Progress of Safety in Japanese Railways -Accidents Investigation, Countermeasures and R&D of Safety Technologies- *

Akira MATSUMOTO **, ***

**National Safety & Environment Laboratory, NTSEL,
7-42-27 Jindaiji-higashimachi, Chofu, Tokyo, Japan

E-mail: matsumo@ntsel.go.jp

***Japan Transport Safety Board, JTSB,

Abstract

Nowadays the safety level of Japanese railways is very high, as 0.6 accidents happen per 10^6 km train-run and nearly zero on-board passengers are killed in a normal year. It is the fruits of technologies for safety and the efforts of people involved in railways. But unfortunately we had not a few serious accidents in the past. In this paper the author reports the outline of accident occurrences, countermeasures against them and safety progress in last 50 years in Japan, and explains the reorganization of the accident investigation body to newly established JTSB.

Key words: Railway, Safety Technology, Accident Investigation, Accident History

1. Introduction

Today the safety level of Japanese railways is very high, as only 0.6 accidents happen for every one million (10^6) km train-running including level crossing accidents and nearly zero on-board passengers are killed in a normal year. For example, *Shinkansen* trains have not killed any on-board passengers for 45 years since the opening, although they have transported 7 billion (10^9) passengers and they achieved 2 trillion (10^{12}) passenger-km transported volumes. It is the fruits of technologies for safety and the efforts of people involved in railways. But unfortunately we had not a few serious accidents in the past.

In this paper the author reports the outline of accident occurrences and countermeasures for the recurrence of the accidents, and overviews the progress of safety improvement in last 50 years in Japan. In final part of this paper the author explains the reorganization of the accident investigation body for aircraft, railway and marine transport, and introduces newly established JTSB; “Japan Transport Safety Board”.

2. Outline of Japanese Railways

2.1 Railway Network and Transportation

We have 27,500km-long railway network in Japan, which consists of 20,000km-long JR group lines and 7,500km-long private railway lines. For an annual result of transportation, 22.3×10^9 passengers (8.8 by JR, 13.5 by private railways) and 396×10^9 passenger-km (249 by JR, 147 by private railways) were carried in 2006. The transported volume of 400 billion passenger-km corresponds approximately to that of the railway

*Received 28 Oct., 2009 (No. R-09-0630)
[DOI: 10.1299/jmtl.3.2]

Copyright © 2010 by JSME

network in all EU countries, as shown in Fig.1. In Japan railway network transports about 30% of transported volume of passengers (Fig.2), and this value is considerably large as compared with those of other developed countries. *Shinkansen* network (2400km-long) account for about 20% of passenger transported volume (80×10^9 passenger-km) in Japanese railway network.

Fig. 1 Passenger transported volumes of railway ⁽¹⁾⁽²⁾⁽³⁾

Fig. 2 Share of passenger transportation in Japan (passenger-km; 2005) ⁽²⁾⁽³⁾

2.2 Statistics of Railway Accidents

The occurrences of railway accident have been reduced in last 50 years. Figure 3 shows the change of the occurrence rate of railway accidents after 1975. The occurrence rate had been reduced clearly before 2000, but after that it has been staying about 0.6 per one million km train-run. The occurrence rate shown in Fig.3 includes “level crossing accidents”, which are caused by automobile drivers, etc., and “human damage accidents”, where passengers on platform are hit by a train, or citizens crossing track are hit by a train. Figure 4 and Figure 5 show the percentage of accidents in 2006 classified by accident type. Figure 4 shows the classification of number of accidents and Fig.5 shows that of casualties. From these figures the occurrences of train accidents, i.e. “train derailment”, “train collision” and “train fire”, is very few, and most of casualties of railway accidents are due to “level crossing accidents” and “human damage accidents”. The number of these accidents has been decreasing gradually in recent years, but not remarkably. The introduction and popularization of “platform door” may reduce the number of “human damage accidents”.

Fig. 3 Decrease of accident occurrences (per 106 km train-run) ^{(3) (4)}

Fig. 4 Classification of railway accidents - Number of accidents ⁽⁴⁾

Fig. 5 Classification of railway accidents - Number of casualties ⁽⁴⁾

Figure 6 shows the change of casualties in railway accidents after 1975. The number of casualties is on a declining trend year after year like the number of accidents, but it increased at the year when serious accidents happened unfortunately. Figure 7 shows the expansion of Fig.6 for 1990-2007. The peak at 1991 is caused by “*Shigaraki Railway* accident” whose casualties were over 650 passengers, and the peak at 2005 is caused by “*Fukuchiyama Line* accident” whose casualties were also over 650 passengers. Except serious accidents the casualties had been reduced before 2000, and after the year stay about 700 in recent years. But most of them are those of “level crossing accidents” including automobile drivers and those of “human damage accidents”. The casualties of “train accidents” are very few, as less than 10 passengers are injured and nearly zero passengers are killed in a normal year.

