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NIMS NOW INTERNATIONAL

NATIONAL INSTITUTE FOR MATERIALS SCIENCE

No. 5

Accident Investigation File

Why did it break?

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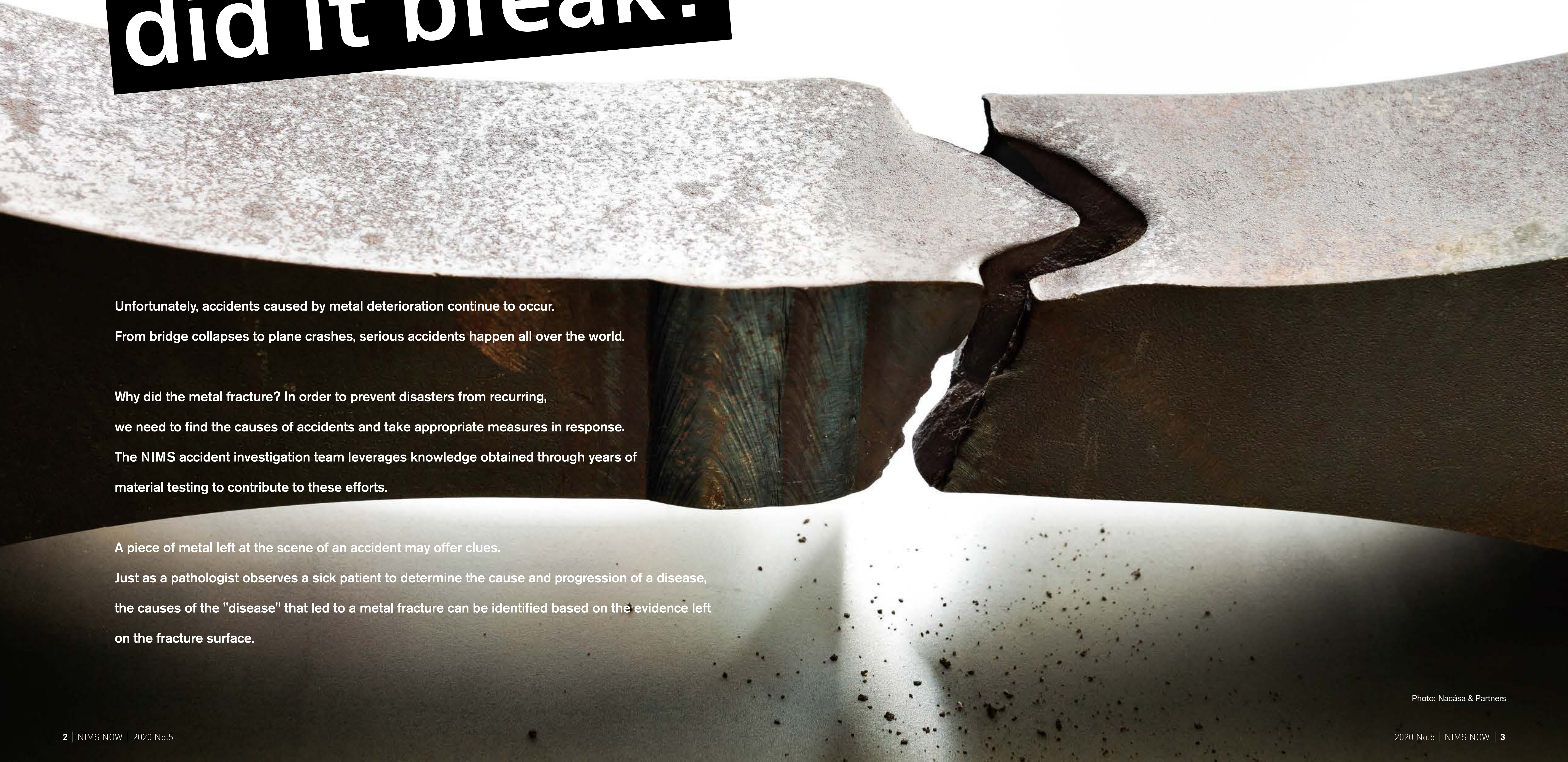


Unfortunately, accidents caused by metal deterioration continue to occur.
From bridge collapses to plane crashes, serious accidents happen all over the world.

Why did the metal fracture? In order to prevent disasters from recurring,
we need to find the causes of accidents and take appropriate measures in response.
The NIMS accident investigation team leverages knowledge obtained through years of
material testing to contribute to these efforts.

A piece of metal left at the scene of an accident may offer clues.
Just as a pathologist observes a sick patient to determine the cause and progression of a disease,
the causes of the "disease" that led to a metal fracture can be identified based on the evidence left
on the fracture surface.

Photo: Nacása & Partners

The Fracture Surface Speaks.

50 years of NIMS accident investigations

感謝状

国立研究開発法人 物質・材料研究機構
理事長 橋本和仁殿

貴機構は 当委員会のジェットフォイル事故調査において安全装置の破面観察のほか 破面の化学分析に尽力され その豊富な経験と優秀な技術を以て当該安全装置の健全性を検証されるなど同種事故再発防止のための分析に大いに寄与されました 貴機構の功績を称え深く感謝の意を表します

令和二年七月吉日
運輸安全委員会
委員長 武田展雄

A letter of gratitude from the Japan Transport Safety Board (June 2020)

Japan Airlines crash and Sodium leak at the Monju fast breeder reactor

NIMS has a long history of accident investigations. NIMS and its predecessor institution, the National Research Institute for Metals (NRIM), have contributed to finding the causes of over 70 accidents over 50 years.

