COMPOSITION OF A SYSTEM FOR MECHANICAL TRACK MAINTENANCE OF RAILWAY

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INTRODUCTION

In the former paper presented in Yokohama (1), the characteristics of railway track irregularity converging to a certain value determined by the growth of irregularity, the characteristics of rectification and the period of maintenance work, are presented.

The track maintenance works on Shinkansen have been so performed as not to transcend the aimed value of track irregularity in spots determined by riding comfort. The real works consist of the overall mechanical tamping performed periodically once or twice a year to decrease the mean value of track irregularity and the spot tamping by hand for rectifying the irregularity tanscending the aimed value.

Even by decreasing the spots transcending the aimed value, the riding comfort has not been necessarily ameliorated. To get good riding comfort, it is becoming common sense to control not only magnitude of vibration at spot but the level of it on a section. To realize this with a single overall tamping, a new computer system has been developed according to the above-mentioned theory.

1. STATE OF THE ART OF RAILWAY TRACK IRREGULARITY

1.1 Characteristics of track irregularity

The permanent way of railway consists of both the subgrade which smoothen the ups and downs of topography and the track on it which is composed of two rails, ties and ballast. The track is the long structure which concretely realizes the network of railway, but is destined to follow the maintenance without the large interruption of train operation once in service.

The quality of track condition is evaluated through rail geometries. The rail geometry is caught by the gauge being the distance between both rails; the cross level, the difference of the heights between both rails on ties; the longitudinal level, the geometry of each rail in vertical and the alignment, the geometry in lateral of each rail. The gauge and cross level are measured as the relative position of both rails in the track. However, the alignment and longitudinal level are the relative values measured by the versine with the chord of 10 - 40 m in many railways.

Hereafter, the longitudinal level is discussed, because more than 70 % of track works are on maintaining the quality of it. Further, it is called simply "track irregularity" as the representative of them.

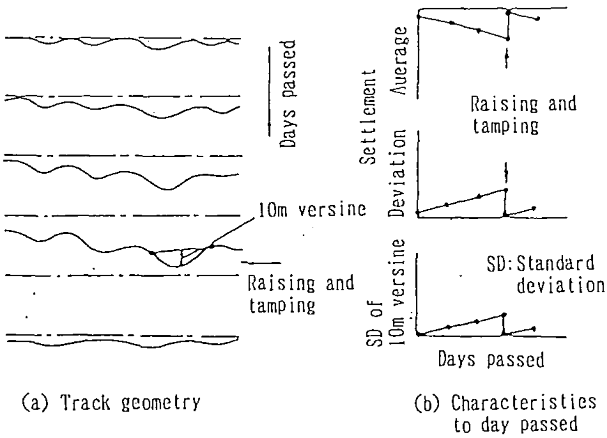


Fig. 1 Variation of track form to time passed

In the track with ballast the track irregularity grows even scarcely any through the settlement of ties in the ballast and sometimes through that of ballast in the subgrade under the passage of trains as shown in Fig. 1. The growth of the track irregularity hurts the riding comfort in trains, happens to damage the running safety and let the behavior of track get out of its objective that the track realizes a smooth runway for wheels. Thus the growth of track irregularity is called "track deterioration".

To rectify the settled track, the rail is raised and the ballast is tamped when the track irregularity attains a tolerance. This action is also shown in Fig. 1. In such a chance, the exchange of such track materials as rails, ties, ballast is executed if necessary.

The permanent way is the dynamic system which stands on the balance of the track deterioration and the track rectification and is necessarily seeking an economically optimum condition.

1.2 Track deterioration

To evaluate the track condition, high speed geometry cars measure the track irregularities above-mentioned. The measurements are executed every 10 days on Shin-kansen and every 2 - 6 months on narrow gauge lines depending on the importance of lines in Japan.

