MEASUREMENT OF RAILWAY SURFACE FLAWS WITH THE CCD LINE SENSOR CAMERA SYSTEM

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ABSTRACT

For railway companies, the maintenance of railway tracks is one of the most important subjects to keep the safe transportation. Especially, the railway tracks of the Shinkansen (the high speed railway system of Japan) requires to pay much more attentions to the maintenance for it's high speed traffics. The rail surface's flaws, which are caused by wheels of the train when it runs at high speed, make noises to the surroundings and also make unpleasant vibrations to the passengers. Recently, the progresses of the technology based on the image sensing and measuring are very successful. This paper reports an application for railway maintenance by the image measuring technology with the image of the CCD Line Sensor Camera .
Main contents of this paper are,

(1) The introduction of the system's architecture

The measuring system is consisted on a CCD Line Sensor Camera, a high speed digital data recorder, and an UNIX work station (SUN : SS-2). The Camera and the Data recorder takes the image data which resolution is 0.5 millimeters per line at the speed of twenty kilometers per hour. And, the recorder takes the Image data of four cameras at same time. All data is recorded successively on the digital data tape.

(2) The way to measure the rail surface's flaw

Almost part of the rail surface is polished to flat by the wheels of train like as a mirror. When contriving to illuminate the rail surface, it is possible to get image the flaw part as very different image from the flat part, and possible to classify the condition of the rail surface from the numerical number which is processed by the UNIX work station.

BACK GROUND

At present, most of maintenance for railway tracks are done by human's patrolling on foot, and it's difficult to detect wrong parts immediately. As the total length of the railway is too long, for example, the total length of TOHOKU Shinkansen railway (East Japan Railway Company) is approximately one thousand kilometers, depending on the human patrolling to check the condition of railways consumes too much time and human powers. And , it's necessary to keep many patrol men who should have special knowledge for the railway maintenances.

On the other hand, for the reason of the Shinkansen trains' speeds are very high (more than two hundred kilometers per hour), it is impossible to maintain the railway in the daytime. And it becomes hard work to maintain them should be done only at midnight. Under this circumstance, it is required to research the detection method of the roughness and flaws on railway surface from photos or motion images.

SYSTEM OUTLINE

The inspecting system, now under developing, is consisted on a CCD Line Sensor Camera (Line Camera) for capturing the successive images, a Digital Data Recorder (DDR) that can record a large image data, and an engineering work station (EWS) which is processing that image data. (Figure 1.)

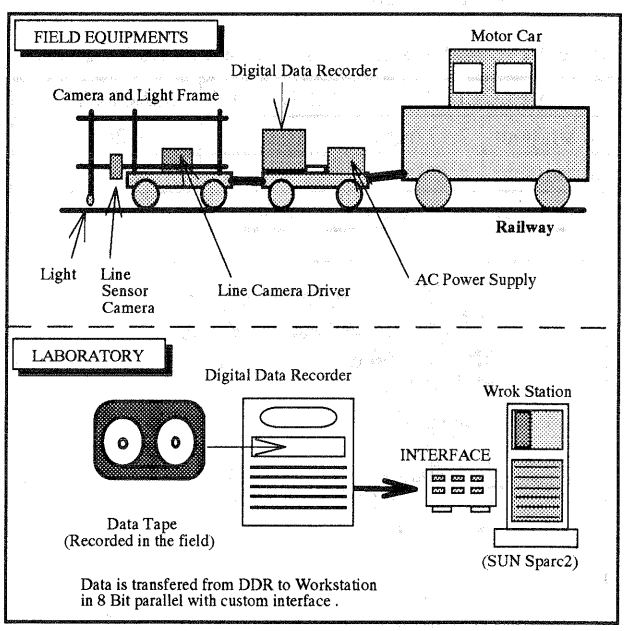


Figure 1. The Line Camera System Constitution

At the filed, these units (the Line Camera and the Digital Data Recorder) are loaded on the trolley and pulled by the engine which is called the Motor Car, and the image data is recorded in real time to the data tape in DDR (Digital Data Recorder). Those data are sent to the engineering work station (SUN :

Spark Station 2) for image processing later in the laboratory.