One "disease" that afflicts metal is metal fatigue, a phenomenon in which a metal weakens due to cracking caused by the repeated application of even minor forces. Most accidents resulting from the deterioration of metals are said to be attributable to metal fatigue. Rust-related corrosion is also an enemy of metals. A variety of public organizations have requested that NIMS conduct investigations when metal fatigue and/or corrosion are believed to be responsible for an accident, including the police, the Japan Transport Safety Board and courts.

The August 1985 Japan Airlines jumbo jet crash was unprecedented in scale: 520 passengers and crew members lost their lives. The component suspected to have triggered the crash was the metal pressure bulkhead located in the rear part of the plane's fuselage. An accident investigation team from NRIM (now NIMS) was given the task of finding the cause. The team carefully inspected the pressure bulkhead, which had miraculously been recovered from the scene of the accident, and concluded that a fatigue failure occurred in this component. The investigation revealed the direct cause of the accident: an error made when the pressure bulkhead was repaired seven years before the crash.

A sodium leak at the Monju fast breeder reactor in December 1995 was another serious accident caused by fatigue failure. An NRIM accident investigation team took charge of the investigation. A metal housing used to protect a thermometer when inserted into a pipe broke from its base, causing a large amount of liquid sodium to leak; an extremely dangerous situation that could have led to a fire. The investigation team analyzed the housing's fracture surface with an electron microscope and found that its base had been subjected to a larger than expected load due to a inappropriate design. This caused metal fatigue to develop rapidly, leading to the fracture.

In addition to these cases, NIMS has led investigations into the causes of accidents involving aircraft, automobiles and ships and even joint prosthesis damage.

Evidence exists on a fracture surface

In the cases of both the Japan Airlines jumbo jet crash and the sodium leak at the Monju nuclear power plant, patterns found on the metal fracture surface were the decisive evidence.

When a metal fractures due to the instantaneous application of a strong force, pulling or the repeated application of smaller forces, characteristic patterns appears on the fracture surface. These microscopic patterns, which can only be seen with an electron microscope (see p. 11 for examples), reveal what forces a metal has been subjected to and how the fracture developed. By examining patterns on the fracture surface, the developments leading to a fracture can be determined.

In fact, striation patterns proving metal fatigue found when investigating the causes of both the Japan Airlines jumbo jet crash and the sodium leak at the Monju fast breeder reactor were decisive evidence. Silent fracture surfaces can testify eloquently.

AI, the successor to "Takumi-no-me (master's eyes)"

Evidence left on a fracture surface is key. However, not just anyone can find an answer immediately just by inspecting a fracture surface. When viewed at the microscopic level, a fracture is vast and time consuming to inspect. Furthermore, the same phenomenon may cause different patterns to form on different materials. Many other factors also need to be taken into account, such as rust-related corrosion and mechanical engineering. Experience helps an investigator promptly identify areas to focus on and correctly read the evidence. However, the number of trained technicians is decreasing.

Finding a way to ensure that these battle-hardened "Takumi-no-me (master's eyes)" are somehow passed on to the next generation using artificial intelligence (AI) is now attracting attention. In April 2020, NIMS commenced a collaboration between researchers engaged in accident investigations and material tests and AI researchers in a project to develop AI capable of diagnosing the causes of a fracture and deterioration levels just by reading images of a fracture surface (see p. 15). In the near future, AI may frequently play an active role in accident investigations.

At the same time, we must preserve our impartiality. In most cases, accidents involve parties with opposing perspectives and liabilities. NIMS' mission is to solely concentrate on fracture surfaces to find the truth by methodically gathering and examining evidence.

Major cases in which NIMS conducted investigations

1972: Damage to Unit 3 of the Kansai Electric Power Company's Kainan Power Station

1985: Japan Airlines jumbo jet crash

1995: Sodium leak at the Monju fast breeder reactor

1999: H-II Rocket No. 8 launch failure see p.6

2002: Small propeller plane crash

2008: NHK press helicopter crash

2016: Nagaragawa Railway train derailment see p.12

2019: Collision of the passenger ship "Ginga"

1970 1980 1990 2000 2010 2020

Investigation File 1:
H-II Rocket No. 8 Launch Failure

Finding the Cause of an Engine Failure

H-II Rocket No. 8 immediately after launch
(photo provided by JAXA)

Recovery of the LE-7 engine

In January 2000, Saburo Matsuoka of the National Research Institute for Metals (now NIMS) found himself standing on the deck of a ship some 380 km off the northwest coast of Chichijima Island waiting for the H-II rocket's LE-7 engine to rise from the depths following a failed launch.

H-II Rocket No. 8 left the Tanegashima Space Center's launch pad on November 15, 1999. Engine combustion stopped 3 minutes and 59 seconds later. Unable to control the rocket's attitude, Command activated self-destruct 7 minutes and 39 seconds after the launch and the wreckage fell into the ocean.

Recorded communications with the rocket had already revealed that the pump responsible for supplying liquid hydrogen fuel to the combustion section of the engine had failed. However, the direct cause of this could not be ascertained without examining the actual engine.

The National Space Development Agency of Japan (now JAXA) calculated the engine's trajectory to narrow down the search area. 85 square kilometers still needed to be intensively searched—an area 3.3 km wide and 26 km long. Finding a single engine on the dark ocean floor at a depth of 3,000 m proved extremely difficult. However, on December 24, 1999, five weeks after the launch, the engine was miraculously found by the Japan Marine Science and Technology Center (now the Japan Agency for Marine-Earth Science and Technology). In January 2000, Matsuoka, a specialist in metallic materials, watched the engine finally break the surface so that he could begin investigating the launch failure.