On the Shin-kansen the number of the spots where the maximum value of track irregularities transcends an aimed value is counted on 1 km. When the quality of track is statistically treated, the mean and the characteristics of distribution of the maxima in 20 m lots are discussed on the section of a certain length. In other countries the discussion of standard deviation of irregularities has prevailed.

The relations between such statistical characteristics were given

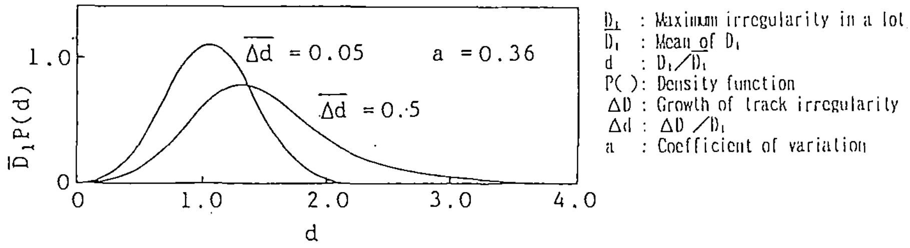


Fig. 2 Growth of track irregularity viewed by distribution

by us(2).

In 1976, a formula on the growth ratio of track irregularity expressed by the maxima in lots was given taking the attribute to track structure, kind of subgrade and transport supported(3).

In this study the statistical distribution of the growth ratio was given as that of exponential having the same values to both the mean and the standard deviation. This means that the irregularity grows as a whole and the deviation also grows in proportion to this. As a result, the irregularity represented by the maximum in lot and distributed in Gaussian comes to have very large values as shown in Fig. 2 given in the former paper(1). It is known that the distribution of this is expressed by that of extreme values, i.e. that of double exponential.

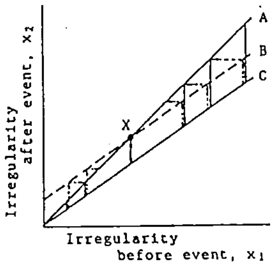
2. SYNOPSIS OF THEORY PRESENTED IN (1)

In the former paper(1), it was demonstrated that the track irregularity converges to the certain value which determined by the growth ratio of irregularity, the characteristics of rectification and the period of maintenance.

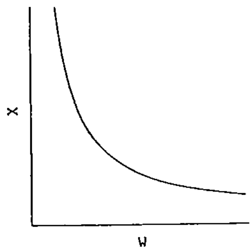
In the followings the main part of this analysis is given.

Expressing the magnitude of track irregularity with the statistical values such as the mean of maxima in lots, the standard deviation of irregularity etc., the irregularities before event, x_1, are given on abscissa and that after event, x_2, on ordinate in Fig. 3(a). On this figure, an irregularity on a line A with the angle of 45 degrees is reduced onto a line C by the rectification done on it. After this, irregularity grows up to the line B determined by the growth ratio of irregularity and work interval. Then, taking this magnitude of irregularity on the line A, it is reduced onto B and so on. Thus, the upper value converges to X and the irregularity varies between lines B and C on this ordinate. Here, the upper value X can be approximated to zero if the repetition per year is increased, that is the work period is shortened.

Assuming a constant growth ratio D of irregularity and a constant rate K of the rectification, the line B is expressed as



(a) Convergence of Irregularity



(b) Irregularity determined by work

Fig. 3 Case A assuming uniform growth and linea rectification

$$x_2 = Kx_1 + D/W \qquad (1)$$

where W is the number of rectifications in a year.

Then, the converged value, X, is given as

$$X = \frac{D}{W} * \frac{1}{1 - K} \qquad (2)$$

This becomes a hyperbola as shown in Fig. 3(b).

This case is called A.

