# Development of a system to detect malfunction by the monitoring of the air spring pressure

Hiroshi FUKUYAMA

East Japan Railway Company

# 1. Background

## Train derailment accident

Date : September 17, 2013.
Location : Sagamiko station, Chuo Line

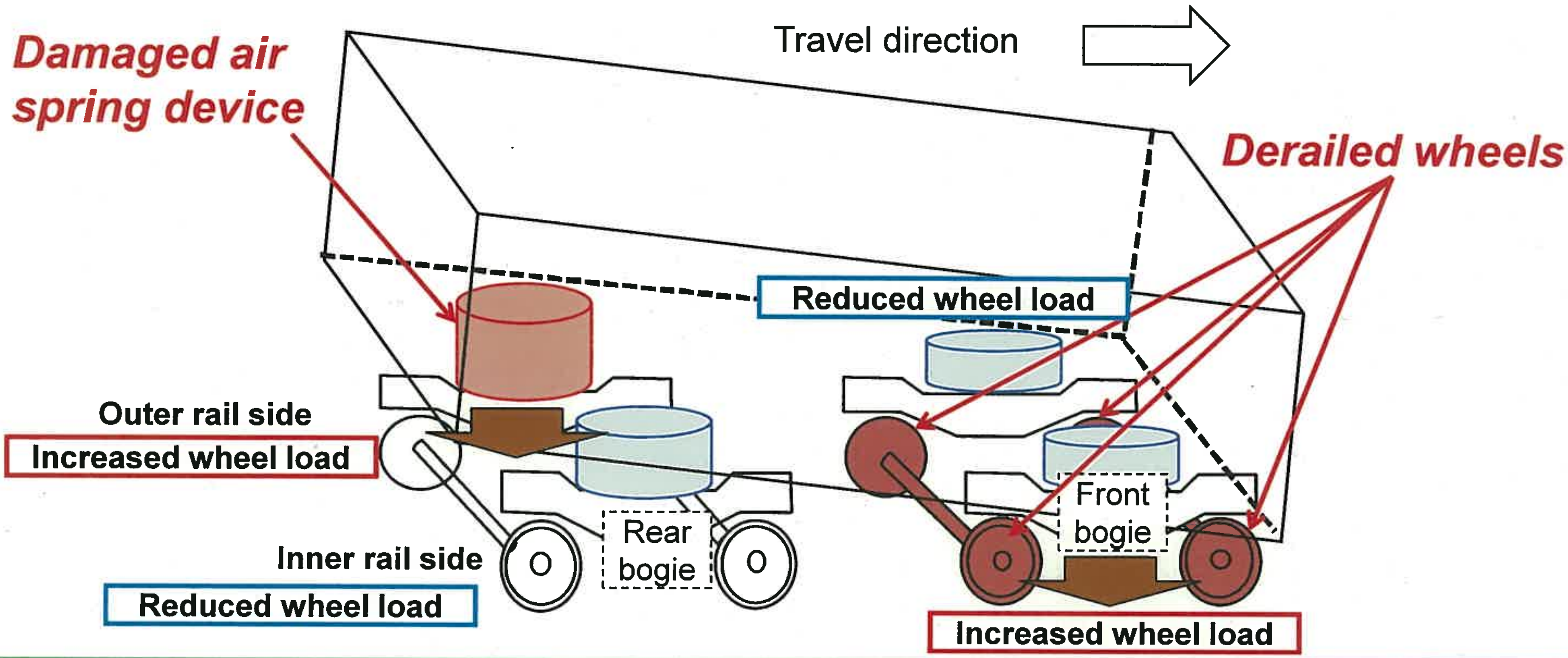
## Outline

- The train detected derailment just before stopping at the Sagamiko station.
- From checking by the crew, it was found that all the wheels of the rearmost railcar's front bogie were derailed to the left in the direction of travel.

# 1. Background

## Probable Causes

- The air spring device damaged from human impact caused a large wheel load unbalance.
- The railcar had been used with the damage gone **undetected**.
- When greater wheel load unbalance occurred on a transition curve, the wheel flange climbed on the rail, and finally derailed.