As predicted, an inspection of the engine revealed that one of the liquid hydrogen turbo pump's inducers, or wings, had cracked (photo on p.8).
The question was why.

LE-7 engine after retrieval from the bottom of the sea
(photo provided by JAXA)

Debate over the crack in the inducer

Inducers need to be able to efficiently supply liquid hydrogen fuel at a temperature of -253℃ to the combustion section while rotating 700 times per second. Because of this, they are made of an extremely durable titanium alloy capable of withstanding extremely low temperatures. However, this material actually cracked.

In order to investigate what caused this crack, a specialist meeting* was held in which Matsuoka participated. First, Matsuoka and the other participants conducted a visual inspection of the fracture surface of the engine. If the engine had been damaged by an impact with another object, the fracture surface would have shown evidence of tearing, but the surface was flat, as though it had been cut with a knife. When a fracture surface is flat, fatigue failure or a brittle fracture is suspected. Fatigue failure is caused by metal fatigue due to the repeated application of smaller forces, while a brittle fracture is a rapid fracture caused by the instantaneous application of a strong force.

A lively debate over these two possibilities erupted because they would require different measures in response. New raw materials and design improvements would have to be considered. The surface of a brittle fracture in a metal made more fragile due to hydrogen exposure looks remarkably similar to the surface of a fatigue failure, and it is extremely difficult to distinguish between them.

In order to draw a conclusion, the National Research Institute for Metals investigation team analyzed the fracture surface of the inducer with a scanning electron microscope (SEM).

Mysterious forces applied to the inducers

The SEM analysis revealed a pattern called striation on the fracture surface of the inducer (top-right photo on p. 9). This is characteristic of metal fatigue. The striation originated at a machining mark 15 micrometers deep on the surface of the inducer, clearly indicating that metal fatigue had developed from a scratch with a depth one quarter of the diameter of a human hair. A pattern called dimple was also observed on the fracture surface, and the configuration of this dimpling suggests that the fracture had occurred at an extremely low temperature. This indicated that the inducer had evidently cracked before the rocket crash.

The investigation team also calculated the forces that had been applied to the inducer based on the intervals between striation lines and found that it had been subjected to forces far exceeding its design specifications. The calculated value would have been insufficient to cause the inducer to crack, but the scratch on the surface was noteworthy. Any scratch on a metal surface induces a phenomenon called stress concentration, locally magnifying the intensity of forces in its vicinity. The inducer was believed to have eventually fractured when the already strong forces to which it had been subjected increased even further.

However, the reason why the inducer had been subjected to such strong forces remained unexplained. Metal fatigue is caused by the repeated application of smaller forces, while rotations generate only a certain level of centrifugal force and forces repeatedly applied are generally negligible.

Accordingly, a combustion test using the same type of engine and a test called a "running water test" were conducted in order to find the source of the forces that had been applied to the inducer. In a running water test, water is substituted for liquid hydrogen in the system so that the fluid motion and accompanying loads can be observed. When the investigation team gradually increased the speed of the engine revolutions, a phenomenon called "rotating cavitation" occurred, creating unexpected vortices and a huge amount of bubbles around the inducer. It was found that this caused a backflow in the water that repeatedly applied extra forces to the inducer. Additionally, it became clear that unexpected oscillations were occurring in the inducer, further increasing the forces.

In addition to the rotating cavitation and unexpected oscillations, the forces were concentrated on the machining mark, ultimately causing the inducer to crack. These results were reported to the Space Activities Commission and the investigation was completed.

Another cause inherent to the material used in the inducers

The story doesn't end there: a problem was later found with the quality of the titanium alloys used in the inducers.

Metals used in rocket engines need to be developed with special care due to the particularly unusual and harsh environments in which they operate, which include exposure to extremely cold liquid hydrogen. Accordingly, the inducers were designed using NASA data on alloy compositions and the fatigue properties of materials at extremely low temperatures. Japan had no independently developed data at that time because Japanese rockets had been developed based on imported technology since the end of World War II.

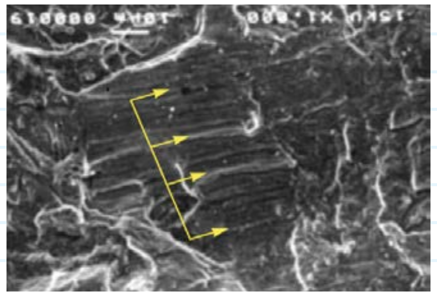
This was a trap. The inducer was carved from a large block of forged metal, whereas NASA's data had been based on alloys made in rolled metal sheets. Different manufacturing methods cause differences in crystalline structure. Differences also appear in the crystal grains which are particularly important in the fatigue properties of titanium alloys.

Inspection of the inducer revealed crystal grains larger than those found in rolled materials, making it slightly more susceptible to metal fatigue. Thus, the inducer's problems began with the quality of the material used to make them.

Developing safe materials requires the use of data commensurate with their actual manufacturing methods and usage environments. NIMS learned from this by collaborating with JAXA to conduct independent tests of the durability of materials under extreme low temperatures. The accumulated results of these tests continue to be published as the "Space Use Materials Strength Data Sheet" and have become indispensable in rocket development (see the column below).

Materials testing data obtained by NIMS is now reflected in JAXA's rocket design specifications. Rocket components now receive mirror finishing to ensure that even minor scratches are not present, and the design of the inducers has been changed to eliminate rotating cavitation. In 2001, H-IIA Rocket No. 1, equipped with an LE-7A engine, was successfully launched. The latest model, the H3 rocket, is scheduled to be launched in 2021. Needless to say, knowledge obtained through NIMS' material tests has been fully utilized in the development of this rocket and it represents the pinnacle of Japanese technology.