In four other cases studied, the converged value, X, of the case D shown in Fig. 4(a) that the rectification is expressed with a line having a non-zero value on the ordinate ($x_2 = K_0 + kx$), is given as follows;

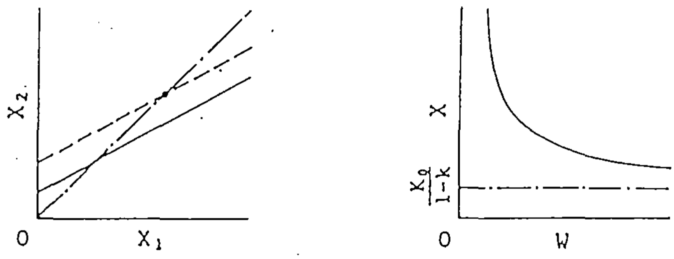
$$X = \frac{1}{1 - k} (K_0 + \frac{D}{W}) \qquad (3)$$

There is a limit to the rectification of irregularrity as shown in Fig. 4(b).

3. PROCEDURE FOR COMPOSITION OF A NEW COMPUTER SYSTEM

3.1 Principle

On the Shin-kansen, the average magnitude of track irregularity is controlled by mechanical tamping performed twice per year on earthworks and once per year on structure and in tunnels as stated in the introduction. The places where the track irregularity suspected to transcend an aimed value are indicated by the control system for Shin-



(a) Convergence of irregularity

(b) Irregularity determined by work

Fig. 4 Case D having non-zero value on ordinate in rectification

kansen installation, contracted for manual rectification and inspected for receiving.

The new system given hereafter is composed depending on the new analysis in Chap. 2 so as to eliminate the place of very large growth ratio, to get the uniform track quality and to make a single over-all mechanical tamping attaining an aimed work period possible. This corresponds to the modern idea of controlling the level of riding comfort in a certain length of time.

The fundamentals of the system is given in Fig. 5. The main part of this system surrounded by a hatched frame has been developed.

In this system, to facilitate the control of magnitude of track irregularity, the track is divided to the sections of more than several hundreds meters, about one kilometer, which have the same characteristics depending on track structure, line form, subgrade and so on. In a section, making a file of track irregularities from the measured data on geometry car, they, originally being 10 m versines in longitudinal level and alignment in Japan, are transformed to the filtered data if necessary. On Tokaido and Sanyo Shin-kansen the longitudinal level and alignment of 40 m versine are supplemented. Deducting them from former data, the growth ratios of track irregularities are calculated. From them the maxima in each 10 or 20 m lot are calculated as the representatives of the track irregularities of the lot. With use of these, the statistical characteristics of the irregularities in the section are calculated.

In the section where the rectification of track irregularities was experienced, the coefficients for it are calculated. If the data for them have not been obtained, the standard values for them should be used.

From the statistical characteristics of the growth ratio of irregularities, the characteristics of rectification and the aimed values for track maintenance, the period of track maintenance work for the section is calculated depending on the newly developed convergent