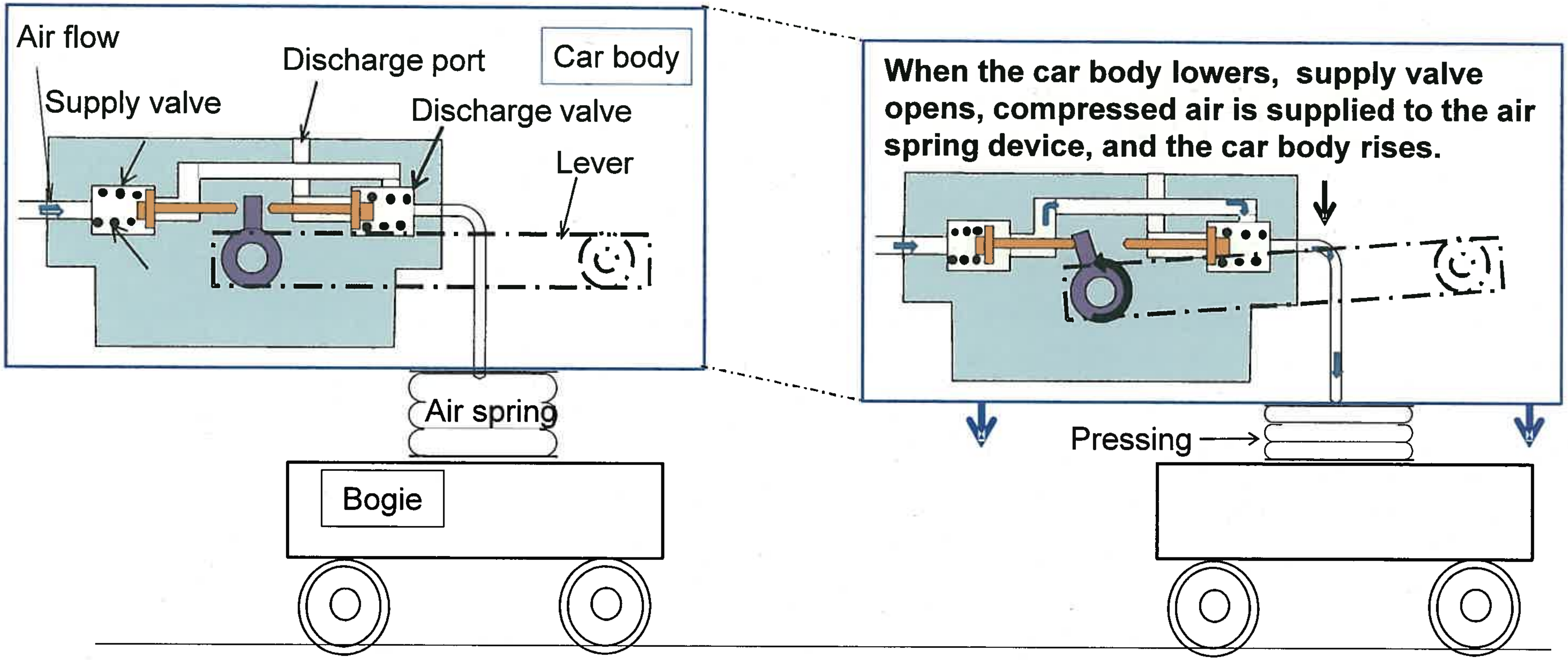


## 2. Purpose

To counter such accidents,

we need to introduce a system to **detect air spring device malfunction** in railcars.

