93, 95, 97
6	No	17418	17696	677500	684500	92, 97	92, 97
7	Yes	20672	25230	774500	107500	92-98	92-98

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Abstract

In the other papers [1] [2] [3] [4], the situation analysis and stability evaluation of LEP (Large Electron Positron Collider) shows some interesting results. Some deformation information comes up from those results. So a new technical has been developed and used to find the deformed zones of the tunnel by filtering the effects of the deformation of machine itself. And an another new technique has been introduced and to find the displaced zones of the tunnel by using a relatively stable mean plane composing of relatively stable points.

Ist Geodäsie eine Wissenschaft?

Überlegungen sowjetischer Wissenschaftler, wie Krassowski, Isotow, Molodenski, Kaschin u. a. führten anhand von Überlegungen zur Bejahung dieser Frage. Im Zusammenhang damit bestätigten jüngste Untersuchungen die Richtigkeit der Gedanken bezüglich der Erdbebenprognose, dass zwei der drei Probleme (wo, Stärke, wann) nur mit geodätischen Methoden hinreichend zu lösen sind, nämlich Ort und maximal mögliche Stärke der nächsten Beben. Es gibt jetzt die reale Möglichkeit, eine wissenschaftlich begründete Strategie für eine genaue Prognose und ihre Verwirklichung auf der Grundlage geodätischer Untersuchungsmethoden von Deformationen der Erdoberfläche zu entwickeln.

Auch heute noch ist zu hören, dass es zwar Sache der Geodäten sei, sich mit Problemen der Geodynamik zu befassen, Messungen auszuführen und ihre Zuverlässigkeit zu bewerten, jedoch stehe die Interpretation der Ergebnisse den Geophysikern und Seismologen zu. Wenn aber der Geodät nicht über hinreichende Kenntnisse der Geotektonik, Tektonik, Geologie und Seismologie verfügt, wird er kein kompetenter Fachmann bei geodynamischen Forschungen sein.

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