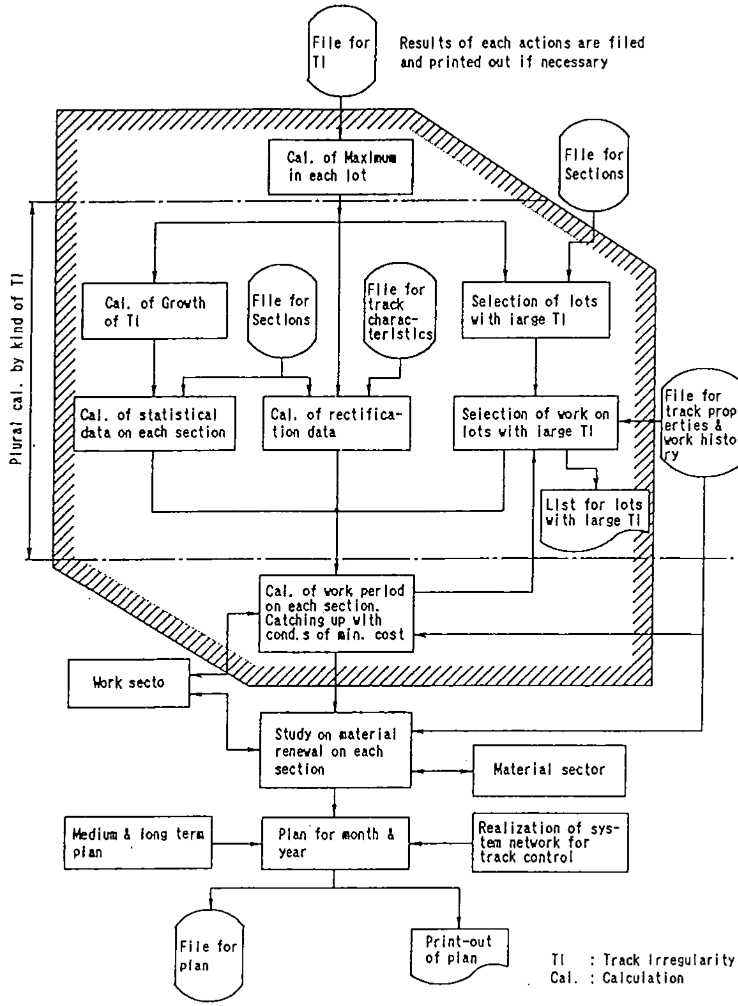


Fig. 5 Control system for control track irregularities in sections

theory of case D in Chap. 2.

Next, calculating the track irregularities in lot after several months, here those after 6 months, the maintenance work periods of them are calculated by the theory of case A. If they are larger than the aimed values and the period of track maintenance for the section is also longer than the aimed one, no action is necessary. If not, the lot which have the large growth ratio of irregularity must be picked up and submitted to the treatments which decrease the growth ratio fundamentally and the elongated work period is calculated for the lot and for the section. Such treatments are repeated one lot by one until the work periods of lot and section become less than the aimed values.

As for the treatment, the exchange of material, rectification of surface roughness by grinding and bending-up of weld, the amelioration of subgrade etc. are candidates.

3.2 System composition

To realize this, a following system is composed.

Fig. 6(a) shows the example of calculated irregularities in a section. This includes the 10 m and 40 m versines of longitudinal level and alignment. The white pillars are for the maxima of irregularities in 20 m lots and the black parts, for the growth in 6 months of them.

Fig. 6(b) shows setting the aimed values for maintaining irregularities and those for the period of work through the section. In a window the values determined in boxes, the calculated periods of maintenance and statistical characteristics are given.

Following these, the information for track properties of the section are given in a window. These include place, velocity, subgrade, line form, kind of track and track materials of the section.

Then, the cumulative distributions of maxima in lots and those after 6 months are given in the window. Here, the lot where the tretment should be discussed is selected with the arrow moved with a 'mouse'.

The track irregularities of the lot is given. The same is done for the alignments too.

The roughness of rail surface included in the lot is given.

The cumulative distribution of the growths of irregularities for lots are given. Here, the lot where the work is discussed is indicated with black circle.

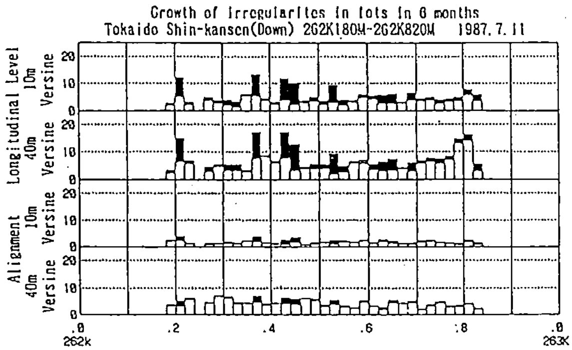
Fig. 6(c) shows the final selection of the work for fundamental amelioration of the growth of track irregularity and the effectuated periods of work for the lot and for the section are demonstrated.

After attaining the aimed period, all the necessary treatments for each lot on the section are printed out.