(By Takeshi Komori)



Fracture surface of the inducer inspected using a scanning electron microscope (SEM)
Striation, a pattern characteristic of metal fatigue, is clearly visible on the fracture surface of the inducer.

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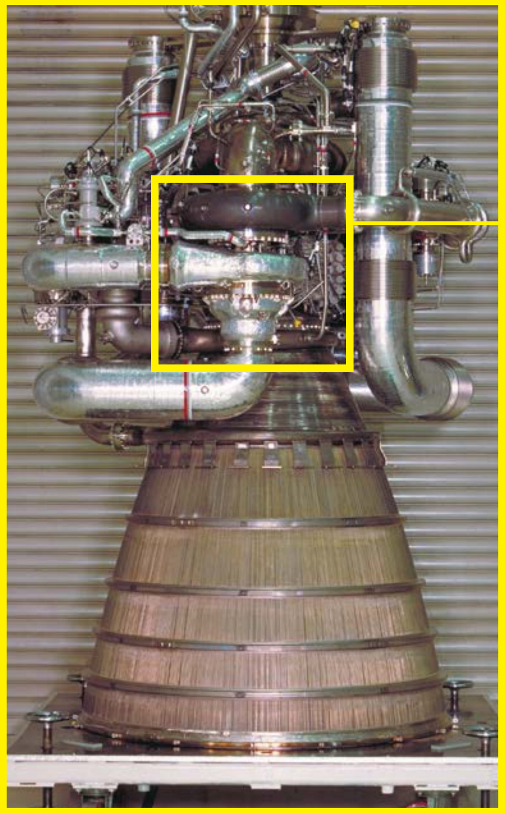
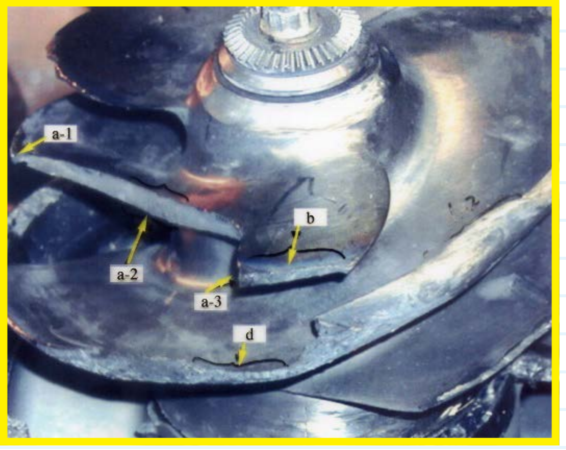
* Specialist meeting: An investigative unit consisting of researchers from research institutes and universities established under the aegis of the Technology Evaluation Committee, Space Activities Commission, Ministry of Education, Culture, Sports, Science and Technology

Diagram of H-II Rocket No. 8



LE-7 engine



The LE-7 engine was installed on the bottom of the rocket. Inspection of the interior of the recovered engine revealed a crack in the inducer of the pump responsible for supplying liquid hydrogen fuel to the combustion section. (photo provided by JAXA)

FOCUS

Guidelines for Rocket Development: a Collaboration between JAXA and NIMS

"Space Use Materials Strength Data Sheet

The H-II Rocket No. 8 launch failure shed light on the difficulty of developing materials for use in specific environments. Safe space development requires independent testing of these materials in their actual operating environments. Sharing a sense of crisis, JAXA and NIMS jointly commenced a new project immediately after the launch failure: the "Space Use Materials Strength Data Sheet."

Rocket fuel consists of liquid hydrogen (-253℃) and liquid oxygen (-183℃). JAXA and NIMS intended to test and evaluate the properties of metallic materials used in rocket engines at these extremely low-temperatures to establish specifications and publish the results. NIMS tests the tensile properties, fatigue properties and toughness of metallic materials selected by JAXA and makes the results available on a NIMS website (https://smds.nims.go.jp/space/en).

Over the course of this nearly 20 year project, NIMS has also endeavored to develop new testing methods and has succeeded in stably simulating extremely low-temperature environments using a freezer and a heater and by using helium gas in lieu of liquid hydrogen. NIMS has also been conducting long-time fatigue tests in a helium gas atmosphere at -253℃. Furthermore, NIMS has also studied the behavior of metallic materials during tests and all other relevant factors. This has led to some notable academic achievements and enabled NIMS to contribute to the elucidation of failure mechanisms.

No rocket launch failures attributable to metallic materials have occurred since this project commenced. Consistent testing on Earth strongly supports our collective dreams of space exploration.

This year's edition is the 29th since it was first published in 2003.

Investigation Process

A brief introduction to our investigation procedures, from initial decisions on the overall approach to detailed analysis

Photos: Michito Ishikawa (excl. a photo of an electron microscope on p. 7)

Step1
Initial investigation

The levels of rust-related corrosion and deformation are checked in a fractured section. Tentative decisions are made on the approach to the investigation. This includes a corrosion specialist in the investigation team when corrosion is considered to be a significant factor.

Step2
Visual inspection

Investigators formulate a hypothesis after carefully inspecting the subject using magnifying glasses and calipers.

The key to a speedy investigation is whether an appropriate guess as to the cause can be made without overlooking trace evidence. According to Furuya, this is a very important part of the process. "Most of the time, the cause of a fracture can be surmised after a visual inspection." Investigation subjects need to be treated with great care because microscopic evidence remaining on a fracture surface can be easily destroyed.