Fig. 6 Casualties in railway accidents ⁽³⁾ (4)

Fig. 7 Casualties in railway accidents (1990-) ⁽³⁾ (4) (5)

3. History of Railway Accidents and Advance of Safety Technologies

Although some safety technologies have been developed for newly developed railway systems, such as ATC for *Shinkansen*, not a few technologies have been developed as countermeasures after serious accidents. Table 1 shows the list of serious railway accidents after 1960 in Japan and the countermeasures for the prevention of the reoccurrence. This table is edited by the author referring some records and information ⁽⁴⁾ (5) (6).

3.1 ATS systems

ATS (Automatic Train Stop) system, which is similar as so-called ATP in western countries, has been introduced after “*Mikawashima Accident*” (shown in Fig.8) in 1962, where red signal was violated by the driver of a freight train. As the original type of JR-type ATS system was not sufficient, it had been improved several times after several accidents caused by incorrect operation of ATS system. After “*Kansai L. Hirano Accident*” in 1973, speed-check type ATS, so-called “ATS-P” had been developed. ATS-P has been improved several times, and introduced to urban area and main lines from around 1990. But unfortunately serious accidents happened at *Tosa-Kuroshio Railway* and *Fukuchiyama L.* of JR West in 2005, where ATS-P had not been equipped. The “*Tosa-Kuroshio Accident*” was caused by over-speed approaching to end-terminal, and the “*Fukuchiyama L. Accident*” was

caused by over-speed running through a sharp curve. The Ministry urgently revised the regulation, to attach ATS-P on such places.

Table 1 Typical accidents and countermeasures for progress of safety in Japanese railways

<i>Accident name (accident type)</i>	<i>Railway</i>	<i>Year</i>	<i>Casualties (died +injured)</i>	<i>Main causes</i>	<i>Countermeasures</i>
Mikawashima (3 trains derailed & crashed) -Fig.8-	JNR	1962	162 +296	+Red signal violated +Train protection missed	+R&D of ATS (early stage of Japanese ATP) +R&D of train radio
Turumi (2 trains derailed & crashed) -Fig.9-	JNR	1963	161 +120	+Multiple-factor derailment	+R of derailment mechanism +New wheel tread, new suspension of freight wagon
Subway Hibiya L. (Train fire)	Tokyo subway (Eidan)	1968		+Rheostatic controller heated +Insufficient flame resistance	+New regulation for flame resistance structure for subway
Fuji-kyuko (Train derailed)	Private; Fuji-kyuko	1971	17+69	+All Brake system failed	+Independent backup brake system (security brake) obliged
Hokuriku tunnel 'Kitaguni' (Train fire)	JNR	1972	30 +714	+Fire from a kitchen car to sleeping cars in long tunnel	+Flame resistance structure for trains running through long tunnel > most of newly built cars
Kansai L. Hirano (Train derailed)	JNR	1973	3 +149	+Over-speed at crossover turnout	+R&D of ATS-P (speed check type ATP)
Shigaraki Rwy (Train head-on crash) -Fig.10-	PFI; Shigaraki Rwy (through -service train from JR West)	1991	42 +614	+Incorrect procedure in substitute block system on single track +Incorrect design and maintenance of signal system	+Exchange of information of design and management between different railway companies
Hanshin-Awaji Earthquake	JR, Private Rwy, Subway, AGT	1995		+Collapse of railway bridges etc. including Shinkansen & subway tunnel +Derailment of trains	+R&D of earthquake-proof technologies +Reinforcement of railway infrastructure
Subway Hibiya L. Nakameguro (Train derailed and crashed) -Fig.11-	Tokyo Subway (Eidan)	2000	5+64	+Multiple-factor derailment on sharp curve; unbalanced wheel loads, twisted transient curve, high μ of W/R	+R&D of sharp curving +High accuracy wheel load balance, Guard rails, W/R friction modifier, Q/P monitoring system
Jo-etsu Shinkansen earthquake (Train derailed)	JR East	2004	0+0	+Heavy earth quake +Rocking derailment (earthquake-proof of bridges were effective)	+R&D of earthquake-proof technologies +Anti-deviation guards, Earthquake detection systems
Tosa-Kuroshio Rwy (Train derailed)	PFI; Tosa-kuroshio	2005	1+9	+Over-run at end terminal (ATS is not effective)	+ATS-P obliged at end terminal
Fukuchiyama L. (Train derailed)	JR West	2005	107 +562	+Over-speed at curve	+ATS-P obliged at sharp curve +On-board data recorder obliged +R&D of car body structure
Uetsu L. (Train derailed)	JR East	2005	5+32	+Overturned by sudden heavy wind (tornado or down-burst)	+R&D of meteorological observation & forecast of blast
ICE Eschede (Train derailed)	DB	1998	101 +200	+Resilient wheel was broken by metal fatigue	
Hatfield (Train derailed)	UK	2000	4+70	+Rails were broken into many pieces by metal fatigue	