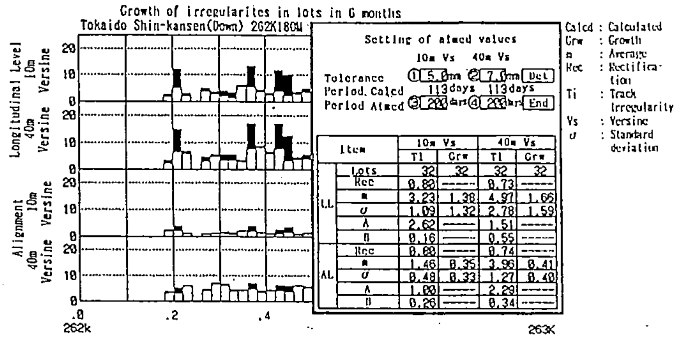
3.3 Example of elongation in work period

As an example of the application of this system, the elongation of work period of the section demonstrated in Fig. 6 is pursued from the largest irregularity to smaller ones for the decrease of the growth of irregularity in lots. The decreasing ratios of the growth ratio is assumed as 0.25, 0.5 and 0.75, meaning that 0.75, 0.5 and 0.25 are multiplied to the original growth ratio.

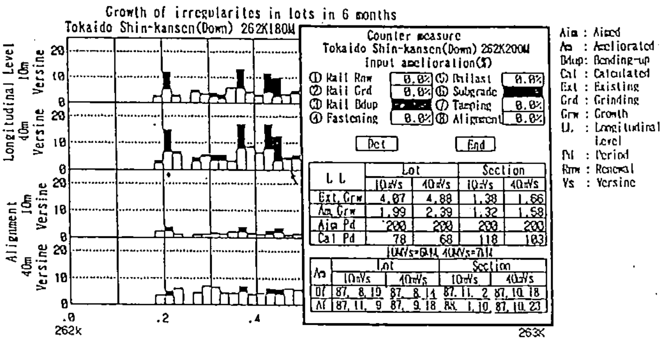
Results are given in Fig. 7. In this case, the aimed period of 220 days is obtained by the amelioration of 2 lots for the ratio 0.75 and 4 lots,for 0.5.