This system can takes the successive images from running car with a line sensor camera, and record to a data tape as a digital image data, and it is possible to process those data by a computer without an analog digital conversion.

One of most different part between a Video Camera (an area sensor camera) and a Line Camera is, a Video camera records a image of area, on the other hand, a Line Camera records a image of line, so if the camera would not move, it is scanning the same line. For the case of using a Video camera (an area sensor camera) and a Video Cassette Recorder, it can only record 30 frames per one second (picture of area images : NTSC standard). It means when recording successive images, a Video Camera can record 30 lines per one second.

But for the case of using the Line Camera, according to the specifications of the Camera (Table 1.) and the result of some experiments in the field, with using DDR, it is possible to get a line of image data (512 pixels per a line) approximately 10,000 lines of image data can record in one second.

Table 1. Specifications of the Line Camera

PIXEL SIZE	13μm × 13μm
LINE SIZE	512 PIXELS
DOT CLOCK	8 MHz
DATA OUTPUT	8 BIT DIGITAL
LINE SCAN RATE	≒10,000 scan /sec

So, if the Line Camera travels at a speed of 20 kilometers per an hour (5.55 meters per a second), a vertical resolution of each scan is approximately 0.56 millimeters. (Figure 2.)
The other hand, a horizontal resolution just depends on optics. If select a Lenz for the Line Camera to take 10 centimeters full width object, a horizontal resolution of images becomes 0.2 millimeters per a pixel dot.

Table 2. Vertical Resolution of the Line Camera Image Data

VELOCITY		LINES / SEC	RESOLUTION
10 km/hour	2.777m/sec	10,000	0.28mm
20 km/hour	5.555m/sec	10,000	0.56mm
30 km/hour	8.333m/sec	10,000	0.83mm

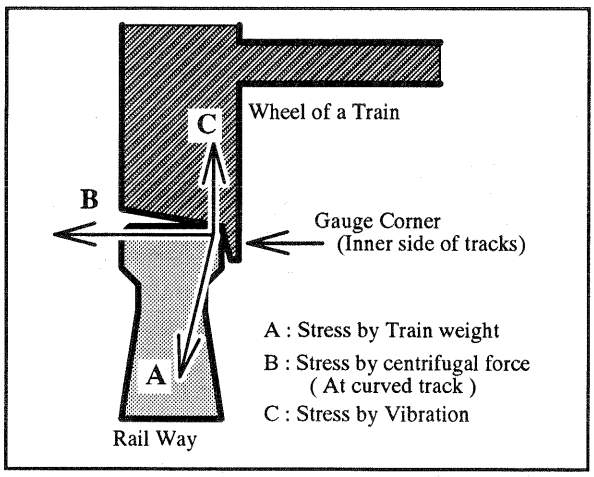


Figure 2. Stresses to Railway

CHARACTERISTICS OF RAIL SURFACE FLAW

When trains run on rail way tracks, those wheels force several kinds of stresses to rail way tracks. Mainly, those stresses are (A)Train weight stress, (B) Centrifugal stress at curved tracks, and (C) Hitting force when trains (or wheels) are vibrating. These complicated stresses make rail way material fatigued. (Figure 2.) So, the vast majority of flaw are break out at curved track area.

In the first stage of fatigue, many small cracks (very fine crack : 0.1 millimeter - 0.3 millimeters) appear on rail material surface (from the gauge corner side). In process of time, number of cracks are increased and those length are stretched to opposite side. Finally, crack reach to deep part of rail material, and make it break.

Practically in filed, when the length of cracks from gauge corner side extended over the limit, the surface of rail of those parts are ground by the grindstone and removed all fine cracks. At the time of maintenance, the condition of the rail surface is judged by measuring the length of flaws from the gauge corner side.

WAY TO GET THE IMAGE DATA

The Line Camera set over the center of Rail in downward vertical position. And the scanning line of the Line Camera meets traveling direction at right angles. (Figure 3.)