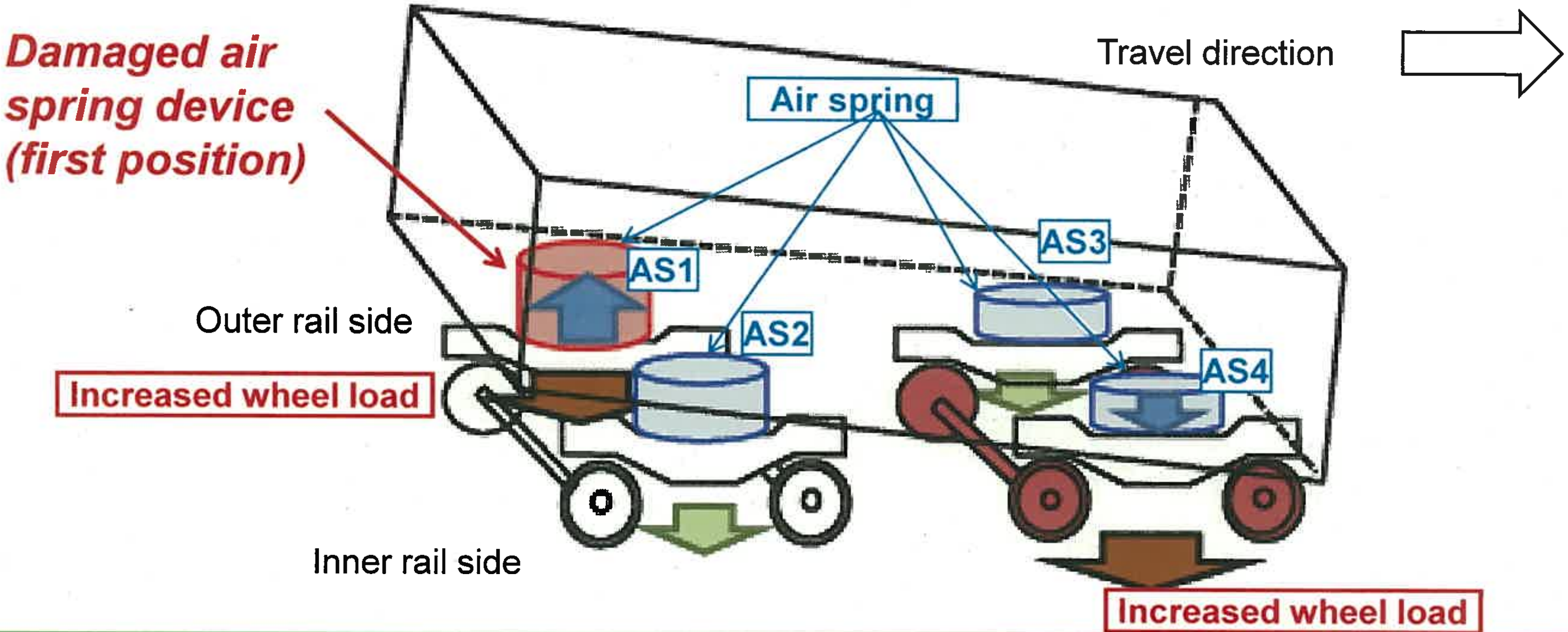
Automatic air spring device leveling



# 3. Railcar conditions at derailment

## Sequence after the air spring device was damaged

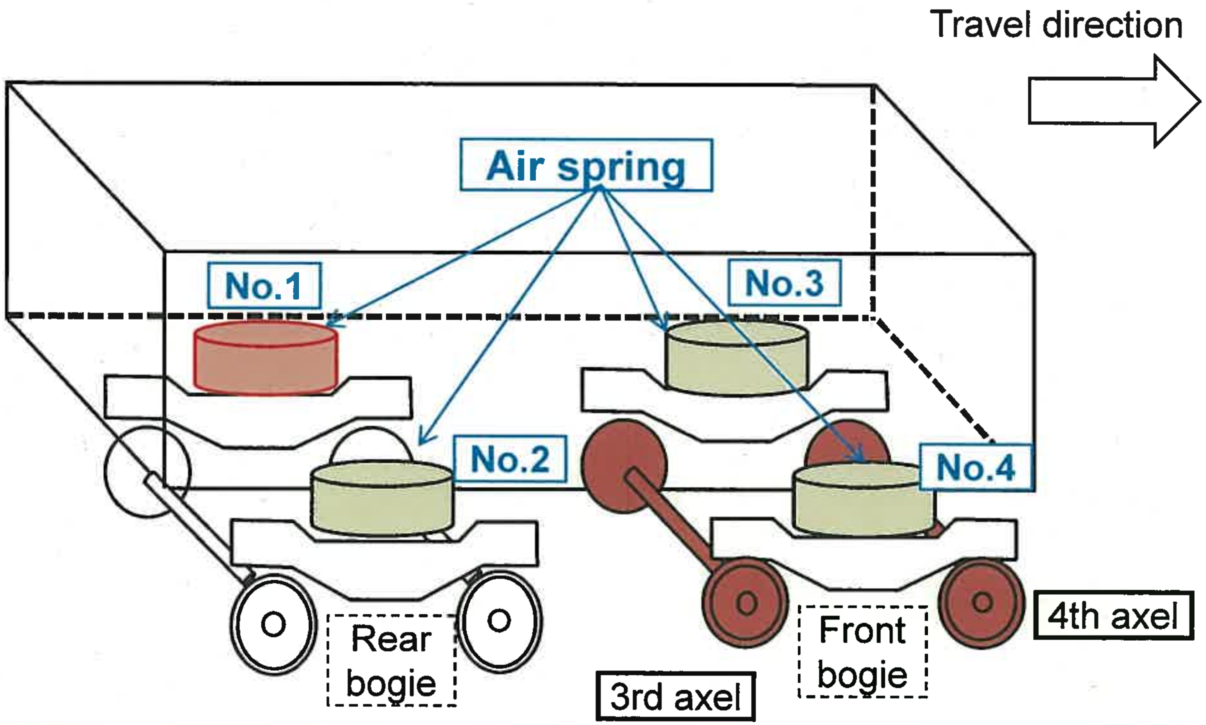
- Compressed air was supplied to the air spring on the rear bogie outer rail side (first position) even though the car body had not lowered.
- Wheel load of the outer rail side of the rear bogie and the inner rail side of the front bogie increase because the level of the air spring at first position rose notably.
- The air spring pressure at first position (AS1 in lower figure) and the inner rail side of the front bogie (AS4) rose.