Fig. 8 Mikawashima accident -1962-

Turning point of R&D of train running safety

Fig. 9 Tsurumi accident -1963-

FEATURE OF ACCIDENT

- +Train head-on crash in a single track line**
“a through-service train from JR-W” vs. “a local train”
- +Failure in signaling system**

CAUSES

- +Incorrect procedure in substitute signal block**
- +Train radio not worked on through-service train**
- +Incorrect design and maintenance of signal system between two railway companies**

Fig. 10 Shigaraki railway accident -1991-

In private lines the Ministry directed to set up speed-check / full automatic type ATS in 1967, after successive accidents in private railways at that time. This direction was effective, and no serious accidents caused by signal violation happened in private railways ever since. But there have been some trends that the existing systems will be improved to higher functional systems after the “*Fukuchiyama L. Accident*”

3.2 ATC systems

Originally ATC (Automatic Train Control) system has been developed for *Tokaido Shinkansen* opened in 1964. ATC system controls train speed automatically except station stop control. After the opening the ATC system of *Shinkansen* has been improved after the accident/incident in 1973/1974, and has achieved the record of no passenger death up to now. Today the digital type ATCs are used in *Shinkansen* lines.

On the other hand ATC has been developed in urban subway lines and AGT lines. Some of them have been operated automatically by ATO system (Automatic Train Operation: full automatic control system including station stop). ATC system is safe enough to achieve no accidents except “*Osaka Newtram accident*” in 1993 up to now. Today some private railway companies plan to introduce ATC system in conventional lines.

3.3 Flame resistance structure

The flame resistance structure of Japanese railway vehicles is the top level around the world. After the accident on Tokyo subway *Hibiya L.* in 1968, the Ministry directed to apply severe flame resistance standard “A-A” for subway vehicles. And after the train fire accident in *Hokuriku* tunnel in 1972, which was the longest tunnel (13.87km long) in Japan at that time, the coverage has been expanded. No serious fire accidents happened in Japan ever since.

3.4 Vehicle running system

“*Tsurumi accident*” in 1963 (shown in Fig.9), which was caused by the multiple-factor derailment of a 2-axle freight car, is the turning point of the research activities on vehicle running safety in Japan. After the accident, Japan National Railway (JNR) had carried out experiments of derailment phenomena on *Karikachi* test track in *Hokkaido*, and developed new tread profile of wheels.

In 2000 “Subway *Hibiya L.* derailment accident” (shown in Fig.11) occurred on sharp curve near *Nakamegro* station of Tokyo Metro. It was caused by multiple factors, such as ‘unbalanced wheel loads’, ‘twisted transient curve structure’, ‘high friction between wheel and rail’ and so on. After the accident countermeasures to prevent ‘the derailment at low speed on sharp curve’ had been studied by the investigation committee of the Ministry. The management of wheel-load balance, the guideline of guard rail setting, higher flange angle, such as 70 deg, and so on, have been introduced as the countermeasures. New technologies, such as friction modifier, derailment coefficient monitoring and air suspension balance control shown in Fig.12, have been studied from that time.

Other new technology of vehicles, such as new bogie structure, active suspension, VVVF drive for propulsion, etc. may help indirectly the decrease of accidents.

3.5 Track system and maintenance technologies

New track structure, such as concrete sleeper, slab track, new turnout structure, and new maintenance technologies, such as track inspection car, may help indirectly the decrease of accidents.

3.6 New technologies against earthquakes and abnormal weather

A train of “*Jo-etsu Shinkansen*” was derailed caused by an earthquake in 2004, and in

2005 a train of "Uetsu L." was derailed by sudden wind, which is suspected to be a tornado. In addition next year another train was derailed by a tornado in *Kyushu*. Technologies for the prevention of such accidents caused by earthquakes and abnormal weather become more important for the safety of Japanese Railways. Anti-derailment/deviation device against the shake of earthquakes and new forecast technologies of tornados have been studied as well as existing technologies, as shown in Fig.13.

Fig. 11 *Subway Hibiya L. accident -2000-*

Continuous monitoring of derailment coef. ⁽⁹⁾

Fig. 12 New technologies of safety on sharp curves

Fig. 13 Accidents by earthquakes and abnormal weather

4. Accidents Investigation Organization

4.1 Aircraft and Railway Accidents Investigation Commission (ARAIC)

“Aircraft Accidents Investigation Commission (AAIC)”, the first permanent organization for transport accidents investigation in Japan, was established in 1974. At that time the public permanent organization had been required after many serious aircraft accidents in Japan, such as “ANA and CP near *Haneda airport*”, “BOAC near *Mt. Fuji*”, and “ANA near *Matsuyama airport*” in 1966, “ANA near *Shizukuishi*” and “TDA near *Hakodate airport*” in 1971. After 27 years activities the AAIC was reorganized to “Aircraft and Railway Accidents Investigation Commission (ARAIC)” in 2001.