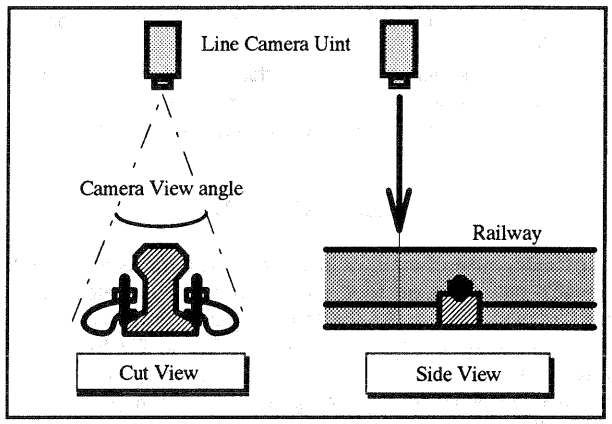


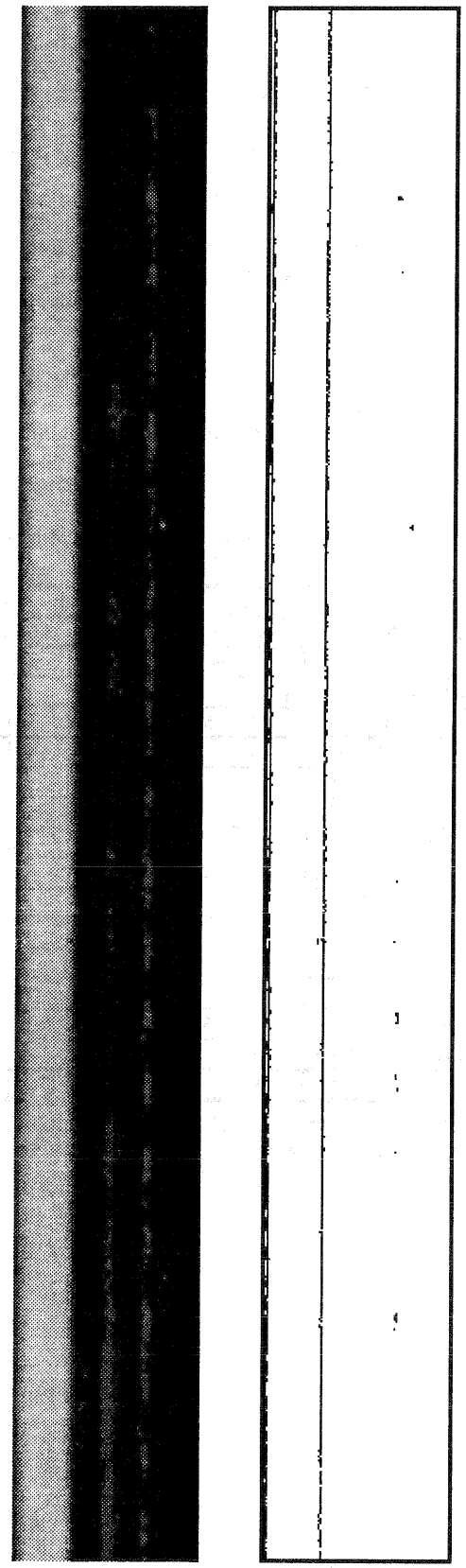
Figure 3. Image of the Line Camera Setting

Under normal condition, rail surface is possible to distinguish two part. One is a polished part like as a mirror by wheels (Gauge corner side), and the other is a rusty part which wheels do not touch (Out side of rails).

When an illuminating light set at lower position (close to rail surface), a rusty part causes diffused reflection. (Figure 4.) In the Line Camera image data, that area is recognized as a bright part. The other side, at a polished part, as every reflected light on rail surface dose not reach to the Line Camera, in the Line Camera image data, that area is recognized as a black part.