(a) Calculated irregularities in a section



(b) setting of aimed values for maintaining irregularities



(c) Selection of woks and effectuated work period

Fig. 6 Screen copies of developed system

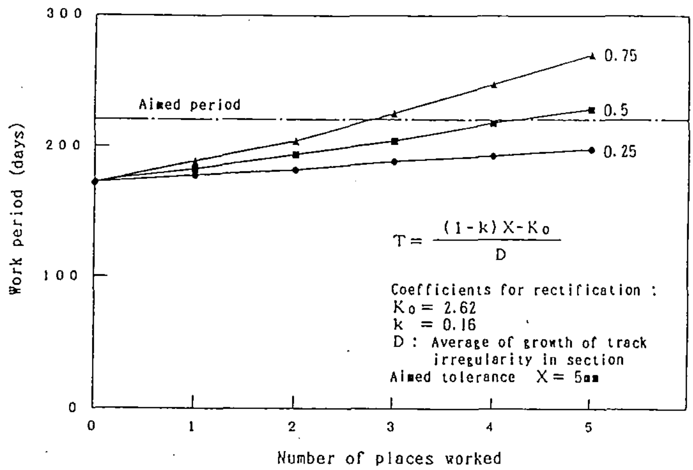


Fig. 7 Attainment of aimed period

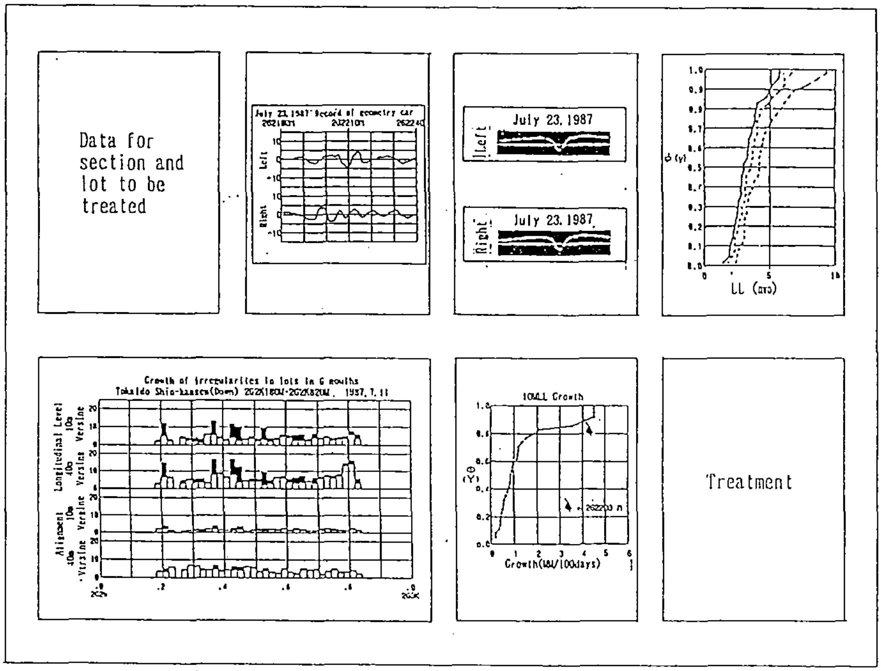


Fig. 8 Future system for controlling track irregularities in section

3.4 Future system

Through the above-mentioned study, the applicability of the system is made clear. In a future system it is recommendable to use windows in a full scale for making all the informations avobe-mentioned visible at a time and making the selection of the treatment in lot easy.

An example is shown in Fig. 8.

4. AIMED VALUES FOR TRACK MAINTENANCE

In Japan, to get better riding quality, 40 m versines of longitudinal level and alignment are in use. To corelate the aimed magnitude of irregularities with the level of riding comfort in ISO 2631, the following calculations are performed.

$$L_T = 10 \log \{ \frac{1}{\alpha_{ref}^2} * \frac{1}{T} \int_0^T \alpha_W^2(t)dt \}$$

$$= 10 \log (\frac{1}{\alpha_{ref}} * \frac{R*W}{C} * \sigma_a)^2$$

$$= 10 \log (\frac{1}{\alpha_{ref}} * \frac{R*W}{C} * k * D_{40}$$

$$= 20 \log (\frac{1}{\alpha_{ref}*C}) + L_W + 20 \log D_{40}$$

$$= L_0 + 20 \log D_{40} \qquad \text{.......................................(4)}$$

where

L_T : Level of riding quality
α_{ref} : Acceleration referred ($=10^{-5} m/s^2$)
α_W : Vibrational acceleration corrected by human sensitivity
R : Relation of Acceleration/track irregularity
L_W = 20 log W : Correcting coefficient by human sensitivity (-6 db for vertical, +3 db for horizontal)
C = $1 - \cos(2\pi L/\lambda)$: Coefficient for 40 m versine (L : 1/2 of chord length, λ : Wave length of irregularity)
σ_a : Standard deviation of 40 m versine
k : Conversion factor from standard deviation to average of maxima in 40 m lot (0.55)
D_{40} : Average of maxima in 40 m lots

The response function of vertical vibration to longitudinal level is shown in Fig. 9 as the theoretical one experimentally authorized. Those for horizontal to alignment is shown in Fig. 10 as experimental ones obtained on Joetus Shin-kansen before the opening to commercial operation in 1982.

The results of calculation are shown in Fig. 11 showing the numericals in Equ. (4) in Table 1. From this figure, it can be seen that the 80 db corresponds to 3.5 mm in longitudinal level and 85 db corresponds to 2 mm in alignment.