# 4. Test reproducing railcar conditions

## Outline of test

- The air spring device was Installed on the railcar of the accident at the first position as it had been at the time.
- It was run at low speed along a straight section on a track in our company's General Rolling Stock Center.
- The air spring level (No.1～4), air spring pressure (No.1～4), wheel load of the front bogie (3rd and 4th axels) were measured



# 4. Test reproducing railcar conditions

JR·EAST

## Result of test

| | Rear bogie | | Front bogie | |
|---|---|---|---|---|
| | No.1 (Outer rail side) | No.2 (Inner rail side) | No.3 (Outer rail side) | No.4 (Inner rail side) |
| Level change of air spring device(mm) | 43 | 12 | 3 | −2 |
| Change rate of air spring pressure | 35.8% | −21.1% | −33.6% | 38.8% |
| Axial position | | | 3rd axel | 4th axel |
| Change rate of wheel load balance | | | 44.4% | 41.2% |

- The level of the air spring at first position had risen considerably.
- AS1 and AS4 were higher, and AS2 and AS3 were lower.
- Change rate of wheel load balance was about 40% for both the 3rd and 4th axels.

⇩

Significant **diagonal unbalance appears** in wheel load and air spring pressure, when an air spring device is damaged.

# 5. Study of method to detect air spring device malfunction

It is generally difficult to monitor wheel load.

⇩

We studied a method to detect malfunction by diagonal unbalance through monitoring of air spring pressure.

"DU" was devised as an index of diagonal unbalance.

$$\mathbf{DU} = \frac{|(AS1+AS4)-(AS2+AS3)|}{AS1+AS2+AS3+AS4} \quad \cdots \quad (1)$$

The results of calculating DU with formula (1) were as follows;

- 0.06 in normal condition, 0.24 in the accident reproducing.
- More than 0.3 in the actual accident, calculated from the recorded air spring pressure in the railcar of the accident.