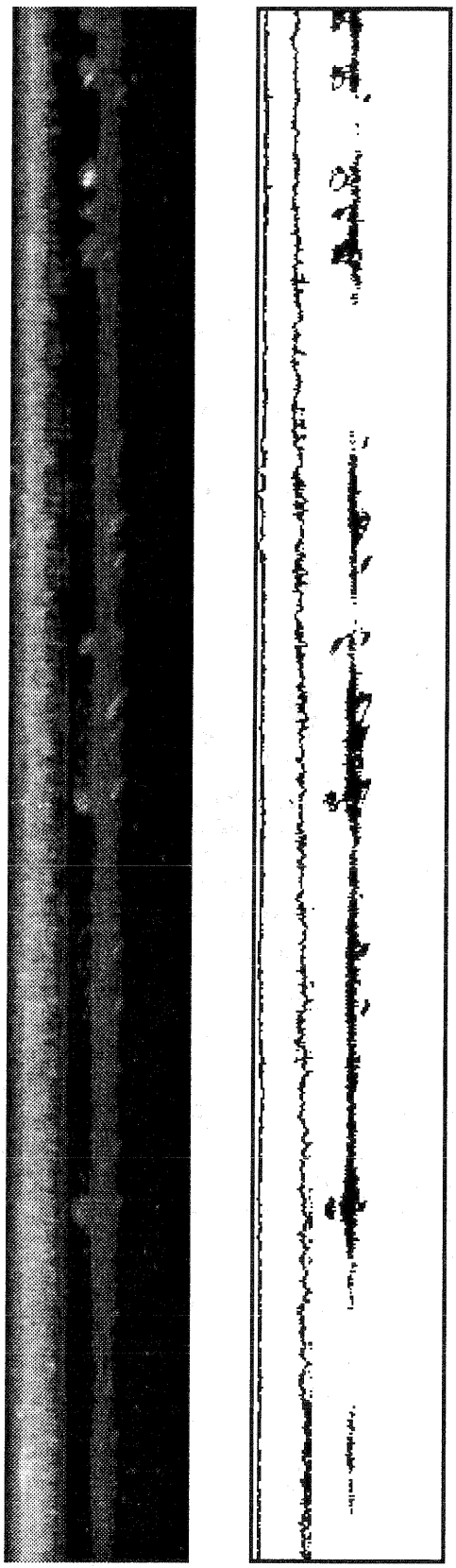
In early time of fatigue, the shape of flaw like as a fine file. So, those flaws also cause diffused reflection, in the Line Camera image data, those are recognized as bright fine bars in a black part. (Figure 5.)

Previous section pointed out, the CCD Line Sensor scans in



Original Image Processed Image

Figure 6. Recorded Image data and Processed Image Data
(Few flaw part)



Original Image Processed Image

Figure 7. Recorded Image data and Processed Image Data
(Cracky part)

fixed interval, so one pixel height of image data is just depends on traveling velocity of the Line Camera. (Table 2.)

