ANALYSIS

EN 13848-6 RECOMMENDATIONS ON THE USE OF STANDARD DEVIATION AS A PAPAMETER FOR TRACK TECHNICAL CONDITION ASSESSMENT.

G.A. KRUG, Ph.D., D. Sc.*

Independent researcher

ABSTRACT

The standard deviation(SD) is the most commonly used parameter for Track Quality Index (TQI) calculation by European Railway Networks. Studied the conformity between the SD values of the ensembles measurements track geometry results for track segments and track technical condition. Shows that the SD value ambiguously describes track technical condition. The values of SD cannot be used to uniquely identify Track Quality Class (TQC).

INTRODUCTION

As specified in the EN 13848-6 Standard in many European Railways for the track quality assessment is used as a rule one parameter –Standard Deviation (SD). Recommendation of the EN 13848-6 for the longitudinal Level irregularity for two speeds ranges are shown In Table 1.

TABLE 1 (EN 13848-6-2014)

LONGITUDINAL LEVEL –STANDARD DEVIATION –D1 DOMAIN

SPEED (in km/h)	Limit value of standard deviation (in mm)				
	TRACK QUALITY CLASS				
	A	B	C	D	E
80<V≤120	<0.75	1.1	1.8	2.5	>2.5
120<V≤160	<0.65	0.85	1.4	1.85	>1.85

Limit value of SD for each TQC based on cumulative frequency distribution of the weighted average of all the networks participating in the European Track Quality Survey. This standard and CEN/TR 16513 Technical Report “Railway applications-Track-Survey of track geometry quality” not be considered a correlation between SD value and track technical condition. We studied the possibility of the using track classification with point of view the consistency of a range of SD values to track technical condition.

*E-mail: viig@inter.net.il

1. SD informational Content

For the track quality assessment SD calculated on the results measuring deviation track geometry parameters for segments 200m length typically at Intervals of 0.25m.

From point of view probability theory this measurements results are random variables that take one of the possible values with probability that depends on the track condition. Each random variables described by the distribution function of the probability density for continuous variables or as a series distribution for discrete variables. In our case we are taking about a discrete random value.

For example longitudinal level track chart record is shown in figure 1 and graphical presentation of the Irregularity Size Distribution Function (ISDF) is shown In figure 2.

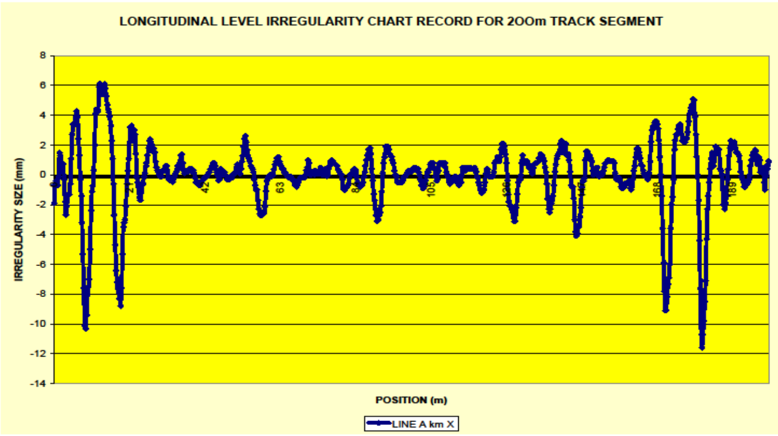

figure 1

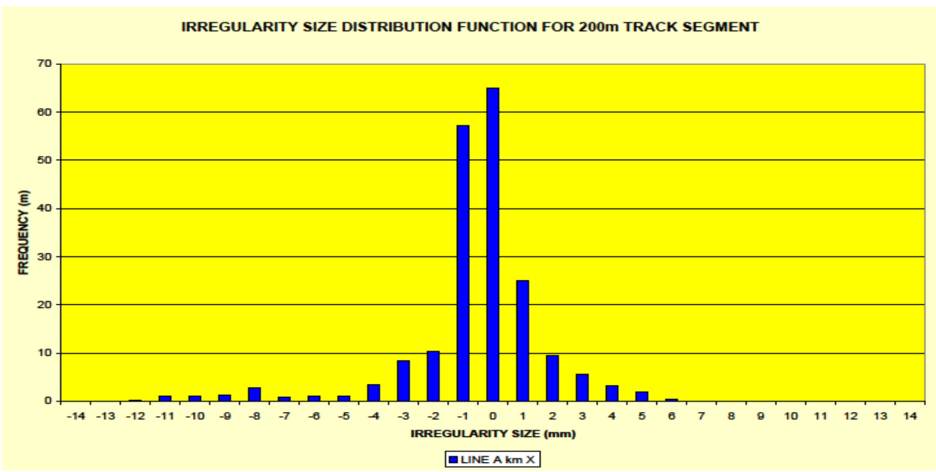

figure 2

The function which is given in figure 2 provides the objective characteristics of the process. SD is only one of the parameters of the random process and does not characterize it fully.   In addition, according to calculated formula SD gives only an integrated assessment of the track quality as seen the influence of “LARGE” irregularities because as the quantity this irregularities is usually much smaller than “SMALL” irregularities quantity.

In figure 3 are shown track chart records and for 4 track segments for which SD values are almost the same (2.2<SD<2.3) as a ISDF shape differ significantly, as shown in figures 4.1, 4.2, 4.3, 4.4.