Step3
Evidence gathering

Areas where doubts remain after a visual inspection are examined in detail using a scanning electron microscope (SEM).

Investigators strive to find the truth by looking for telltale patterns and fine scratches on the fracture surface.

A fracture surface can rust in the days following an accident. In such a case, an investigator cleans the surface with an acid treatment before inspecting it. Great skill is required to remove only the rust without ruining evidence of the fracture.

Editorial supervisor: Yoshiyuki Furuya

Group Leader, Fatigue Property Group,
Analysis and Evaluation Field,
Research Center for Structural Materials

Investigation subject

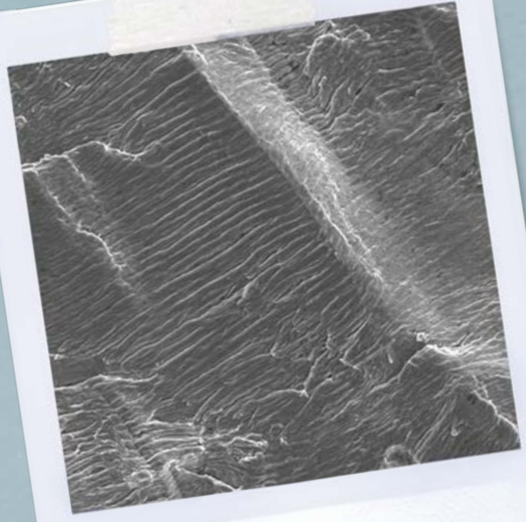
Magnifying glasses

◀ The fracture surface and surrounding areas are checked. Great care is required, as a slight scratch or minor difference in metallic luster may be a clue.

◀ When the subject of the investigation is too large to transport, an investigator may go to the scene of the accident.

Calipers

▲ The level of deformation is measured. Whether the fracture is accompanied by deformation may narrow down the cause.

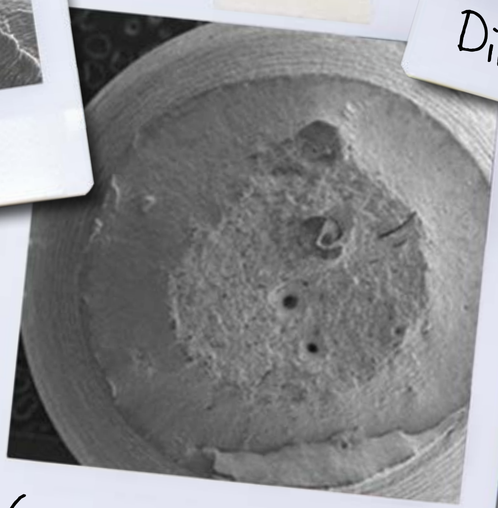


Striation

▲ A pattern that appears when the repeated application of smaller forces exceeds a material's limits and causes a fracture (**fatigue failure**). Characteristic lines appear showing the repeated development and halting of cracking. The magnitude and frequency of the forces applied can be estimated from the number of and intervals between these lines.

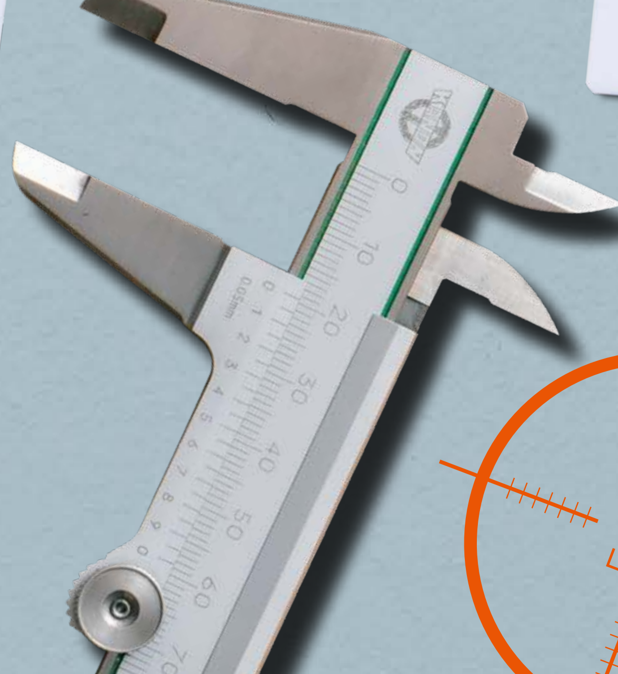
Dimple

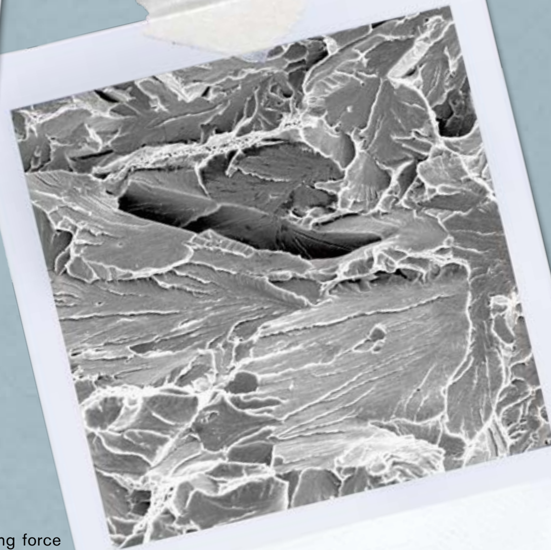
▲ A pattern that appears when a strong force applied causes a fracture accompanied by deformation and tearing fashion (**ductile fracture**). Dimpling appears all over the fracture surface.



