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Investigations of lightning accidents on automobiles

Shunichi Yanagawa[a], Kazuo Yamamoto[b,*], Yuta Naito[a], Naoto Takahashi[c], Michihiro Matsui[d]

[a] SHODEN Co., Ltd, Chiba, Japan
[b] Chubu University, Electrical Engineering, Kasugai, Aichi, Japan
[c] Nissan Motor Co., Ltd, Yokohama, Kanagawa, Japan
[d] Franklin Japan Co., Ltd, Tokyo, Japan

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ABSTRACT

Many kinds of electronic equipment have been used in recent automobiles. Eco-friendly automobiles such as electric, fuel-cell and hybrid vehicles have spread rapidly. Those automobiles are usually sensitive to electromagnetic disturbance caused by lightning and so on. When an automobile is struck by lightning, lightning current usually flows into the earth through the vehicle body. The corresponding transient electromagnetic fields appearing inside the vehicle and shunt lightning current through electronics systems are considered sources of malfunctions. From an automobile safety and equipment protection viewpoints, investigations of protective measures are imperative. Before lightning protection methodologies are proposed, existing lightning damages to automobiles must be clarified. The statistical data on automobile lightning damage reports by conducting field surveys and web-based researches had been gathered. In this paper, the result of statistical data has been introduced. Right in the middle of the field surveys of lightning protection for automobiles, the outstanding fire accident of an automobile in Kanto district in Japan occurred. Right after hearing the news, interviews against the fire fighters about their field survey had been conducted; the scene of the accident and burned automobile had also been investigated. In this paper, the results of the interview and investigation have also been discussed.

1. Introduction

In recent years, as control technologies for automobiles have become more sophisticated, automobiles have utilized increasing numbers of electronic parts. In addition, the electrical drive to reduce CO_2 emissions has popularized as low environmental load vehicles, such as electric, hybrid and fuel-cell vehicles [1,2]. Such vehicles are at especially high risk of malfunctioning when exposed to electromagnetic disturbance caused by a lightning strike [3–9].

When an automobile is struck by lightning, lightning current usually flows into the earth through the vehicle body. The corresponding transient electromagnetic fields appearing inside the vehicle and shunt lightning current through electronics systems are considered sources of malfunctions. Compared to gasoline-powered automobiles, electric, hybrid and fuel-cell vehicles utilize more electronic control parts as mentioned at the previous paragraph. Although such lightning damage is expected, lightning protection methodologies for automobiles have not been developed due to lack of theoretical and experimental knowledge. Reasonable lightning protection countermeasures have not been undertaken in this situation. From an automobile safety and equipment protection viewpoints, investigation of protective measures is imperative.

Until now, the faults caused by electromagnetic fields have only been researched and introduced in the previous papers of Refs. [3–8]. In fact, the shunt lightning current through electronics systems in an automobile may also cause faults directly. Therefore, based on the field surveys of actual faults on automobiles, the occurrence mechanisms of faults need to be clarified.

In the present situation, statistical data on lightning accidents or malfunctions of automobiles has rarely been reported. Even if the malfunctioning vehicle is repaired, the damage reports have not been archived to our knowledge. Therefore, the statistical data on automobile lightning damage reports by conducting field surveys and web-based researches have been gathered. In this paper, the result of statistical data has been introduced.

Right in the middle of our field surveys and web-based researches of automobile lightning accidents, the outstanding fire

* Corresponding author. Tel.: +81 568 51 9969; fax: +81 568 51 9969.
E-mail addresses: yanagawa@sdn.co.jp (S. Yanagawa), kyamamoto@mem.iee.or.jp (K. Yamamoto), naitoyu@sdn.co.jp (Y. Naito), ti123anarita@vega.ocn.ne.jp (N. Takahashi), matsui@fjc.co.jp (M. Matsui).

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Table 1
Trends of lightning attachment points.

Attachment point	Number	Ratio [%]
Antenna	28	15.6
Roof	19	10.6
Front bonnet	12	6.7
Windshield	12	6.7
Nearby lightning	7	3.9
Rear glass	6	3.4
Side of vehicle body	4	2.2
Rear bonnet	3	1.7
Side window	2	1.1
Tire	1	0.6
Unknown	85	47.5
		Total no. 179

Table 2
Trends of damages due to lightning.

Kinds of damage	Number	Ratio [%]
Failure of electrical and electric equipment	41	15.4
Drive breakdown (impossible to drive)	29	10.9
Damage of an antenna	27	10.1
Discharge marks	25	9.4
Fire	25	9.4
Blowout	22	8.2
Damage of a rear window	10	3.7
Malfunction of air bags	10	3.7
Damage of wires	8	3.0
Damage of lighting equipment	8	3.0
Damage of a windshield	8	3.0
Damage of an instrument panel	7	2.6
Damage of side mirrors	6	2.2
Other	41	15.4

accident of an automobile in Kanto district in Japan occurred. Right after hearing the news, the interviews against the fire fighters about their field survey have been conducted; the scene of the accident and burned automobile have also been investigated. In this paper, the results of the interviews and investigations have also been discussed.