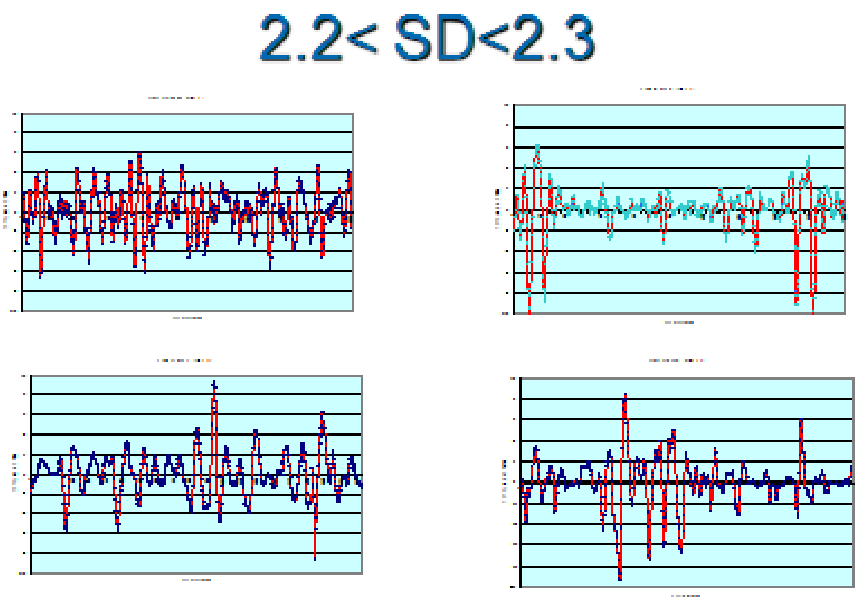

figure 3

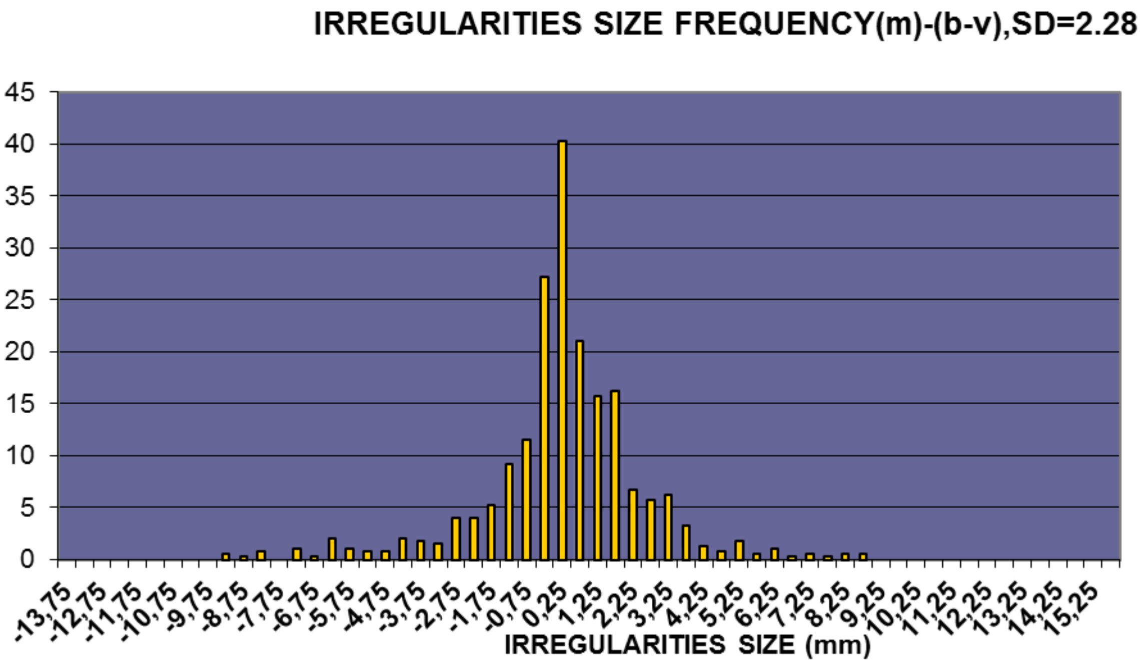

figure 4.1

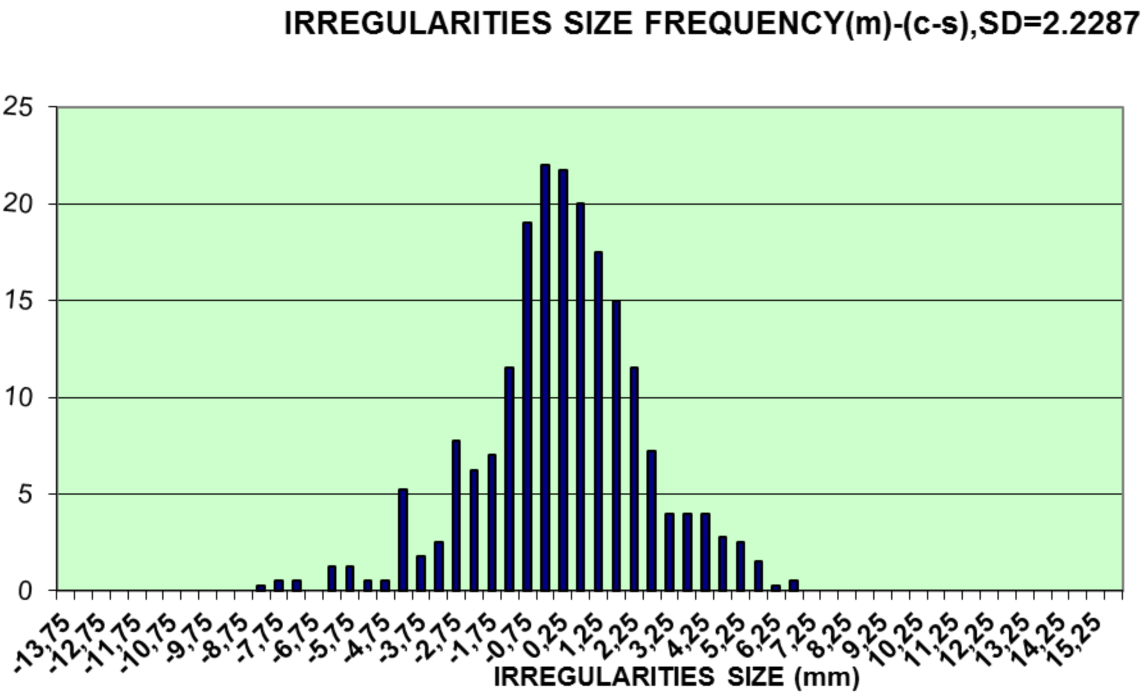

figure 4.2

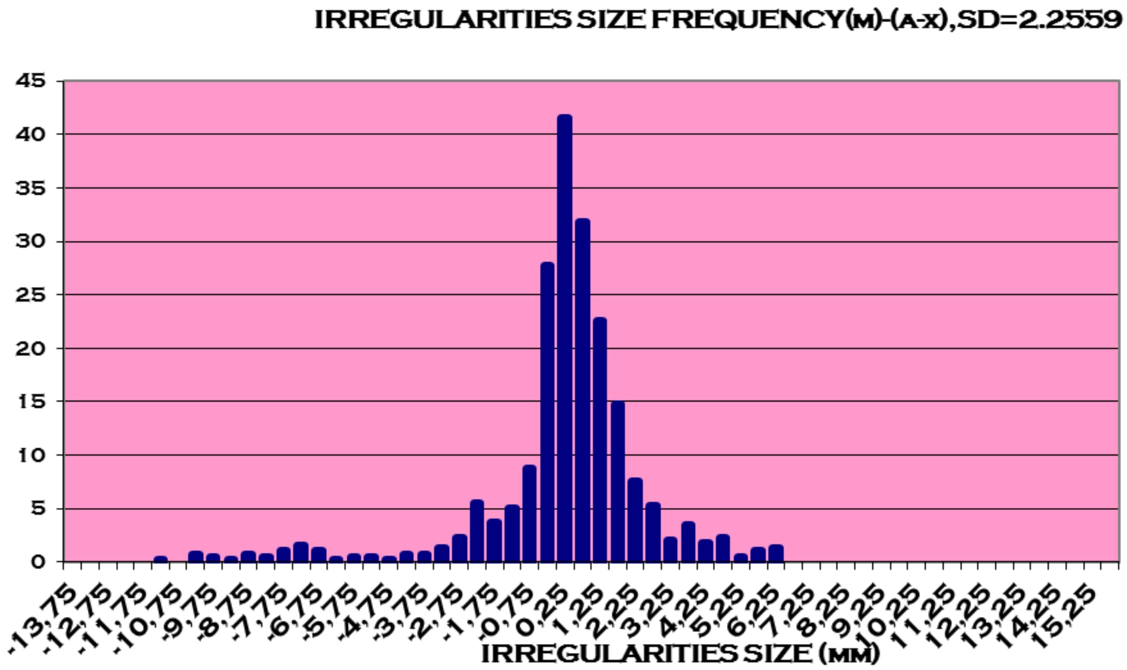

figure 4.3

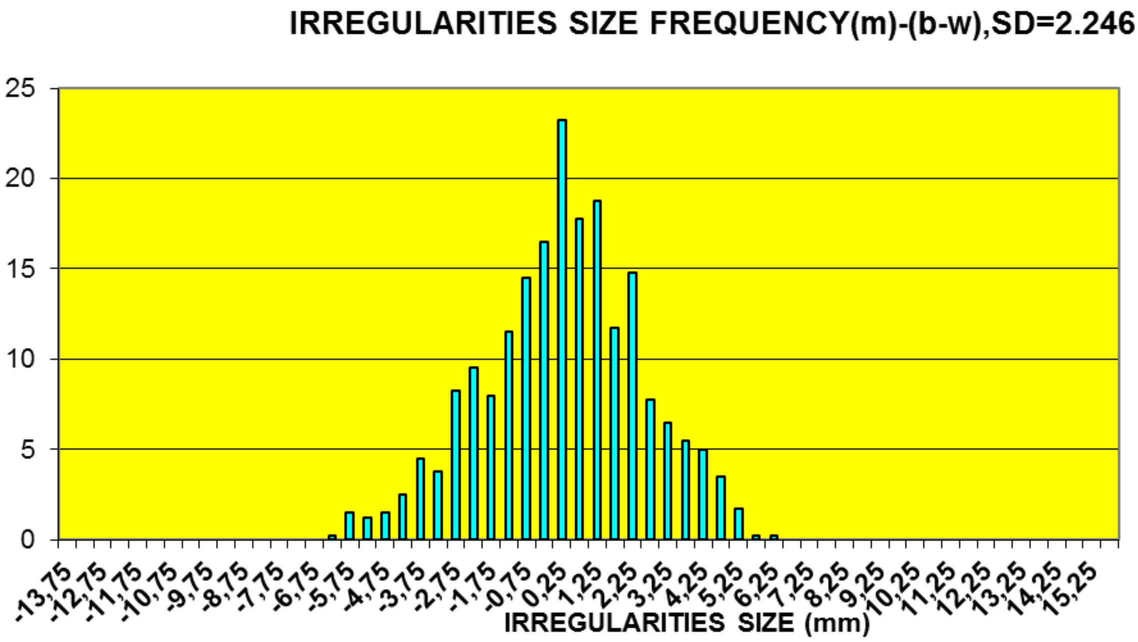

figure 4.4

2.DATABASE

To analyze a database was established containing longitudinal level irregularity measurements for 1056 segments, every 200 m length of track.

Segments distribution by track quality classes for speeds 80≤V≤120 km/h in accordance with EN 13848-6 shows in table 2.

TABLE 2

TRACK QUALITY CLASS	SD (mm)	NUMBER OF SEGMENTS
A	SD<0.75	104
B	0.75≤SD<1.1	167
C	1.1≤SD<1.8	330
D	1.8≤SD<2.5	321
E	SD>2.5	134

3. STUDY OF THE DISTRIBUTION FUNCTION PROPERTIES

As already mentioned the distribution function is an objective and not distorted description of measurement results track geometrical condition. In this paper we present results of the study matching this function properties and SD values used for classification of track technical condition in accordance with the EN 13848-6.

Such properties, in our view, are:

-statistical distribution law of measuring results,

- extreme irregularity sizes for every track quality class (TQC) in accordance with the SD specified range,

- shape of the Irregularity Size Distribution Function (ISDF).

3.1 EXAMINATION OF THE LAW OF DISTRIBUTION MEASURING RESULTS