Cup and Cone

▲ An example of the macro phase of a ductile fracture. The inside of the metal breaks in a tearing fashion, while the outside crystals break in a sliding fashion (shearing), creating two different patterns.





Cleavage

▶ A pattern that appears when a strong force applied instantaneously causes a rapid fracture without deformation (**brittle fracture**). A crack develops in the most easily breakable direction on a crystal face.

Investigation File 2: Nagaragawa Railway Train Derailment

Searching for the Decisive Cause of a Rail Fracture

Onsite investigation by the police and other investigators on the day after the accident (photo provided by Sankei Shimbun Co., Ltd.)

Derailment in a tunnel

On Friday, April 15, 2016, an accident occurred in the Suhara Tunnel on the Nagaragawa Railway's Etsumi-nan Line in Mino-shi, Gifu prefecture. The single car train left Han-no Station on time at 7:23 pm. The weather was clear and the sun had already set at 6:25 pm.

The train was traveling at 50 km/h with the driver and two passengers. When the train entered the tunnel and began following a curve to the right, the driver felt a violent shock accompanied by an abnormal sound. Both axles in the rear bogie derailed to the left and the rear of the vehicle struck the side of the tunnel. The train finally stopped near the center of the tunnel after traveling approximately another 90m.

"A little while after entering the tunnel, I heard a sudden, loud thump and felt a shock as though the vehicle had been knocked up," the driver testified. "I quickly applied the emergency brake but had no idea what was happening as the car shook side to side and up and down. I couldn't do anything but hang on to something to avoid falling down until the train stopped."* Fortunately, the passengers were uninjured and the driver received only minor injuries.

The following day, the Ministry of Land, Infrastructure, Transport and Tourism's Japan Transport Safety Board dispatched investigators to the accident site. It was obvious that the left rail, i.e., the outer rail on the curve, had broken. However, it was necessary to find out why so that effective measures could be taken in response. Accordingly, in September 2016, the Japan Transport Safety Board requested that NIMS conduct a more detailed investigation.

Mysterious crack in the rail

The fractured portion of the rail was provided to NIMS as the investigation subject. Yoshiyuki Furuya (Group Leader of the Fatigue Property Group at the Research Center for Structural Materials), a member of the investigation team, took a look back on his experience.

"A cursory inspection showed significant grinding on the rail. It was very worn down. The rail had not been changed since it was first laid over 30 years ago and its cross section had decreased by 40%. We therefore premised our investigation on a belief that the rail had fractured due to deterioration."

Furuya assumed that the rail had gradually cracked due to the repeated application of force and that the rail had been in an advanced state of metal fatigue. Corrosion thinned the rail further and the rail eventually fractured when the train passed over it.

"However, one thing attracted my attention: a mysterious crack on the upper part of the fracture. Determining whether this crack occurred before or after the rail fractured was a problem."

Normally, the lower corner of a rail bears most of the load. In short, when a rail fractures due to fatigue, the fracture generally starts at the lower part and proceeds to the upper part. If the rail fracture in this case was caused by the crack on the upper part of the rail, the general theory would not be applicable.

Furuya continued. "This crack was bewildering. It left open the possibility that the accident resulted from the rail being inherently weak; that is, a problem with the quality of the material or the manufacturing method. This would mean that a rail manufactured under the same conditions could fracture anywhere." If so, this would naturally raise liability issues for the manufacturer of the rail. On the other hand, if the cause of the accident is found to be fatigue and corrosion, the rail maintenance company would be liable. Therefore, the measures taken in response and the locus of liability would differ significantly depending on whether the fracture began at the upper or lower part of the rail.

Rust and corrosion of the rail

To narrow down the causes of the fracture, investigators focused on the properties of the rail itself and corrosion with rust. Furuya asked a corrosion specialist, Hideki Katayama (Group Leader of the Corrosion Property Group at the Research Center for Structural Materials) and others to join a seven-member investigation team.

Inspection of the material revealed that the rail had a pearlite structure—the structure generally used in rail steel—and that its chemical composition met JIS standards. On the other hand, the speed of the corrosion remained unclear.

The thickness of the cross section of the fractured rail was 6.75mm compared with 14.29mm when new. Corrosion this rapid is usually found in coastal areas, where it is often a serious problem. It was found that water seeped from the ceiling and walls within the tunnel, creating an environment susceptible to corrosion. Analysis of the rust also clearly showed that the rail had been in contact with water for a considerable period of time. However, investigation of the quality of the water sampled at the site revealed low concentrations of substances that are generally considered to accelerate corrosion (Cl^- and SO_4^{2-}). In other words, this water alone could not have caused the corrosion.

"We reported this result to the Japan Transport Safety Board," Furuya recalled. "The Board replied that it was possible that used rail had been laid." If the rail had already corroded to some extent before being laid, a level of corrosion incongruent with the surrounding environment would be understandable.

The influence of the corrosion was most obvious at the bottom of the rail. The rail was originally fixed to railroad ties with bolts, but it was found that the distance between the rail and the railroad ties had expanded as corrosion thinned the bottom of the rail.

It is evident that a considerable load had been applied to the rail at the time of the accident. Nevertheless, conclusive evidence proving this to be the decisive cause had yet to be found. The team of metal fatigue specialists led by Furuya conducted an inspection using a scanning electron microscope (SEM).