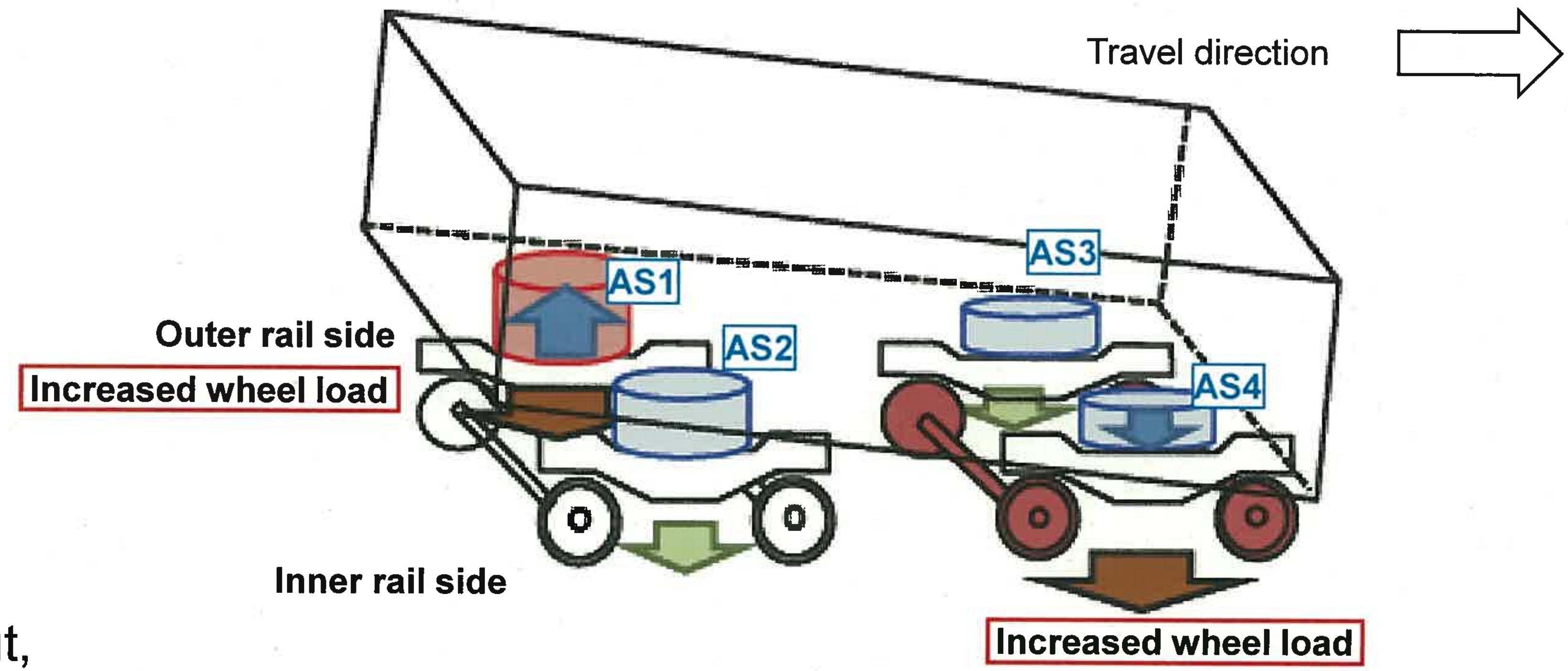
⇩

DU will continue to be more than 0.2, if an air spring device is damaged.

DU of operating trains were measured on 10 railcars of 4 different types.

# 6. Measurement results of operating trains

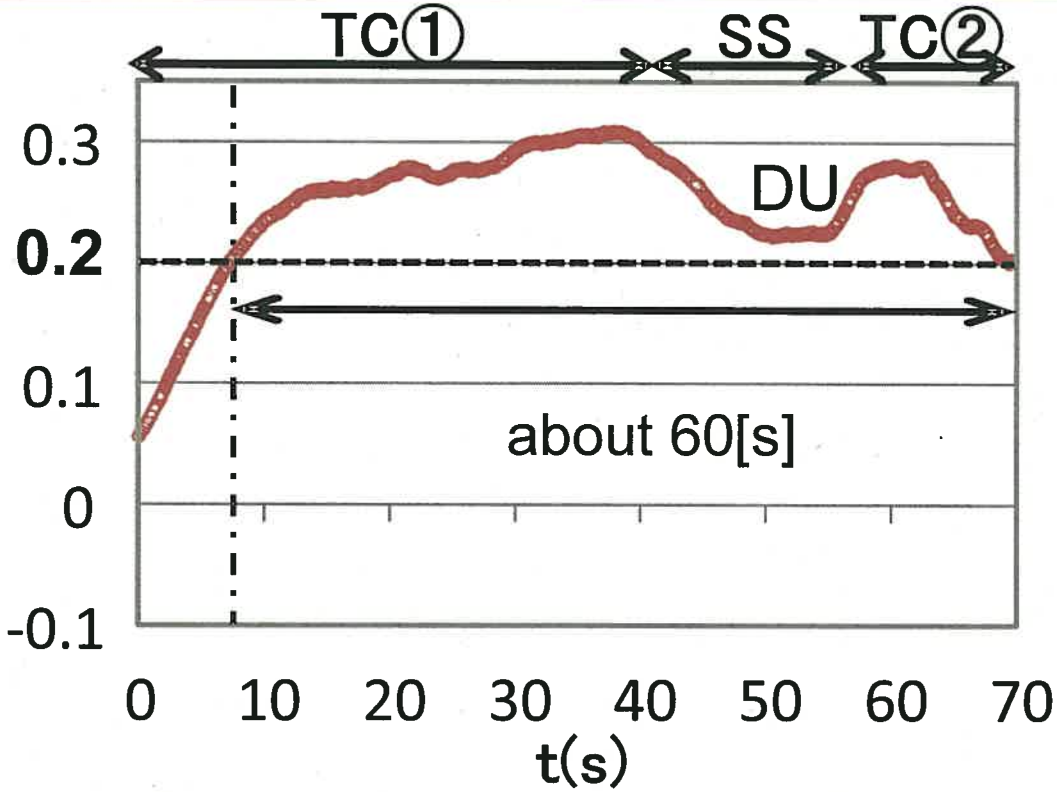
- Wheel load unbalance occurs, since car is theoretically supported at three points on transition curves.
- DU will be more than 0.2, since transition curve where the left side in the direction of travel is on the outer rail side and the cant gradually becomes smaller is the same condition as in the reproducing test.




But,

there were sections where that condition continued over long periods.

# 6. Measurement results of operating trains




**Measurement result with the longest continuation of DU> 0.2**

In this example, the train was passing over a transition curve ①(TC ①) → straight section (SS) → transition curve ②(TC ②) at low speed.

⇩

DU > 0.2 due to the transition curve may continue even after the train has passed it.

# 7. Exclusion of transition curve influence

## Method that uses the time taken to pass over the transition curve

It is necessary to exclude transition curves when judging malfunction.

But,

the tendencies in DU while the train is passing over a transition curve at low speed or stopped cannot be distinguished from when the cause is air spring device damage.