Before the establishment of the ARAIC, there was no permanent organization for railway accidents investigation in Japan. As shown in Table 1, “*Shigaraki Railway Accident*” happened in 1991, and “*Tokyo Subway Hibiya L. Accident*” happened in 2000. For “*Shigaraki Accident*”, the cause of the accident was investigated mainly by police, where the author was engaged in for a specialist for judgment, and for “*Hibiya L. Accident*” the cause was investigated by both of the Metropolitan Police Department and the Ministry of Transport, and the author was engaged in the investigation of both groups. Before that accident, in 1999 the Ministry established a semi-formal investigation committee of railway. Although the “*Hibiya L. Accident*” was the first experience, the committee successfully concluded the causes. This committee acted as a pilot to the establishment of the ARAIC.

Fig. 14 History of “accidents investigation organization” in Japan ⁽⁷⁾

4.2 Japan Transport Safety Board (JTSB) ⁽⁷⁾

In 2008 the ARAIC was reorganized to “Japan Transport Safety Board (JTSB)”, which investigates marine accidents as well as aircraft and railway. This reorganization stands on the principle of the IMO, or International Marine Organization, that the disciplinary action and cause investigation should be separated.

The objective of the JTSB is to prevent recurrences and to mitigate damages caused by accidents. The JTSB conducts investigations to determine the causes of aircraft, marine and railway accidents, serious incidents and damage caused by the accidents. “Serious incidents” mean situations deemed to bear the risk of accidents occurring. The causes of

accidents/incidents are investigated through objective/scientific processes. Based on the findings of the investigations, the JTSB provides recommendations or opinions to relevant ministers or parties involved, concerning the measures to be taken to prevent accidents/incidents and to mitigate damage caused by accidents. The JTSB conducts research and studies, in order to fulfill the above mentioned duties. The JTSB consists of chairperson, 12 board members and secretariat. Aircraft, railway and marine accident investigators belong to secretariat.

Railway accidents and incidents are investigated usually by railway subcommittee and railway accident investigators. The objects of investigation are “train derailment accident”, “train collision accident”, “train fire accident”, “accidents with 5 or more casualties”, “accidents with passenger death”, “accidents with peculiar characteristics” and “serious incidents”. The number of accidents/incidents investigated is around 20 in normal year. Investigation reports will be opened at the end of every month, but only Japanese version is released for railway accidents now.

5. Conclusion

The numbers of railway accidents have been reduced due to the effects of safety technologies and the efforts of people involved in railway, but it may be staying at same level in recent years. In order to reduce the number of accidents, the expansion of new safety technology, such as “platform door” for prevention of “human damage accidents”, is expected. In addition the appropriate response should be more desired to the results of accidents investigation.

The author thinks that the last safety problems for Japanese railways are “level crossing accidents”, “human damages accidents” and “accidents caused by natural disaster”, such as earthquake and extraordinary weather. If we overcome these problems, serious accidents should be cleared from Japanese railways.

References

- (1) Railway statistics, (2008.7.1), web of UIC
- (2) Railway statistics, web of Ministry of Land, Infrastructure and Transport, Japan, <http://toukei.mlit.go.jp/60/monthly/index.html>
- (3) "Suuji de miru tetsudou 2008 (Railway statistics handbook 2008)", Institution for transport policy studies (2008) (in Japanese)
- (4) Information on safety of railway and tramway transportation (FY2007), Railway bureau, Ministry of Land, Infrastructure and Transport, Japan (2008.10) (in Japanese)
- (5) Records of railway serious accident; reprinted edition, Japan train operation association (2008) (in Japanese)
- (6) ATS-ATC, Railway electrical engineering association of Japan (1996) (in Japanese)
- (7) Web of JTSB, <http://www.mlit.go.jp/jtsb/english.html>
- (8) Suda Y., Iwasa T., Komine M., Tomeoka M., Nakazawa H., Matsumoto K., Nakai T., Tanimoto M., Kishimoto Y., Development of onboard friction control, *Wear*, Vol.258 (2005), pp1109-1114
- (9) Matsumoto A., Sato Ya., Ohno H., Tomeoka M., Matsumoto K., Kurihara J., Ogino T., Tanimoto M., Kishimoto Y., Sato Yo., Nakai T., A new measuring method of wheel-rail contact forces and related considerations, *Wear*, Vol.265 (2008), pp1518-1525