Study of distribution law of measurement results of interest for several reasons:

-the use of the 3σ parameter to evaluate track technical condition to legitimately only if ensemble measuring results correspond to the normal law distribution,

- analysis of the track condition changes, checking the condition of the track according to technical requirements as well a comparison of the status of various track segments based on the SD value are in the term of probability theory as legitimate only in cases where the measuring results correspond to the same statistical distribution law.

By default, the famous regulations require that the measuring results law distribution is normal. For test, the hypothesis that the ensembles of measurements results follow to the normal distribution law we used ANDERSON –DARLING method. It is one of the most powerful statistical tools for detecting most departures from normality. Analysis results as PROBABILITY PLOTS graphs exemplary are presented in figure 5 (MINITAB software).

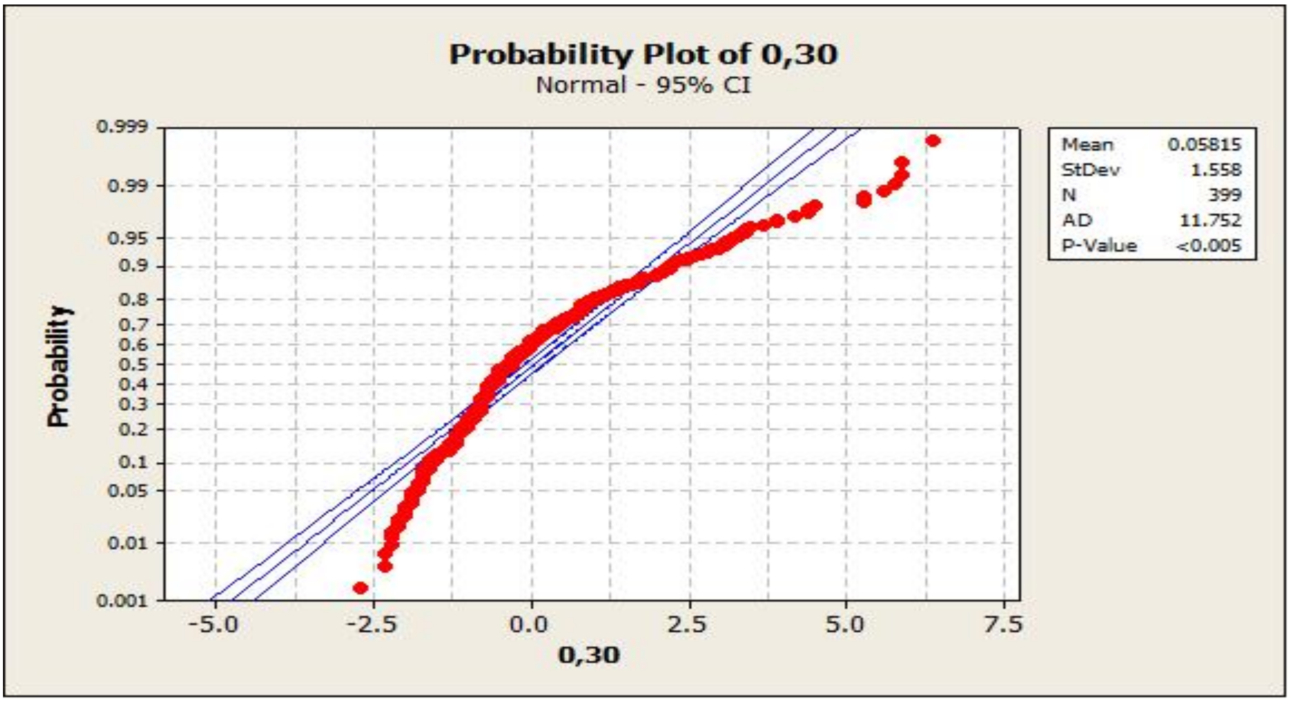

figure 5

PROBABILITY PLOT use to evaluate the fit of distribution to data estimate percentiles (probabilities) and compare different sample distribution. A probability plot does the following:

-plots each value vs percentage (probability) in the sample that are less than or equal to it , along a fitted distribution line (middle blue line).