⇩

- A method that uses the time taken to pass over the transition curve (hereafter "passing time") to exclude transition curves when judging malfunction was devised.
- Train speed range divided into 3 patterns of mid-high speed, low speed, and extremely low speed was considered, since passing time varies depending on train speed.

# 7. Exclusion of transition curve influence

JR-EAST

## Exclusion through passing time for each speed range

(1) Mid-high speed range(25 km/h or over)

- Passing time in the mid-high speed range is set taking into account the longest time to pass over a transition curve at 25 km/h or over.
- Passing time is excluded when evaluating malfunction, even if DU> 0.2.

(2) Low speed range(between 5 to 25 km/h)

- Passing time within this range is set and excluded when evaluating malfunction, as in (1).

(3) Extremely low speed range(5 km/h or under)

- The extremely low speed range is excluded when evaluating malfunction.

Transition curves were excluded, according to the above criteria.

# 7. Exclusion of transition curve influence

The method that uses the passing time was applied to exclude transition curves.

But,

influence from transition curve continued over long periods when running on S-curves.

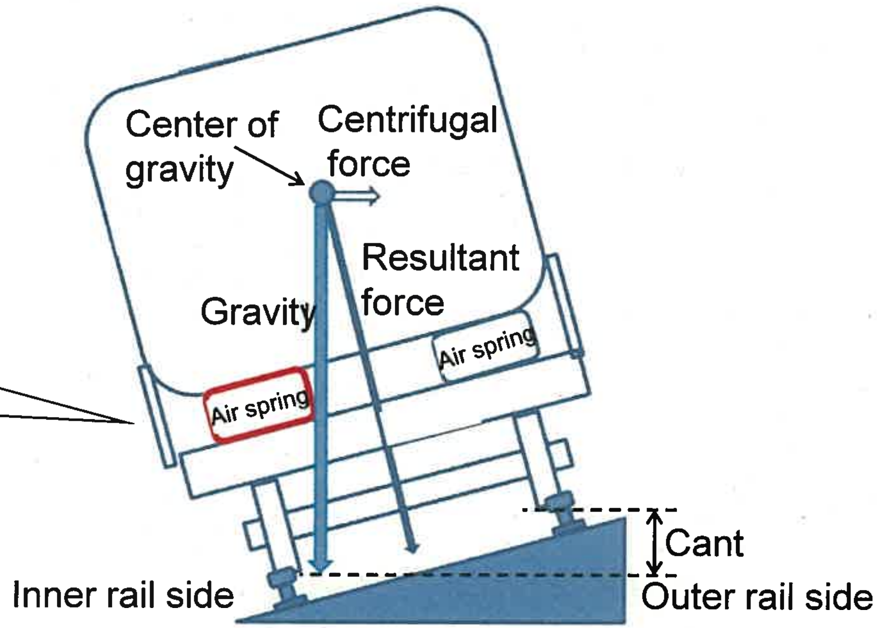
⇩

A method of excluding sections where the influence of S-curves through lateral unbalance was considered.

## Lateral unbalance

If a train is running over curves at low speed, overtilting occurs, air spring pressure will show a lateral unbalance.

Air spring pressure of the inner rail side > air spring pressure of the outer rail side



# 7. Exclusion of transition curve influence

## Exclusion through lateral unbalance

Also on a transition curve, lateral unbalance will be greater when the train runs at low speed along the inner side of a circular curve.

⇩

We studied a method of excluding lateral unbalance when evaluating malfunction.

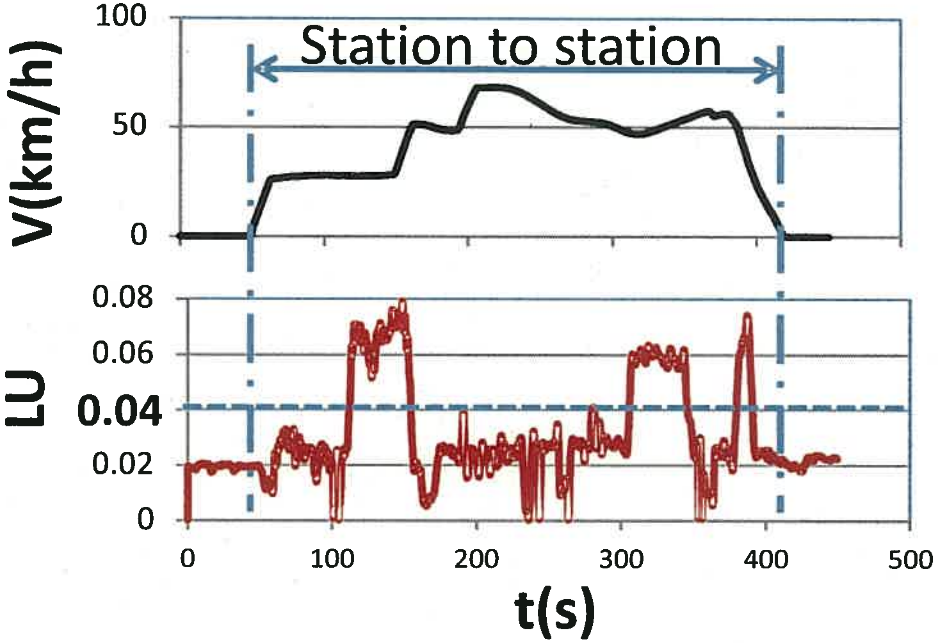
**"LU" was devised as an index of lateral unbalance.**