Whether the fracture began at the upper or lower part

First, a striped pattern was found at the corner of the lower part of the rail (p. 14, Figure - Point A). This is called striation, which shows progressive fatigue at this point. The accident site is a curve to the right and the influence of centrifugal force on the rail was significant, in addition to the weight of the train. In other words, the corner on the outer side of the curve was subject to heavy loads.

At the same time, a cleavage pattern broadly covered the adjacent area (Figure - Point B), which means that this area fractured all at once due to a shock. Cleavage patterns were also observed on the rail body (Figure - Point C) and the upper part (Figure - Point D). What matters is the cause of the cleavage: due to fatigue on the lower part or a crack on the upper part.

The answer was found in the cleavage pattern: a so-called "river" pattern. A cleavage develops in the most breakable direction on the crystal plane and multiple cleavages successively integrate into a single break in the manner of narrow tributaries gathering into the main stream, leaving streaky patterns behind. Tracing the route of these patterns as they integrate reveals the direction from which the cleavage developed.

As a result, the river pattern on the fracture surface revealed that the fracture started from the lower part and continued to the upper part. As Furuya initially assumed, it was clear that the crack developed due to fatigue and corrosion on the lower part of the rail and that the cleavage occurred all at once when the rail's limits were exceeded, leading to the rail fracture. It was concluded that the crack on the upper part occurred after the rail fractured.

The investigation results were submitted to the Japan Transport Safety Board on December 22, 2016, three months after the investigation commenced.

Solution and measures taken

The broader investigation revealed that the rail had been scheduled for replacement immediately before the accident because another driver had noticed abnormal sounds at the same location. A rail fracture had also occurred in another tunnel, but the accident occurred before the scheduled replacement.

In its report, the Nagaragawa Railway Co., Ltd. commented, "We did not imagine that the rail would fracture due to corrosion in such a short time." The rail was replaced and measures were implemented to prevent water seepage within the tunnel.

"The corrosion team led by Dr. Katayama cooperated very effectively with our metal fatigue team," Furuya noted. Even where the cause of an accident seems obvious, questions can be solved through good team work by specialists from the relevant fields, and firm conclusions on the cause can eventually be drawn. This case is a good example of this kind of investigative collaboration.

(By Takeshi Komori)

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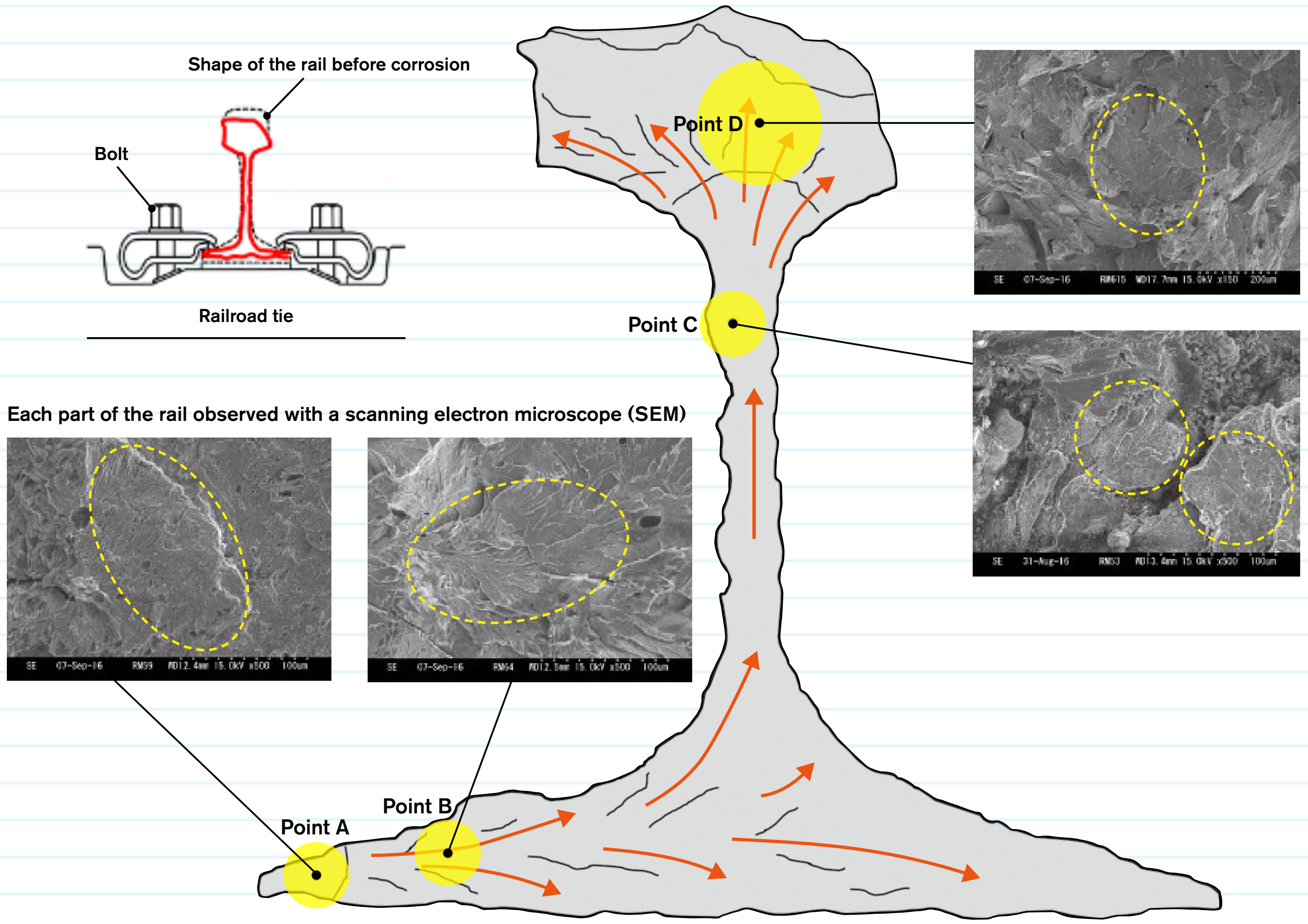
*1 "Railway accident investigation report: RA2017-1" published by the Japan Transport Safety Board, MLIT



Striation, evidence of metal fatigue, was observed at Point A, while cleavage patterns showing that cracks occurred due to a strong force applied instantaneously were found at Points B, C and D. The river pattern at Point B determined the direction in which the crack developed.