-may display the approximate 95% for the presently.

Curved blue lines displays approximate 95% confidence interval for normal distribution. Points outside the confidence intervals correspond to the tails- the extreme values of the measuring results.

In accordance with the Anderson –Darling test measuring results fit normal distribution in following cases:

-the plotted points will roughly form a straight line,

-the plotted points will fall close to the fitted distribution line,

-the Anderson –Darling statistic will be small, and associated p-value will be larger than chosen α-level. Statistic (p-value) is the weighed distance from the plot points to the fitted line with larger weights in the tails of the distribution. Probability plot perform a hypothesis test to examine whether or not the observations follow a normal distribution. For normality test, the hypotheses are:

H_0: data follow a normal distribution,

H_1: data not follow a normal distribution.

P-value determines the appropriateness of rejecting the null hypothesis test. The p-value is the probability of obtaining a test statistic that is at least as extreme as calculated value if the l hypothesis H_0 (data follow a normal distribution) is true. Associated P-value are displayed with the plot. If p>(1-CI) H_0 is TRUE.

A commonly used CI value is 0.95. As can be seen from the fig.4 the ensembles data do not satisfy these conditions. This condition does not satisfy for approximately 80% of the database segments.

3.2 STUDY OF THE RALATIONSHIP BETWEEN SD RANGES AND EXTREME IRREGULARITY SIZE

For each segment it was calculated SD value and ISDF value with 1mm steps. On the basis of the ISDF defined maximum and minimum irregularity size value. Analysis results for all the segments are shown in tables 3 and 4. The data in the tables show distribution of number of track segments (in percent) according to the maximum (s>0) or minimum (s<0) irregularity size. Graphical presentation of analysis results can be seen in FIG. 6,7.

From tables 3 and 4 and charts in Fig 6, 7 shows that every TQC correspond a wide range of irregularity sizes. Therefore, the irregularity size distribution function for various TQS (different ranges of standard deviation) has common area irregularities sizes.

TABLE 3

TQC	SD VALUE	MIN IRREGULARITY SIZE (mm) / NUMBER OF SEGMENTS (%)	1	2	3	4	5	6	7	8	9	10	11	12	13	14
A	SD<0.75		58.7	38.5	2.9	0	0	0	0	0	0	0	0	0	0	0
B	0.75≤SD<1.1		4.8	59.9	28.1	6.0	1.2	0	0	0	0	0	0	0	0	0
C	1.1≤SD<1.8		0	0	4.5	35.5	35.5	13.9	7	2.1	0.3	0	0	0	0	0
D	1.8≤SD<2.5		0	0	2.2	20.6	40.0	20.0	8.8	5.9	1.3	0.9	0.3	0	0	0
E	SD≥2.5		0	0	0	0.7	13.4	39.6	16.4	16.4	5.2	6.7	0.7	0.7	0	0

TABLE 4

TQC	SD VALUE	MIN IRREGULARITY SIZE (mm) / NUMBER OF SEGMENTS (%)	-1	-2	-3	-4	-5	-6	-7	-8	-9	-10	-11	-12	-13	-14
A	SD<0.75		0	39.4	47.1	10.6	1.9	1	0	0	0	0	0	0	0	0
B	0.75≤SD<1.1		0	0.6	34.1	34.7	19.8	10.8	0	0	0	0	0	0	0	0
C	1.1≤SD<1.8		0	0	0.9	9.4	17.0	20	19.7	18.8	9.4	3.9	0.6	0	0	0
D	1.8≤SD<2.5		0	0	0	0	0	0.9	8.8	15.6	24.7	20.3	10	8.1	6.3	5.3
E	SD≥2.5		0	0	0	0	0	0	0	1.5	9.7	11.9	17.9	19.4	20.1	19.4

Thus from point of view of analysis extreme irregularity dimensions using standard deviation criteria can lead to wrong decision on the track condition.

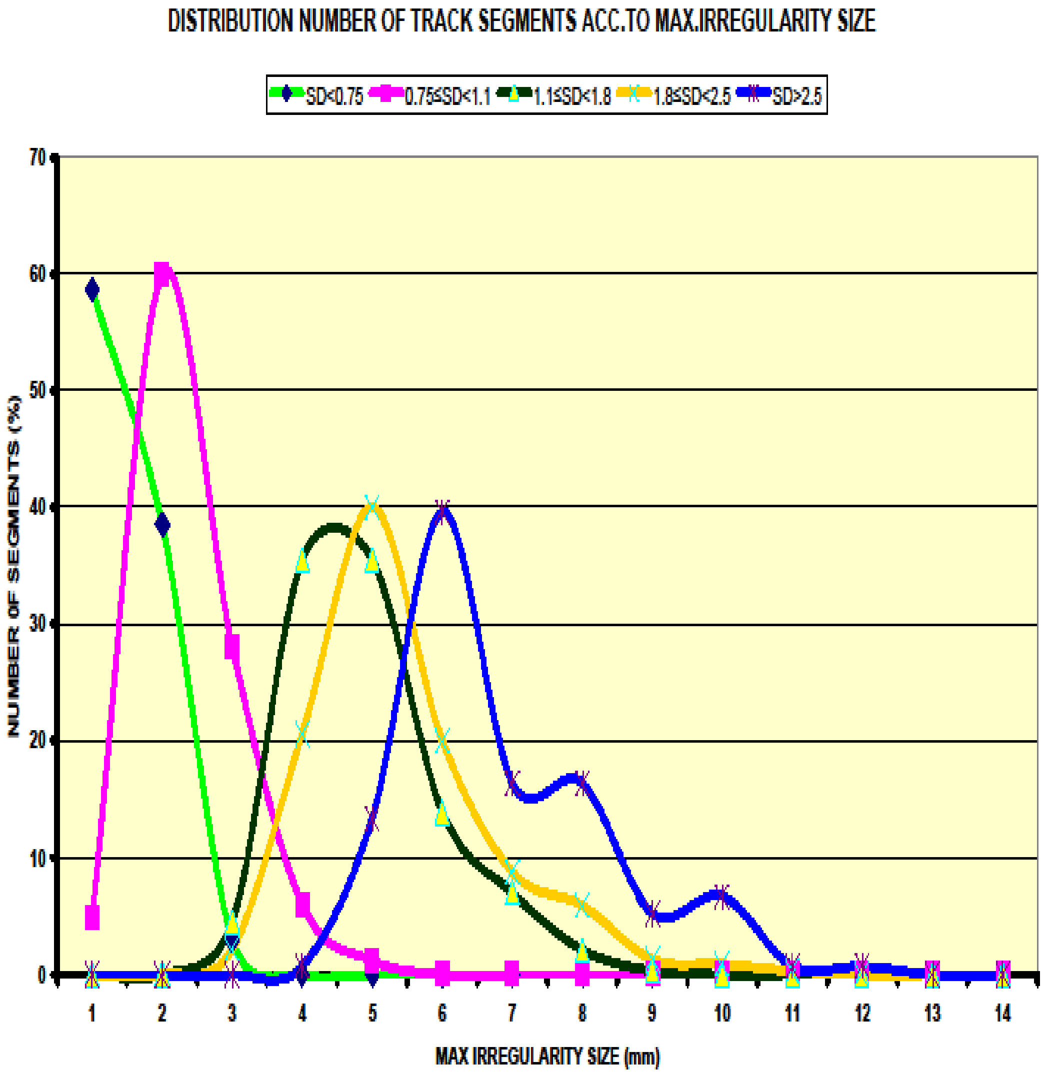
DISTRIBUTION NUMBER OF TRACK SEGMENTS ACC.TO MAX.IRREGULARITY SIZE
SD<0.75
0.75≤SD<1.1
1.1≤SD<1.8
1.8≤SD<2.5
SD>2.5
NUMBER OF SEGMENTS (%)
0
10
20
30
40
50
60
70
1
2
3
4
5
6
7
8
9
10
11
12
13
14
MAX IRREGULARITY SIZE (mm)