$$\mathbf{LU} = \frac{(AS1+AS3)-(AS2+AS4)}{AS1+AS2+AS3+AS4} \quad \cdots (2)$$

|LU| is normally 0.04 or less.

⇩

We decided to exclude sections where | LU |> 0.04 when evaluating malfunction, even if DU> 0.2.




**An example of LU measurement**

# 8. Passing time threshold

## The passing time was defined as follows;

Passing time :
The time from the moment when DU> 0.2 and | LU |> 0.04 to the moment when DU> 0.2 and | LU | ≦ 0.04

⇩

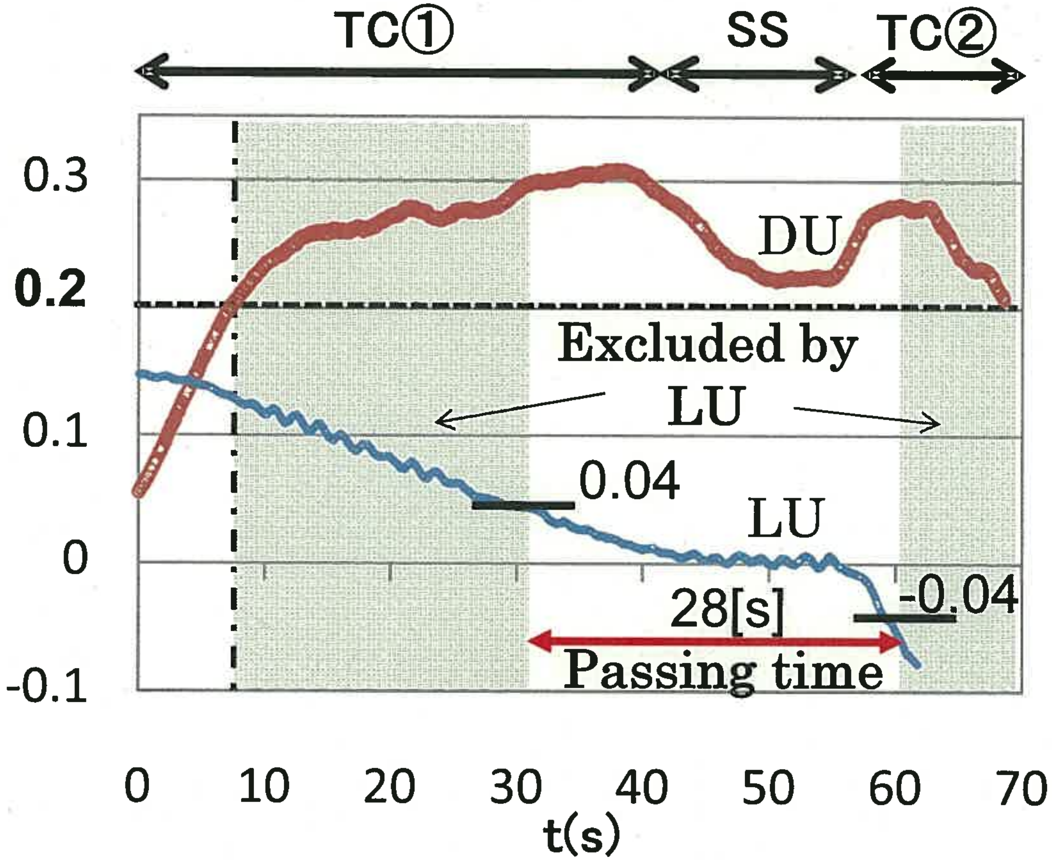
- Passing time where DU > 0.2 was the longest was 28[s].