COLUMN

Using AI to diagnose the deterioration of metals!

Project "Takumi-no-Me (Master's Eyes)"

The examination of fracture surfaces is indispensable when investigating the causes of accidents. Clues can be found using an electron microscope, but the most important tool is a well-trained eye. An experienced investigator can elicit the truth from suggestive patterns on fracture surfaces. However, the number of trained technicians has been decreasing and the successor problem has begun to arise in the field of accident investigations.

A similar problem is occurring in the assessment of thermal power plant life. Periodic inspection of pipes and boilers that operate in harsh, high temperature and high-pressure environments is very important in preventing accidents. One inspection method is to remove a part from an operating machine to study its metallographic structure, but diagnosing problems is completely dependent on the observations of a dwindling number of trained technicians.

Against this background, NIMS commenced the Project "Takumi-no-Me (Master's Eyes)" in April 2020. NIMS intends to prepare two types of artificial intelligence (AI)—one for accident investigations and one for life assessments—and train them using images of metallographic structures and information on material compositions and specific types of deterioration with the aim of enabling them to automatically determine the causes of fractures.

The AIs will be trained mainly using images that NIMS has accumulated through over 50 years of material tests. The accident investigation AI will focus on images obtained through metal durability fatigue tests related to pulling and bending forces, while the life assessment AI will focus on images obtained through creep tests conducted to check the durability of steel when subjected to heat and applied stress. The diagnostic accuracy of the AIs may differ depending on what images are selected. Therefore, the experience of NIMS' trained technicians will be fully utilized in selecting the images used to train them.

NIMS has substantial database construction know-how accumulated through its Materials Informatics efforts to find new materials based on big data which it intends to leverage to develop a test model of a separate data processing AI within the next several years.

This project combines NIMS' many years of material testing and rapidly developing AI research to create a new means of protecting the safety of society.

Creep test machines

NIMS NEWS

1 NIMS releases MDR and DICE, a materials data platform

Materials Data Platform Center, Research and Services Division of Materials Data and Integrated System (MaDIS) at NIMS released the "Materials Data Repository (MDR)" and web site of the “Materials Data Platform, DICE".

MDR is a data repository to collect and store research papers, presentation materials, and related scientific data. MDR comply with FAIR concept, and particularly designs for the use them for materials informatics. Users can search the documents and information about the data (metadata) such as specimens, instruments, methods, and from the full text of the deposited data, to browse and download by open access manner. User registration is not required and there is no charge for use.

DICE incorporates “NIMS Materials Database (MatNavi)”, “NIMS Materials Data Conversion Tools (M-DaC)”, and “Materials Data Repository (MDR)”. A variety of services will be provided on DICE in the future, including the dissemination of related information and further expansion of data.

DICE

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2 Impact Factor of STAM climbs to a record high of 5.866

The Impact Factor of the journal *Science and Technology of Advanced Materials* (STAM) has risen to 5.866 according to the 2020 Journal Citation Reports announced by Clarivate Analytics.

STAM is one of the world’s leading materials science journals that is published with support from NIMS and the Swiss Federal Laboratories for Materials Science and Technology. As of December 2020, STAM is published by an international team of more than 70 experts from 14 countries including the Editor-in-Chief, Kazuhito Hashimoto, who is also the president of NIMS. STAM is a Gold Open Access Journal that is internationally recognized as an open-science platform that provides the latest findings on world-class research for materials scientists worldwide.

STAM Impact Factor Trends (Clarivate Analytics, 2020)

STAM Methods Launches in January 2021

STAM is pleased to announce the launch of its sister journal, *STAM Methods*. The journal focuses on novel and innovative methods to improve and accelerate the development of materials, including methodology, informatics, databases, instrumentation, and programming. Articles submitted before 31 December 2020 are eligible for special offers: waiver of Article Processing Charge (APC) for the first 10 articles accepted for publication, APC of all subsequent articles accepted is discounted to 500 USD. Waiting for your submissions!

STAM Methods

Hello from NIMS

Hi, my name is Vasili and I am from Greece. I am a theoretical physicist investigating the interactions between quantum emitters and their nanostructured environment. I have always been attracted by maths and physics and applying them in the nanoworld fascinated me to tackle real life problems. NIMS is a well-known research center with experts and top-quality research facilities, thus I was happy when I joined in October 2019 as an ICYS fellow.

The research environment in NIMS is stimulating. I am exposed to different research fields and cutting-edge technology. The ICYS gives me the freedom to develop as an independent researcher and pursue my research on using 2D materials as a platform for increasing light-matter interactions. My aim working in NIMS is to design practical applications for the society; biosensors, efficient single photon sources and quantum computing application.

At the bamboo grove in Kyoto.

Vasileios Karanikolas
(Greece)
ICYS Research Fellow,
ICYS

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