figure 6

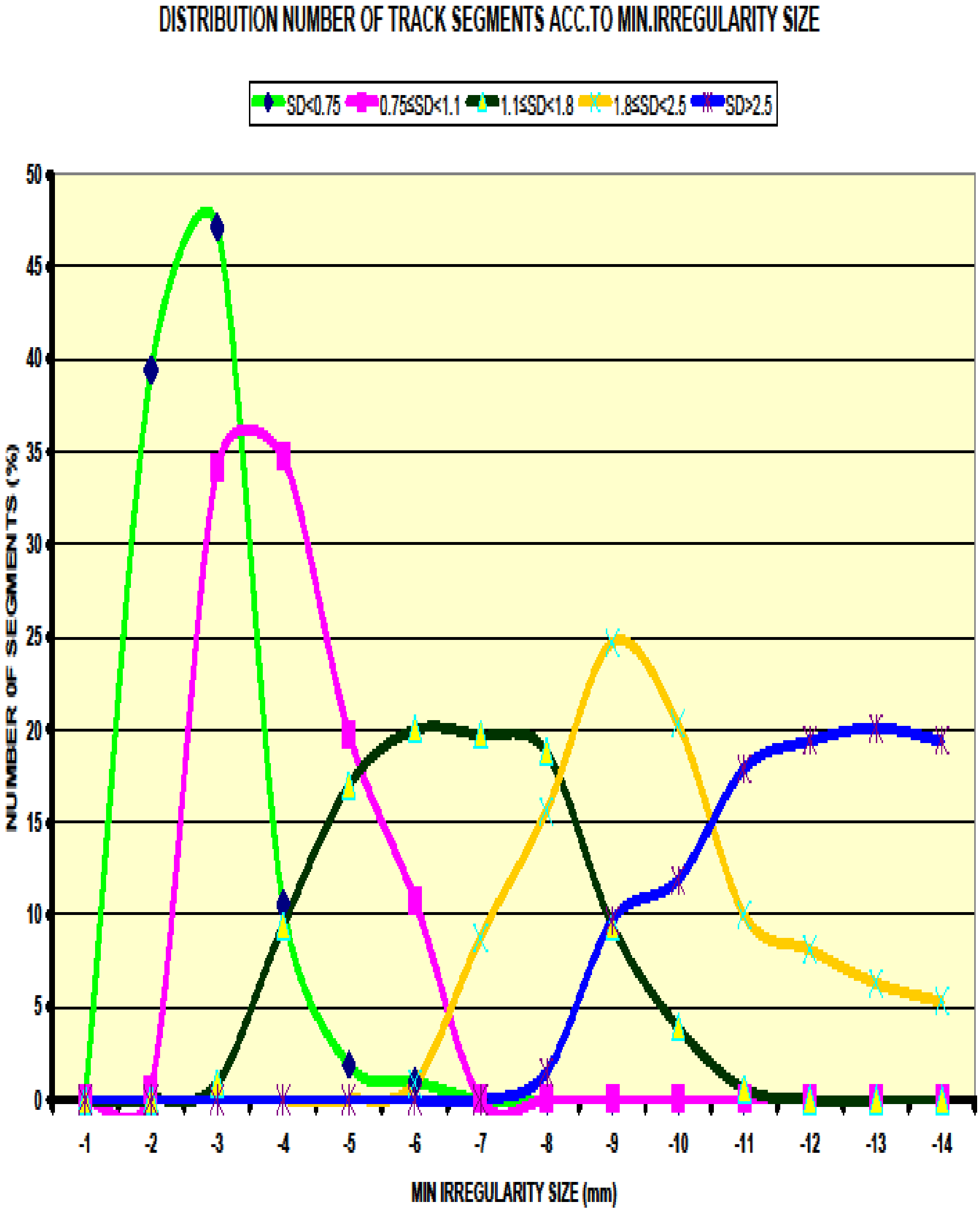

figure 7

3.3 **STUDY of the SHAPE IRREGULARITY SIZE DISTRIBUTION FUNCTION**

Shape of the ISDF, in other words the ratio between the numbers of Irregularities of different sizes within the track segments defines integrated force, who acting on the track from the rolling stock. To describe a shape of the ISDF, we use application" SUM" from MINITAB software. This application allows getting a complete set of the random process parameters for detail analysis. Sample table of the results shown in fig 8. This summary table contains basic statistical characteristics of the process as well the value of the confidence interval for mean, median and SD. Note, that that specifying the limits of the confidence intervals the necessary condition for strictly analysis for each random process.