2. Statistical data of lightning accidents

The web-pages describing clear lightning accidents on automobiles and the field surveys of lightning accidents have been investigated by both experts in the fields of the lightning protection and the automobile structure. All data are discussed from both viewpoints. The most reliable dataset obtainable comprised 173 cases of lightning damages. Reliability was assessed from our previous experience based on photographs, animations and descriptive documents related to lightning damage in case of web-based researches. In the case of field surveys, the reliability was assessed from our previous experience based on photographs, descriptive documents and interviews conducted by ourselves. When lightning attachment point and damage conditions could not be extracted from documents, photographs and animations, the case was categorized as “unknown”.

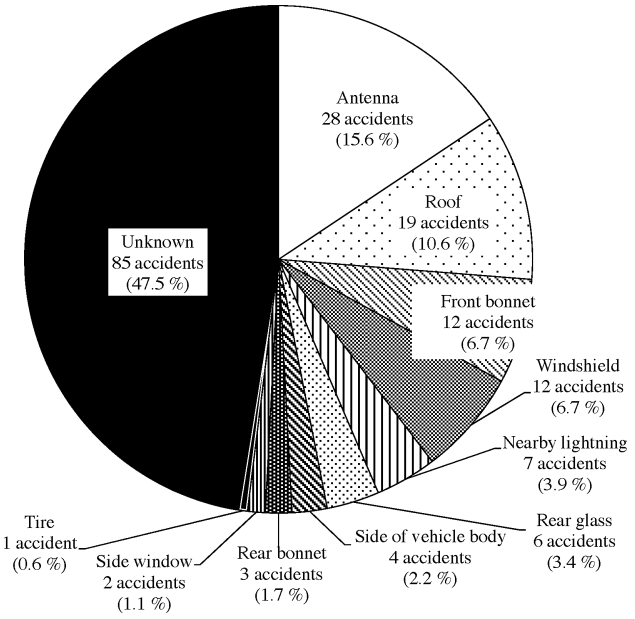

Fig. 1. Trends of lightning attachment points.

2.1. Trends of lightning attachment points

Trends of lightning attachment points are shown in Table 1 and Fig. 1. In 88 cases out of 173 (50.9%) of lightning accidents, the lightning attachment point was identified. Antenna was the most likely lightning target, followed by roof, front bonnet and windshield. Damages to the upper body such as the antenna, roof, front bonnet and windshield are easily understood because lightning stroke to them is very probably. Especially, the antenna is often attached to the highest point of the vehicle; thus, the possibility of lightning stroke to the antenna is higher than at other surrounding parts. The height of antenna affixed to modern vehicles often approximates the roof height. The relationship between antenna height and lightning attachment point is a future consideration. Incidentally, the data of Table 1 and Fig. 1 sum to 179, the number is larger than that of the reported accidents (173). This anomaly arises from a single of triple-strike and four times of double-strike lightning accidents involved.

2.2. Aspect of lightning damages

Table 2 and Fig. 2 categorizes the different types of automobile damages caused by lightning strokes. The specific damage could be identified in 95 cases out of 173 (56.1%). In Table 2 and Fig. 2, “Drive breakdown” category implies that the vehicle could not drive due to engine failure or similar; “Failure of a battery” category implies that driving capability was restored by the battery replacement during vehicle repair. The sum of the damaged cases in Fig. 2 is 267, the

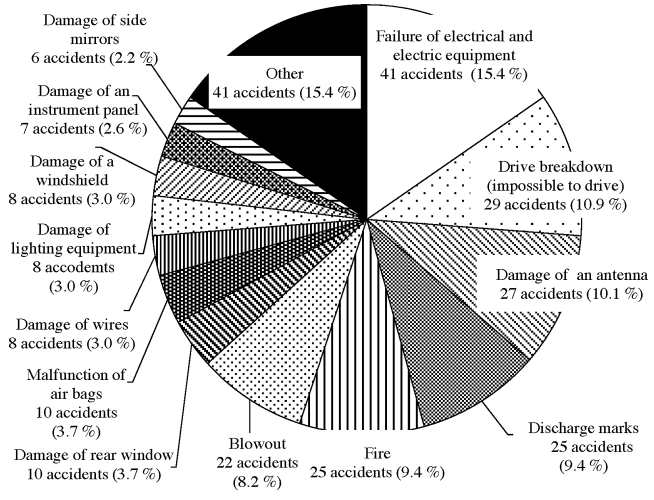

Fig. 2. Trends of damages due to lightning.