In the other sections,

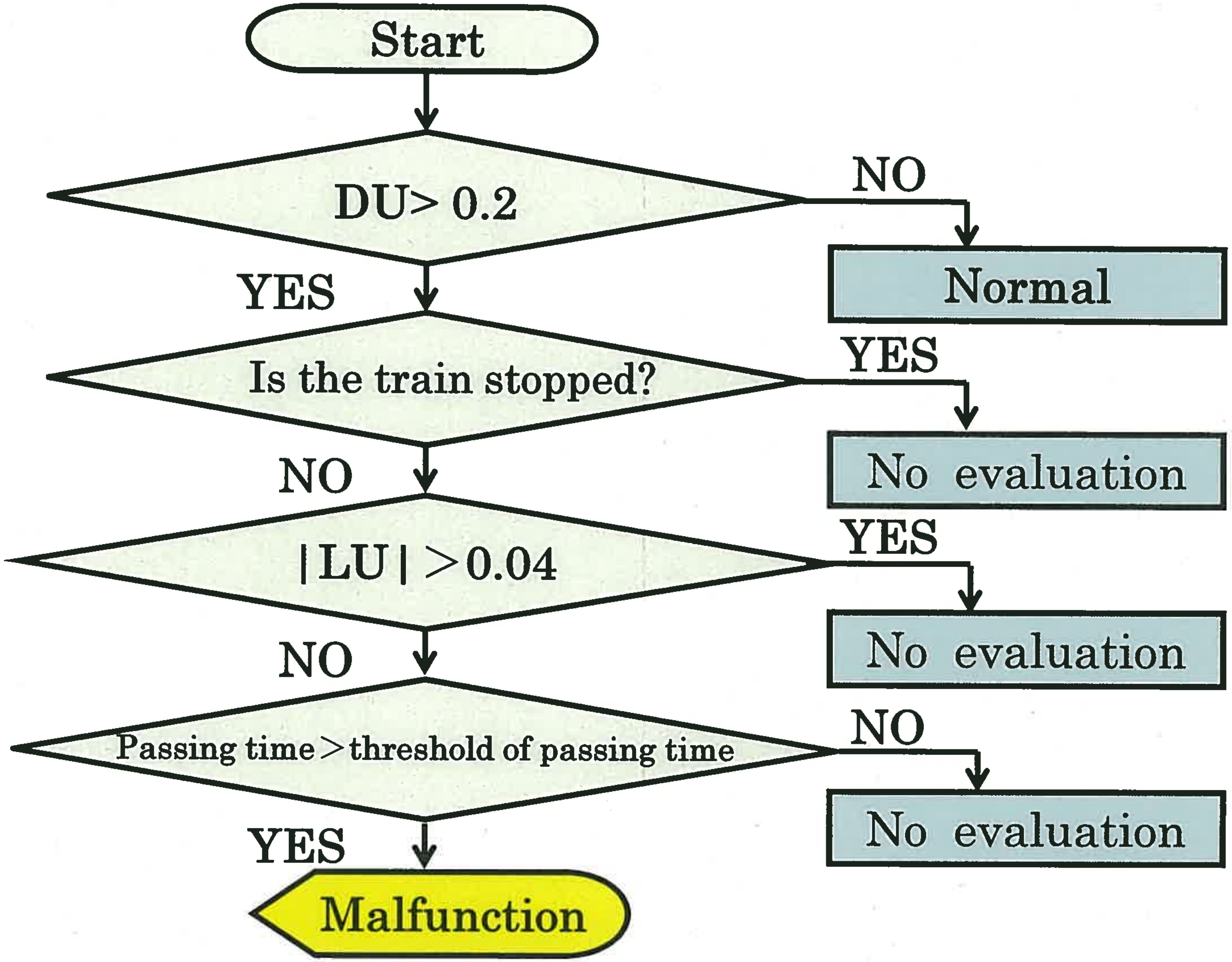
- 8[s] in the mid-high speed range.
- 16[s] in the low speed range.

⇩

The passing time threshold is determined by adding the margin time.



## 9. Algorithms for malfunction detection




**Flowchart for malfunction detection**

# 10. Conclusion

We devised a method to detect malfunction in air spring devices by diagonal unbalance of monitoring air spring pressure, and verified it based on data of various operating trains.

## Result of verification

- Malfunction of an air spring device causing large wheel load unbalance can be detected by diagonal unbalance of air spring pressure.
- On a transition curve or a section where the influence of the transition curve remains, diagonal unbalance may have the same tendency as the malfunction of the air spring device.
- We devised a method to exclude these sections from the judging malfunction by lateral unbalance and the time taken to pass over a transition curve.

⇩

Currently, this system is installed in JR East's newer models for actual introduction, and the threshold has been verified by monitoring run.


Thank you for your attention.