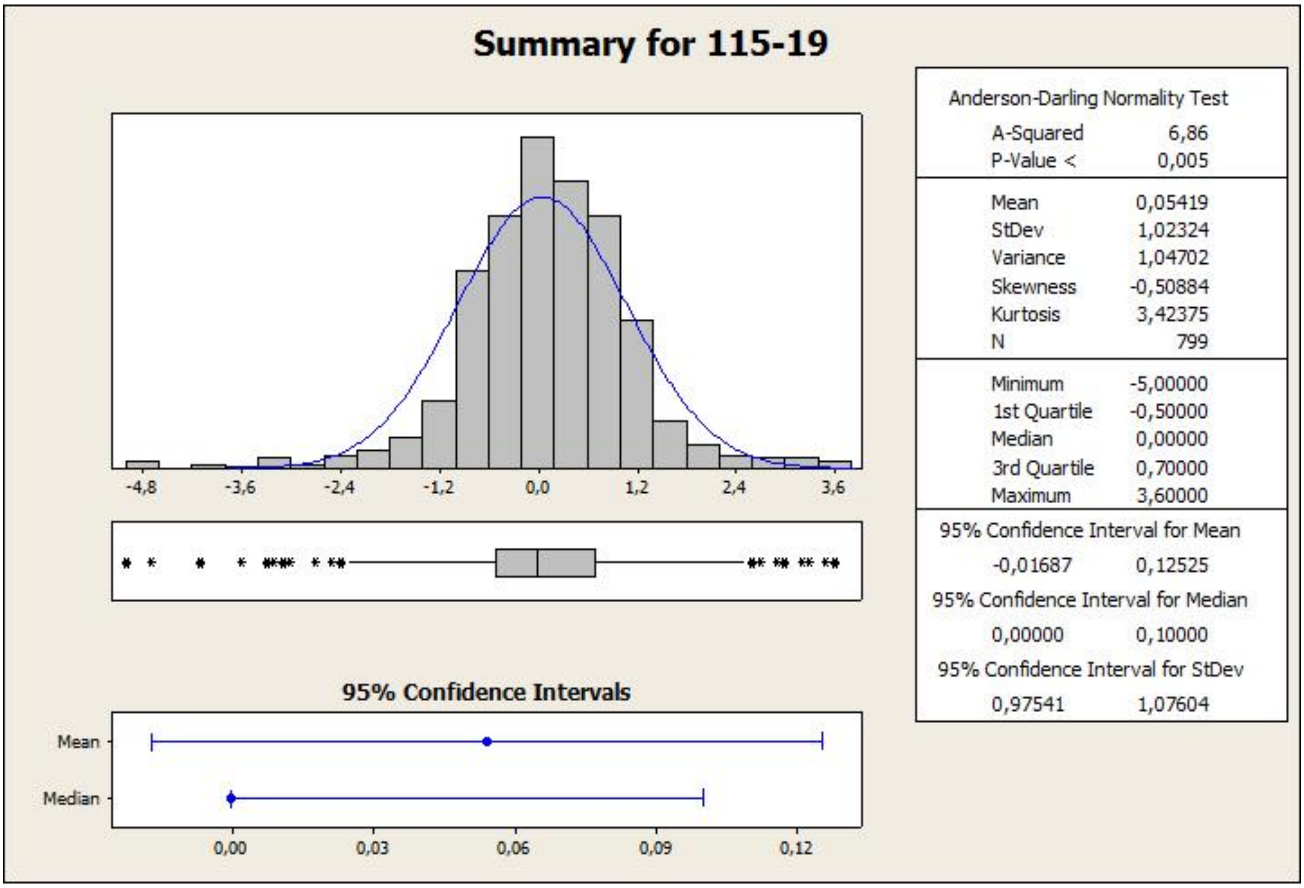

figure 8

For the analysis in the data base within each track quality class are selected segments, for which the standard deviation values do not differ significantly. Summary of the statistical parameters for every track segments are shown in the table 5.

Summary of the statistical parameters for every chart are shown in the table. IS range it is difference between maximum and minimum irregularity size in accordance to irregularities size distribution function. This parameter is used for the analysis because typically irregularity size distribution function is asymmetrical.

Analysis of the data contained in the table shows that with close values of SD , there are significant differences in the track technical condition , that depends not only on the SD but on the shape ISDF.

Statistical parameter which, to a certain extent characterized the shape of the distribution function is the fourth central moment (kurtosis-K). K is a measure of how flat the top of symmetric distribution is when compared to a normal distribution of the same standard deviation. In cases where for two track segments the design values SD are the same and K is differ shape ISDF and contact stress and the energy dissipated in the wheel-rail contact will be different.

Kurtosis is actually more influenced by scores in the tails of the distribution than scores in the center of distribution. It provides additional opportunities in determining the extreme values of irregularities.

Figures 9, 10, 11, 12 comparison functions ISDF for track segments with almost equal SD value (0.5, 1.5, 2.1, 2, 3) and different K. Apparent significant differences in the function, in particular in the extreme areas.

Table 9

CLASS	SD(MM)	SKEWNESS	KURTOSIS	IS^* min	IS max	IS range
A	0.39	0.12	0.47	1.2	1.3	2.5
A	0.46	0.49	0.84	1.2	1.6	2.8
A	0.72	-1.26	8.53	4.7	2.2	6.9
A	0.45	-.003	1.32	1.7	1.5	3.2
A	0.36	-0.34	2.61	1.9	1.2	3.1
A	0.70	0.32	0.97	1.8	2.4	4.2
B	1.01	-3.01	21.95	8.3	3.6	11.9
B	0.77	-2.61	20.7	6.2	3.6	9.8
B	1.01	-1.31	7.3	6.2	3.1	9.3
B	1.06	-1.15	6.96	6.7	3.8	10.5

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B	0.79	-0.13	0.7	2.6	2.4	4.8
B	0.96	0.02	0.64	2.6	3.1	5.7
B	0.81	-0.02	-0.1	2.2	2.5	4.7
B	0.8	0.03	-0.15	2.2	2.4	4.6
B	1.02	0.5	3.42	5.0	3.6	8.6
B	1.47	-1.7	10.2	9.7	5.2	14.9
C	1.18	-0.75	3.87	6.2	3.3	9.5
C	1.22	0.32	0.48	3.9	4.2	8.1
C	1.12	-0.11	2.12	3.8	4.6	8.4
C	1.60	-1.12	6.92	9.2	6.1	15.3
C	1.79	-1.52	4.58	9.5	4.2	13.7
C	1.47	-1.74	10.20	9.7	5.2	14.9
C	1.69	-0.83	1.98	7.2	4.0	11.2
C	1.77	-1.44	5.35	10.1	5.0	15.1
C	1.57	-2.03	8.99	9.5	3.9	13.4
C	1.71	-1.01	4.10	7.4	5.0	12.4
C	1.72	-0.76	1.90	8.2	4.7	12.9
C	1.17	-0.71	2.87	5.8	3.9	9.7
C	1.18	0.37	0.46	3	3.9	6.9
D	2.14	-0.68	0.44	7.9	5.3	13.2
D	1.93	-0.87	1.0	6.8	3.9	10.7
D	2.0	-0.4	0.23	5.7	5.1	10.8
D	2.02	-0.6	1.94	8.2	6.0	14.2
D	2.44	-1.02	2.12	9.3	7.5	16.8
D	2.15	-1.78	6.11	12.1	6.4	18.5
D	2.33	-1.39	5.58	13.0	6.9	19.9
D	1.95	-0.36	0.42	6.7	5.2	11.9
D	2.31	-0.76	0.76	7.6	5.2	12.8
D	2.39	-0.98	0.91	7.7	5.1	12.8
D	2.34	-0.69	1.93	9.6	7.3	16.9
D	1.91	-1.06	1.86	7.7	4.6	12.3
D	2.25	-0.17	-0.09	6.6	6.1	12.7