5. CONCLUDING REMARKS

The track irregularities have mainly been controlled by suppressing the large values. Recently the riding comfort is discussed on the

Table 1 Numericals for calculation

Coef / λ (m)		R (m/s² /cm)	Cλ	L.
Lateral	20	$6.97\times10^{-4}V^{1.10} = 0.263$ (×10/2) *1	1.00	99.3
	30	$1.31\times10^{-4}V^{2.36} = 0.442$ (×10/2)	1.50	101.1
	40	$1.09\times10^{-4}V^{1.97} = 0.449$ (×10/2)	2.00	98.8
	50	$3.09\times10^{-4}V^{2.18} = 0.395$ (×10/2)	1.81	98.5
	60	$6.79\times10^{-4}V^{1.96} = 0.265$ (×10/2)	1.50	96.7
Vertical		1.6	1.467 (λ=61.1m)	89.5

*1 PP – Amplitude V = 220 km/h
mm → cm

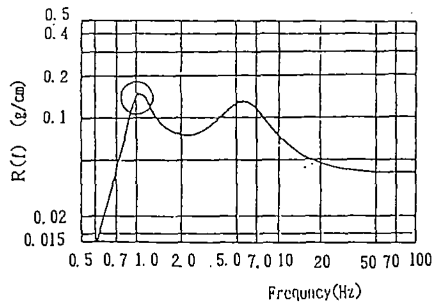


Fig. 9 Response of car in vertical

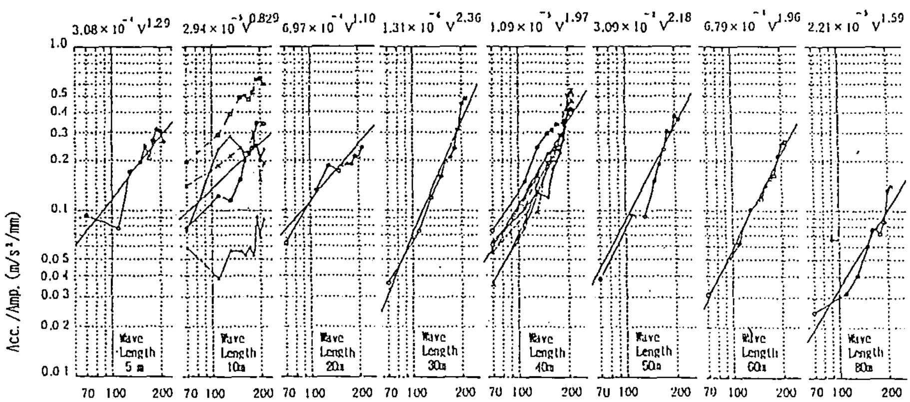


Fig. 10 Response of car in lateral

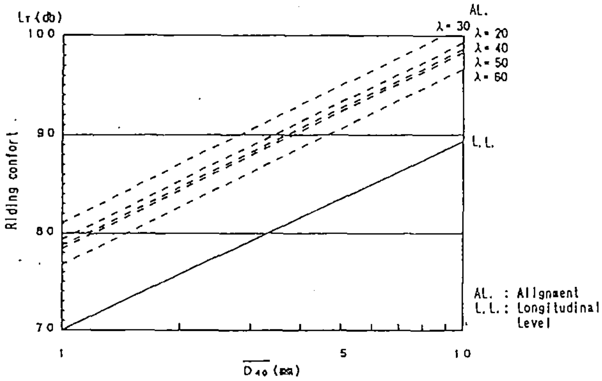


Fig. 11 Tolerances for track irregularities from riding comfort

level of it in a certain length of time. On the other hand, the mechanical track maintenance can suppress the magnitude of track irregularities as a whole. Thus, the fundamental treatment in lot to decrease the large growth ratio of track irregularities becomes important.

To realize this, a new system is proposed here and effectiveness of this is demonstrated. Further the merit of this system is on the point that this can eliminate the spot work by hand and all the work can be mechanically done at a time in a period aimed.

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