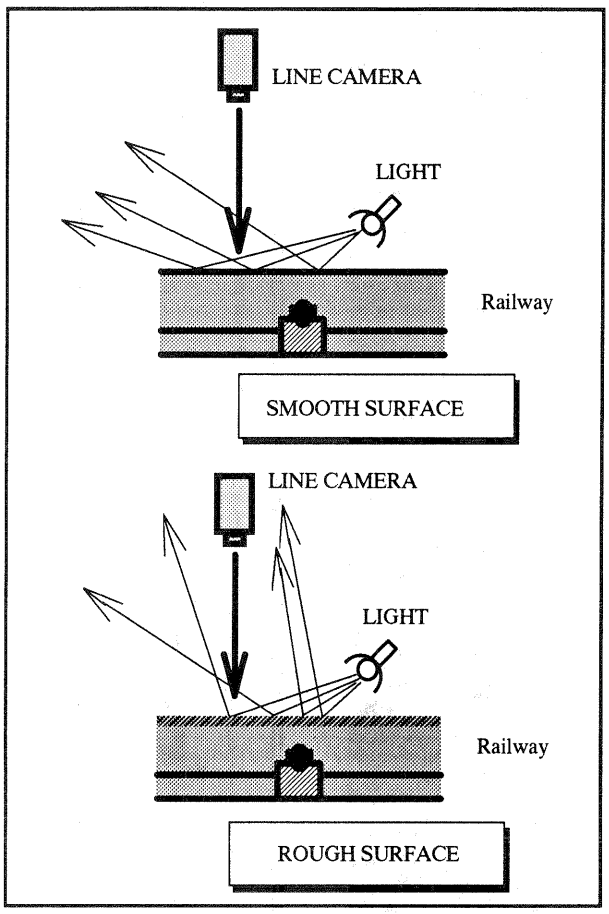


Figure 4. Illumination for taking Flaw Image

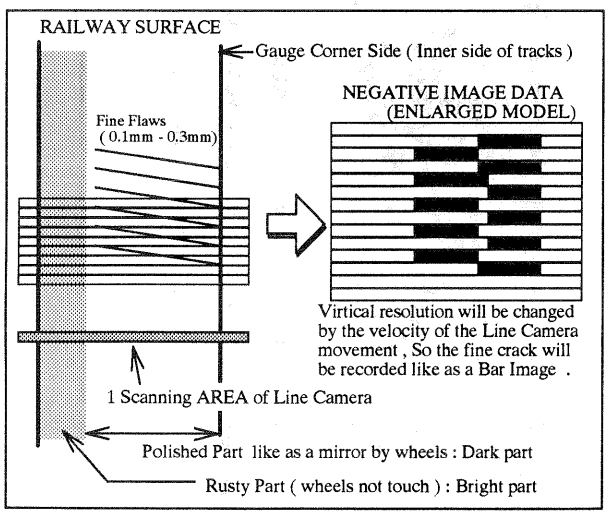


Figure 5. Flaw image mode in Recorded Image Data

When the Line Camera travels at a speed of 20 kilometers per an hour (5.55 meters per a second), a vertical resolution of each scan line is approximately 0.56 millimeters. In such situation, as almost of fine flaw width is less than 0.3 millimeters, it is impossible to distinguish each flaw from the Line Camera image data.

However, the purpose of measurement is not to count the number of flaws, but to measure the length of flaws form the gauge corner side. So, if it is possible to distinguish flaw part form polished part, it means achieved the purpose.

RESULT OF FIELD TEST

Field test had held on actual rail way track of TOHOKU Shinkansen in mid night. Figure 6. and Figure 7. are Picture of original recorded image data which had taken at field test at a speed of 20 kilometers per an hour and processed image data. It is able to distinguish between rusty part and polished part from the image of few flaw part of original data. And also possible to find flaw part in polished part from the image of cranky part of original data.

Table 3. is the other result of field test. At this case, the image data had taken with three kind of illuminate strength. This result says the illumination not in right condition is easily causes incorrect result of recognition. In right condition of illumination, result value of analysis close to read data.

Table 3. Compare with Real Value and Calculated Value
(With three kinds of Illumination)

LOCATION	Result by Computer analysis (mm)					
	Too Bright		Standard		Too Dark	
	test1	test2	test1	test2	test1	test2
14K990m (Real Flaw length : 20mm [median])						
14K 997m - 14K 998m	49	53	19	15	58	59
14K 996m - 14K 997m	0	5	12	16	57	59
14K 995m - 14K 996m	5	6	9	16	56	59
14K 994m - 14K 995m	52	33	22	16	55	59
14K 993m - 14K 994m	53	34	20	18	58	59
14K 992m - 14K 993m	51	48	19	18	59	59
14K970m (Real Flaw length : 20mm [median])						
14K 972m - 14K 973m	51	4	19	34	22	0
14K 971m - 14K 972m	6	50	17	31	21	0
14K 970m - 14K 971m	5	51	20	33	18	0
14K 969m - 14K 970m	50	51	20	32	17	0
14K 968m - 14K 969m	5	3	20	20	15	0
14K 967m - 14K 968m	9	4	13	31	14	11

Test1 : Go to Far Side Test2 : Come from Far Side
Velocity of the line camera movement : 20 km / hour
Too Bright : Too strong Illuminated
Standard : Standard Illuminated
Too Dark : Too weak Illuminated

CONCLUSION

There are confirmed,
(1) Impossible to distinguish each flaw on rail surface with the present line sensor camera system.
(2) The flaw area on rail surface is able to detect from the image data which is recorded by the line sensor camera.

The greatest problem is to shortening the processing time on the engineering work station. Still now, it takes about Five days to process the data of 60 kilometers length. (Approximately 55G bytes) But the progress of performance of computers is still going on, so it is expected that this system is possible to use in practically in the near future.

Hereafter there are some another plan with this system, that an expansion of items of track materials, for automatic inspection such as damage rail surface or another part of tracks.