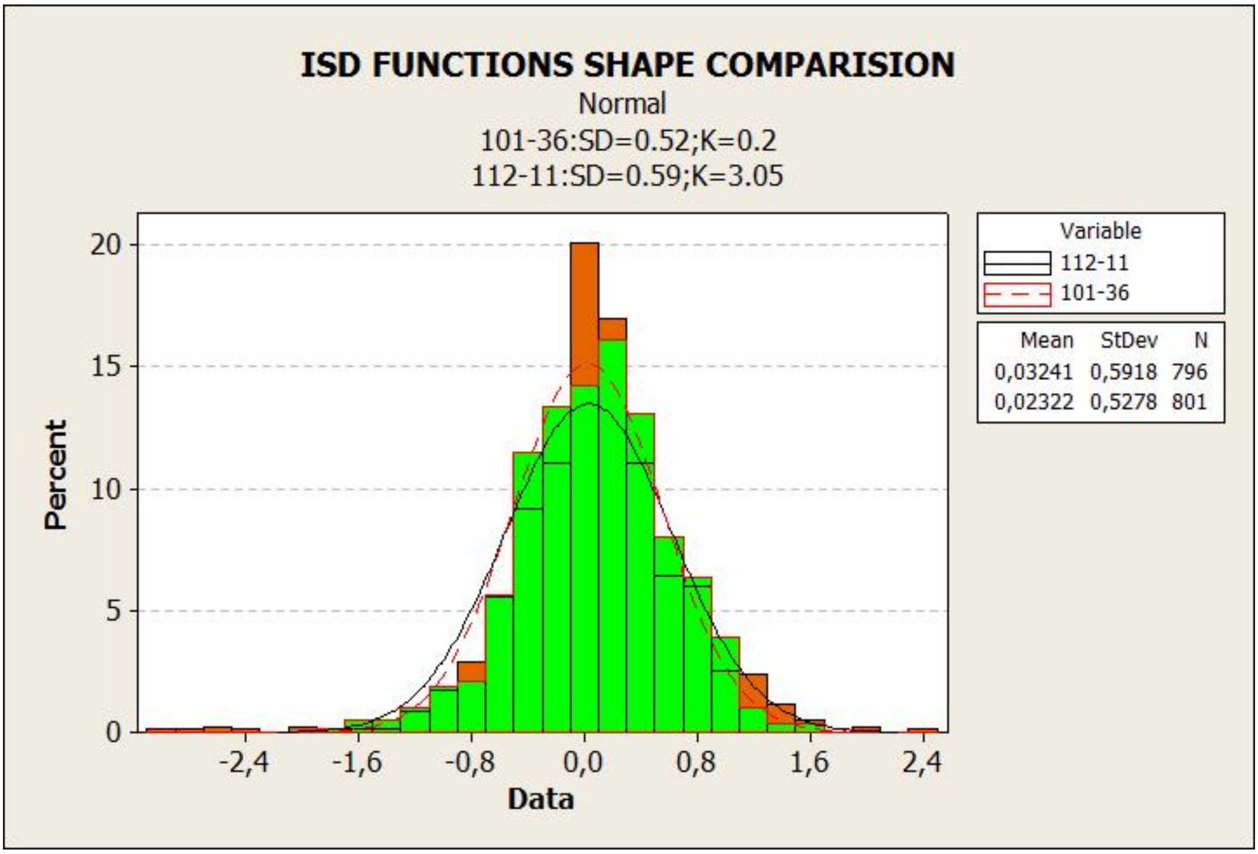

figure 9

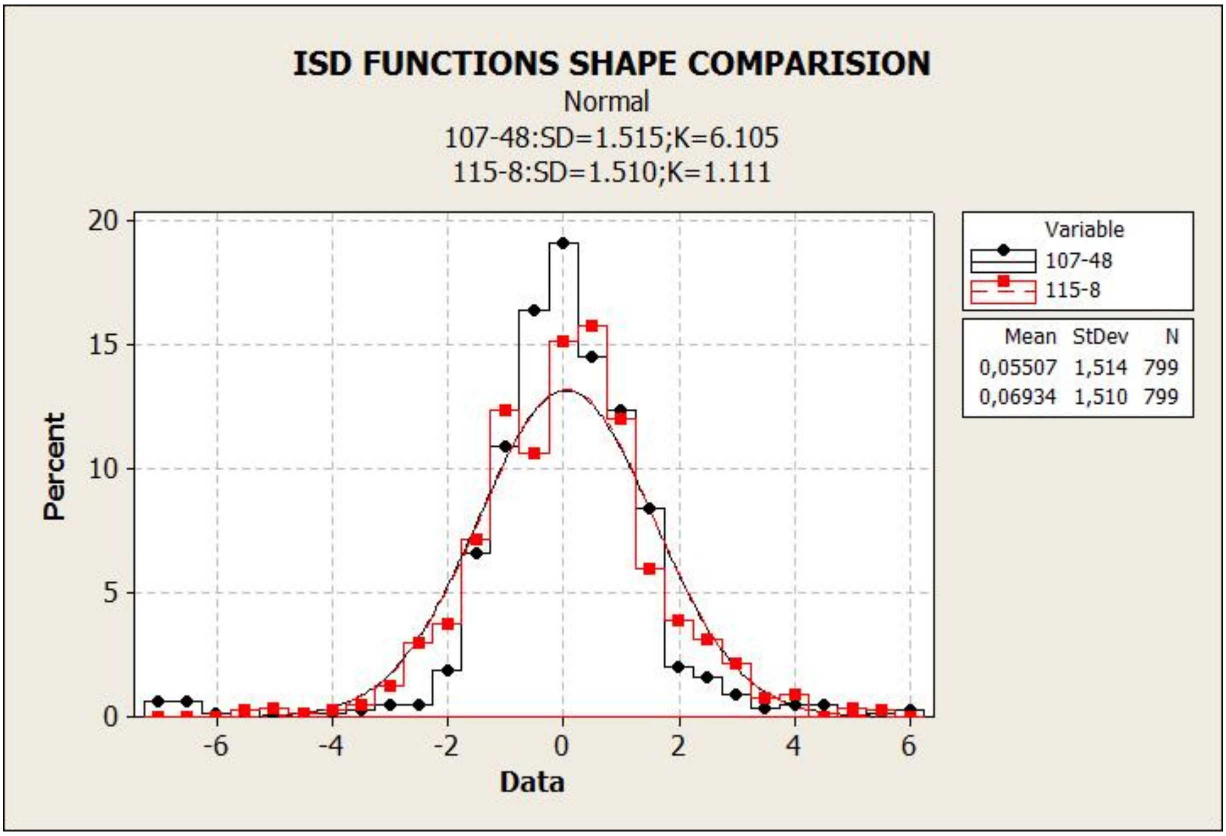

figure 10

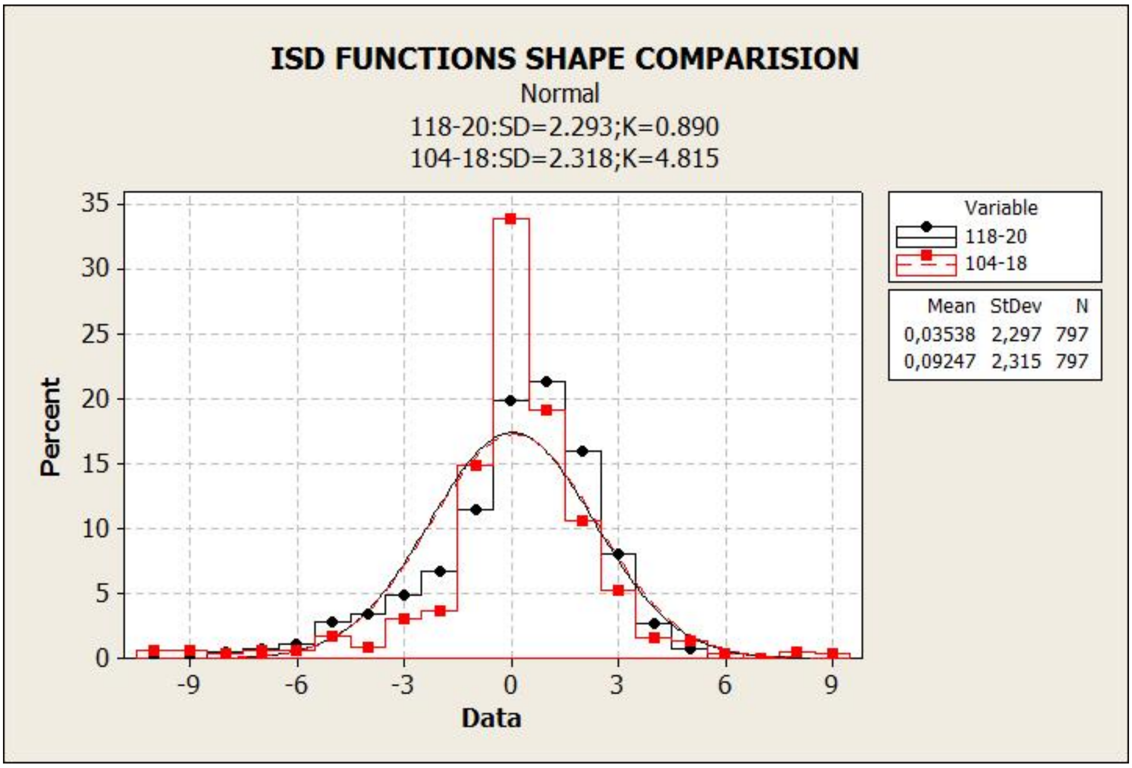

figure 11

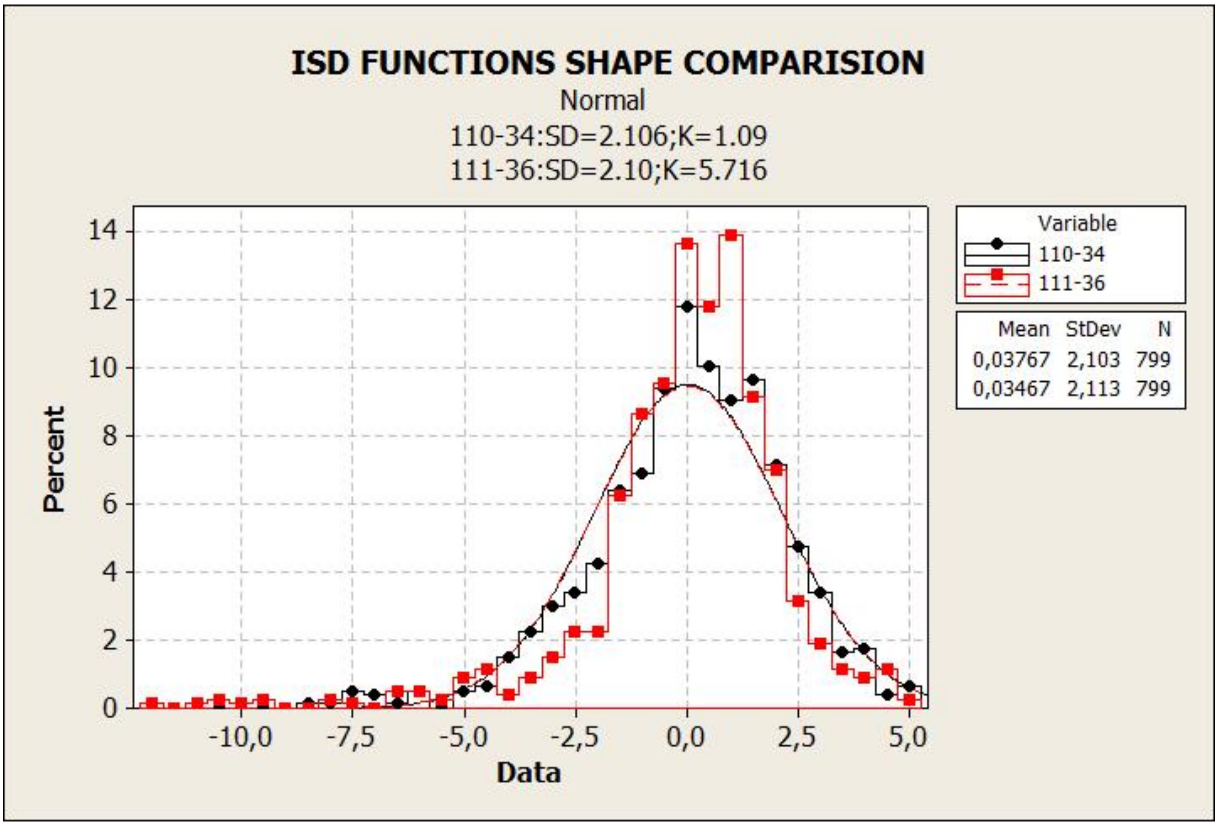

figure 12

CONCLUSION

1. The track geometry measuring results (ISD FUNCTION) as a rule not follow a normal distribution, because comparison between the parameters of various statistical laws distribution is not correct.
2. To each Track Quality Class (TQC) according to EN 13848-6 standard corresponds track segments with different values of the extreme size irregularities and vice versa.
3. SD criterion does not take into account the shape of ISDF and for track section with the same values of SD contact stress and the energy dissipated in the wheel –rail contact will be different.

RECOMMENDATION

1. In the text of the EN 13848-6 standard draw attention to the ambiguity of the definition Track Quality Class (TQC) based on SD value.
2. The effectiveness of using the deterministic approach to the assessment track technical condition instead of the statistics methods need to study.

NOTE: The author does not consider the results an ultimate truth and is ready to check this analysis method with other databases.